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Ref. # 10 CFR 52

December 14, 2009

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. 3006

Dear Sir:

Luminant Generation Company LLC (Luminant) herein submits the response to Request for Additional Information No. 3006 for the Combined License Application for Comanche Peak Nuclear Power Plant Units 3 and 4. The affected Final Safety Analysis Report pages are included with the response.

Should you have any questions regarding these responses, 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 December 14, 2009.

Sincerely,

Luminant Generation Company LLC

Donald R. Woodlan for

Rafael Flores

Attachment: Response to Request for Additional Information No. 3006 (CP RAI #122)

D090
NRO

cc: Stephen Monarque w/attachment

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Attachment

Response to Request for Additional Information No. 3688 (CP RAI #92)

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-18

This Request for Additional Information (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 (GDC) 2.

CP combined license (COL) 3.8(29) in Comanche Peak Nuclear Power Plant (CPNPP) COL FSAR inserts subsection 3.8.4.4.3.2, "UHSRS", which references Appendix 3KK. In Appendix 3KK, Section 3KK.1, "Introduction," the first paragraph (Page 3KK-1) states that "The SASSI model is confirmed by comparing the structural frequencies between the SASSI model mesh and the fine mesh design model. The structural frequencies are calculated from modal analysis performed in ANSYS, and the similar results ensure compatibility between the two models and indicate that the SASSI model is acceptable."

The applicant is requested to provide the following information:

(a) Describe the "fine mesh design model" mentioned in the first sentence.

(b) Provide a table listing the natural frequency, modal participating factor, and modal participating mass ratio for the first three modes in the directions, x, y, and z, assuming the fixed base condition for both ANSYS and SASSI models. The modal participating factor should be calculated by Eq. 3.2-4 of American Society of Civil Engineers (ASCE) 4-98.

ANSWER:

(a) The fine mesh design model, or ANSYS Design Model, is a three-dimensional finite element model of the UHSRS that is used for calculation of demands used for design. The model includes all relevant structural details (walls, column, beams, major openings, masses) with adequate mesh refinement to accurately calculate member demands at critical design locations. The model includes shell elements for walls and slabs, beam elements for columns and beams, mass elements for equipment and impulsive hydrodynamic fluid masses, and spring and mass elements for convective hydrodynamic fluid. This model consists of approximately 29,000 shell elements, 1,600 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 in SASSI. For the fixed base comparison below, the analyses are both in ANSYS and no soil modeling has been added to either model.

(b) The following table is provided:

Comparison of Major Structural Modes of UHSRS between ANSYS Design Model and SASSI SSI Model(1)

Mode	Frequency (Hz)		Modal Participation Factor (calculated per ASCE 4-98, Eq. 3.2-4)		Modal Mass Ratio	
	ANSYS Design Model(2)	SSI Model Mesh(3)	ANSYS Design Model(2)	SSI Model Mesh(3)	ANSYS Design Model(2)	SSI Model Mesh(3)
E-W, Mode 1	6.77	7.08	7.07	7.28	0.251	0.306
E-W, Mode 2	6.55	6.78	2.93	2.48	0.043	0.035
E-W, Mode 3	4.15	4.48	2.89	2.84	0.042	0.047
N-S, Mode 1	7.37	7.62	5.86	5.84	0.172	0.203
N-S, Mode 2	11.49	11.23	2.44	3.55	0.030	0.075
N-S, Mode 3	13.86	14.73	2.33	2.38	0.027	0.033
Vertical, Mode 1	17.37	17.73	2.15	2.00	0.023	0.020
Vertical, Mode 2	10.65	10.67	2.05	1.91	0.021	0.018
Vertical, Mode 3	12.88	16.89	2.04	1.90	0.021	0.018

1 All eigenvalue analyses are performed in ANSYS

2 ANSYS Design Model is the fine mesh model used to calculate demands for design

3 SSI Model Mesh is the identical mesh of the UHSRS used for SSI analysis but eigenvalue analysis is performed in ANSYS

FSAR Appendix Section 3KK.2 has been revised and notes are added in FSAR Table 3KK-9 to incorporate this response.

Impact on R-COLA

See attached marked-up FSAR Revision 1 pages 3KK-1, 3KK-2, 3KK-4, and 3KK-19.

Impact on S-COLA

None.

Impact on DCD

None.

3KK MODEL PROPERTIES AND SEISMIC ANALYSIS RESULTS FOR UHSRS

3KK.1 Introduction

This Appendix discusses the seismic analysis of the ultimate heat sink related structures (UHSRSs), including the ultimate heat sink (UHS) Basin and its pump house. The computer program SASSI (Reference 3KK-1) serves as the platform for the soil-structure interaction (SSI) analyses. The three-dimensional (3D) finite element (FE) models of the UHSRS used in the SASSI analysis are generated from FE models with finer mesh patterns initially developed using the ANSYS computer program (Reference 3KK-2). The ~~SA~~coarser mesh SSI model is confirmed by comparing the structural frequencies between the ~~SA~~SSI model mesh and the fine mesh design model. The structural frequencies are calculated from modal analysis performed in ANSYS, and the similar results ensure compatibility between the two models and indicate that the ~~SA~~SSI model is acceptable. RCOL2_03.07.02-16 RCOL2_03.07.02-16

Dynamic analysis is performed in SASSI to obtain seismic responses including in-structure response spectra (ISRS), maximum accelerations, and dynamic soil pressures of the structure that includes SSI effects. Response spectra analyses are performed in ANSYS to obtain seismic ~~design~~ demands. used for design (Table 3KK-8 summarizes the analyses performed for calculating seismic demands) The SASSI analyses results for ~~maximum accelerations~~ISRS at the base slab and seismic soil pressures are used to verify the load demands assigned to the ANSYS structural design analysis that are included in the load combinations in accordance with the requirements of Section 3.8. The SASSI analysis ~~and results presented in this Appendix~~ include site-specific features such as the layering of the subgrade, embedment of the UHSRS, flexibility of the basemat and seismic motion scattering. Due to the low seismic response at the Comanche Peak Nuclear Power Plant site and lack of high-frequency exceedances, the spatial variation of the input ground motion is deemed not significant for the design of the UHSRS. Therefore, the SASSI capability to consider incoherence of the input control motion is not implemented in the ~~design~~analysis of the UHSRS. RCOL2_03.07.02-16 RCOL2_03.07.02-16 RCOL2_03.08.04-20 RCOL2_03.08.04-20

3KK.2 Model Description and Analysis Approach

The SASSI FE structural model for the UHSRS is shown in Figures 3KK-1. Table 3KK-1 presents the structural element material properties for the SASSI FE model. Detailed descriptions of the UHSRS are contained in Subsection 3.8.4. Figures 3.8-206 through 3.8-211 show detailed dimensions and layout of the UHSRS.

The fine mesh model, or ANSYS Design Model, is a three-dimensional finite element model of the UHSRS that is used for calculation of demands for design. The model includes all relevant structural details (walls, columns, beams, major openings, masses) with adequate mesh refinement to accurately calculate RCOL2_03.08.04-18

member demands at critical design locations. The model includes shell elements for walls and slabs, beam elements for columns and beams, mass elements for 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. RCOL2_03.08.04-18

The UHSRS model is developed and analyzed using methods and approaches consistent with ASCE 4 (Reference 3KK-3), and accounting for the site-specific stratigraphy and subgrade conditions described in ~~Chapter 2~~Subsection 2.5.4, as CTS-00922 well as the backfill conditions around the embedded UHSRS. The four UHSRS (per unit) are nearly ~~symmetric~~identical with minor variations on backfill layout for RCOL2_03.07.02-16 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. RCOL2_03.08.04-21 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. ~~Due to symmetry, s~~Since the structures are otherwise identical, soil-structure interaction (SSI) analysis is performed only on UHSRS B/D, and the responses are deemed applicable to the other UHSRS. RCOL2_03.07.02-16 RCOL2_03.08.04-27 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.

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 RCOL2_03.08.04-23 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 (~~for the~~ lower bound case) RCOL2_03.07.02-16

The UHSRS analyses were verified by the following methods: RCOL2_03.07.02-16

- Comparison of eigenvalue analysis results between a coarser mesh (used for SASSI SSI analyses) and a finer mesh (used for ANSYS design analyses), the results are presented in Table 3KK-9. RCOL2_03.08.04-18

Review of SASSI transfer functions to verify that interpolation was reasonable and that expected structural responses were observed. All SASSI output results were compares between soil profiles to verify reasonably similar responses between the cases.

Operating-basis earthquake (OBE) structural damping values of Chapter 3 Table 3.7.1-3(b), such as 4 percent damping for reinforced concrete, are used in the site-specific SASSI analysis. This is consistent with the requirements of Section 1.2 of RG 1.61 (Reference 3KK-4) for structures on sites with low seismic responses where the analyses consider a relatively narrow range of site-specific subgrade conditions. The SASSI analyses produce results including peak accelerations, in-structure response spectra, and seismic soil pressures. All results from SSI analyses represent the envelope of the six soil conditions. The SASSI analyses results are used to produce the final response spectra and provide confirmation of the design spectra and seismic soil pressures used in ANSYS. RCOL2_03.07.02-11

Shell elements are used to model the basemat and brick elements are used for the concrete fill that is present beneath basemat and for the soil on the sides. Beam elements are used for the concrete beams, ~~that~~which support slabs and equipment in the structure, and for the concrete columns in the cooling towers. Beam elements are also used to model the steel members in the UHSRS. Shell elements are also used for the reinforced concrete walls and elevated slabs. Where shell elements and brick elements are connected, the shell element is connected to overlap a face of the brick element. There are no locations in the models where shell elements are connected perpendicularly to the brick elements with the intention of transferring moments through nodal rotational degrees of freedom. Walls are modeled using gross section properties at the centerline. All roof slabs and elevated slabs (pump room, fan slab, missile shield protection) are considered as cracked with an out-of-plane bending stiffness of ½ of the gross section stiffness in accordance with ASCE 43-05 (Reference 3KK-10). The properties assigned to the slab elements are modified to account for cracked out-of plane flexural stiffness and non-cracked in-plane axial and shear stiffness of the slabs as follows: RCOL2_03.08.04-25 RCOL2_03.08.04-26 RCOL2_03.08.04-25 RCOL2_03.08.04-26

$$E_{cracked} = [1/(C_F)^{0.5}] \cdot E_{concrete}$$

$$t_{cracked} = (C_F)^{0.5} \cdot t$$

$$\gamma_{cracked} = [1/(C_F)^{0.5}] \cdot \gamma_{concrete}$$

Table 3KK-9

RCOL2_03.07.02-16

Comparison of Major Structural Modes of UHSRS between ANSYS Design Model and SASSI SSI Model[1]

Mode	Frequency (Hz)		Modal Participation Factor (calculated per ASCE 4-98)		Modal Mass Ratio	
	ANSYS Design Model[2]	SSI Model Mesh[3]	ANSYS Design Model[2]	SSI Model Mesh[3]	ANSYS Design Model[2]	SSI Model Mesh[3]
E-W, Mode 1	6.77	7.08	7.07	7.28	0.251	0.306
E-W, Mode 2	6.55	6.78	2.93	2.48	0.043	0.035
E-W, Mode 3	4.15	4.48	2.89	2.84	0.042	0.047
N-S, Mode 1	7.37	7.62	5.86	5.84	0.172	0.203
N-S, Mode 2	11.49	11.23	2.44	3.55	0.030	0.075
N-S, Mode 3	13.86	14.73	2.33	2.38	0.027	0.033
Vertical, Mode 1	17.37	17.73	2.15	2.00	0.023	0.020
Vertical, Mode 2	10.65	10.67	2.05	1.91	0.021	0.018
Vertical, Mode 3	12.88	16.89	2.04	1.90	0.021	0.018

1. All eigenvalue analyses are performed in ANSYS RCOL2_03.08.04-18
2. ANSYS Design Model is the fine mesh model used to calculate demands for design
3. SSI Model Mesh is the identical mesh of the UHSRS used for SSI analysis but eigenvalue analysis is performed in ANSYS

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-19

This Request for Additional Information (RAI) is necessary for the NRC staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.2, "UHSRS", which references Appendix 3KK. In Appendix 3KK, Section 3KK.1, "Introduction," the second paragraph (Page 3KK-1) states that "Dynamic analysis is performed in SASSI to obtain seismic response of the structure that includes SSI [soil-structure interaction] effects. Response spectra analyses are performed in ANSYS to obtain seismic design demands."

The applicant is requested to provide the following information:

(a) Explain the purpose of performing the SASSI analysis. Are the results obtained from the SASSI analysis used only in checking the results obtained from the ANSYS analysis?

(b) Specify which response spectra are used in the response spectra analyses in ANSYS.

In Subsection 3.8.4.4.3.2, "UHSRS," the second paragraph states that the soil springs based on the ASCE 4 Section 3.3.4.2 are placed at the bottom of the base slab in the ANSYS model. This model is the so-called "non-classical damped system," and the classical normal mode analysis cannot be performed. As a result of this, the response spectra analysis cannot be carried out. Provide the technical basis and provide information that shows how these response spectra analyses were performed in the CPNPP COL FSAR.

ANSWER:

(a) The purpose of the SASSI analysis is to determine the safe shutdown earthquake seismic soil pressures, peak accelerations, and in-structure response spectra for the UHSRS accounting for soil structure interaction effects including embedment effects and soil variability. The SASSI in-structure response spectra calculated at the UHSRS base slab are used to confirm the design input response spectra for the ANSYS dynamic analyses and the SASSI dynamic soil pressures are used to confirm the design soil pressures applied in ANSYS. In addition to providing results used in checking the ANSYS seismic design analyses, the SASSI analyses produce final in-structure response spectra.

(b) The design input response spectra are based on the standard plant CSDRS (DCD Table 3.7.1-1 and 3.7.1-2) anchored to 0.1g peak ground acceleration, which envelopes the site-specific FIRS spectra. The UHSRS ANSYS analyses used the 5% damped design input response spectra. The response spectra input was increased to address the low damping of hydrodynamic modes by using 0.5% damped spectra values in the low frequency region (< 1Hz) where convective hydrodynamic modes exist based on SRP 3.7.3.

(c) Only the soil springs of ASCE 4 were included in the ANSYS analysis, not the lumped damping coefficients, and therefore the system analyzed was classically damped. The soil springs used in the ANSYS design model were assigned to represent the soil flexibility. ANSYS analyses are performed based on two support conditions: (1) flexible rock subgrade by applying soil springs across all base slab nodes, and (2) rigid base by applying fixed restraints across all base slab nodes. All results from these two conditions are enveloped for the design. The stiffnesses of the horizontal and vertical springs were assigned to reflect the base flexibility to (1) allow calculation of base mat design demands that cannot be obtained in a fixed base analysis, (2) alter the design demands on walls and other elements integral with the base slab, and (3) include the frequency shift resulting from the SSI flexibility. Since the structural frequency is above the peak of the design spectra, including the soil flexibility condition could increase the structural responses.

The response to part (c) has been incorporated in FSAR Subsection 3.8.4.4.3.2 in response to RAI No. 2994 (CP RAI #108) Question 03.08.04-12 via Luminant Letter TXNB-09078 dated December 10, 2009. FSAR Section 3KK.2 has been revised to incorporate this response.

Impact on R-COLA

See attached marked-up FSAR Revision 1 pages 3.8-11 and 3KK-7.

Impact on S-COLA

None.

Impact on DCD

None.

the soil compaction pressure. The dynamic soil pressures are described in Appendix 3LL. ~~in accordance with ASCE 4-98 (Reference 3.8-34).~~ RCOL2_03.08.04-11

3.8.4.4.3.2 UHSRS

The UHSRS are designed to withstand the loads specified in Subsection 3.8.4.3. The structural design of the UHSRS is performed using the computer program ANSYS (Reference 3.8-14). The seismic analysis and the computer programs used for the seismic analysis are addressed in Appendix 3KK.

The seismic responses for the design are calculated using a two step analysis method as defined in ASCE 4-98 (Reference 3.8-34). Step 1 is the SSI analysis using the program SASSI and step 2 is calculating the seismic demands for the design using the program ANSYS as described below. RCOL2_03.08.04-12

The ANSYS design analysis models for the UHSRS were placed on soil springs calculated by methods provided in ASCE 4-98 (Reference 3.8-34) to provide localized flexibility at the base of the structure. The flexibility of the base allows for calculation of the base slab demands. The effects of embedment are included in the SSI analysis. The seismic lateral pressure and inertia loads applied to the ANSYS design model represent the total seismic loading from the SSI analysis.

ANSYS analyses are performed based on two support conditions: (1) flexible rock subgrade by applying soil springs across all base slab nodes and (2) rigid base by applying fixed restraints across all base slab nodes. All results from these two conditions are enveloped for design. ~~on the model placed on soil springs at the bottom of the base slab, with the springs representing the stiffness of the rock subgrade. To address the sensitivity of the structural response on the subgrade stiffness, an additional set of analyses simulating a fixed base condition is performed on the model.~~ The stiffness of the subgrade springs is calculated using the methodology in ASCE-4 Section 3.3.4.2 (Reference 3.8-34) for vibration of a rectangular foundation resting on an elastic half space. The springs were included to provide localized flexibility at the base of the structure to calculate base slab demands. The soil adjacent to the UHSRS is not included in the design model in order to transfer the total seismic load through the structure down to the base slab. Embedment effects are included in the SSI model from which the seismic lateral soil pressures and inertia loads are based. The evaluation of subgrade stiffness considers the best estimate properties of the layers above elevation 393 ft. Since the support below the structure will not exhibit long-term settlement effects, the subgrade stiffness calculated from ASCE-4 Section 3.3.4.2 is used for analysis of both static and seismic loads. RCOL2_03.08.04-19 RCOL2_03.08.04-32 RCOL2_03.08.04-12 RCOL2_03.08.04-32

The equivalent shear modulus for the ASCE spring calculations is based on the equivalent shear wave velocity which is determined using the equivalent shear wave travel time method described in Appendix 3NN. The equivalent Poisson's ratio and density are based on the weighted average with respect to layer thickness. The springs are included in the model using three individual, uncoupled uni-directional spring elements that are attached to each node of the base mat. The sum of all nodal springs in each of the three orthogonal directions are equal to the corresponding generalized structure-foundation stiffness in the same RCOL2_03.08.04-15 are calculated from the seismic soil pressure and seismic inertia including hydrodynamic effects which are then added to all other design loads discussed in Section 3.8.4.3. Seismic inertial responses are calculated using response spectra analyses in ANSYS using the design input response spectra based on the standard plant CSDRS anchored to 0.10 g acceleration, which envelops the site-specific FIRS spectra. Hydrodynamic effects are included in the response spectra analysis as described above except that the convective mass is included in the analysis using point masses and uni-directional springs which are attached to the end walls of each hydrodynamic region at the height of the convective pressure distribution centroid, h_C (see Table 3KK-7). The mass is equal to the convective mass (W_C) noted in the table and the springs are assigned stiffness such that the mass-spring system has a frequency equal to the convective frequency (f_C) noted in the table. Separate mass-spring systems are provided for all hydrodynamic regions. RCOL2_03.07.02-11 RCOL2_03.08.04-19, RCOL2_03.08.04-31

For seismic soil pressure cases, analyzed statically in ANSYS, seismic soil pressure demands are applied to the structural elements as equivalent static pressures. The equivalent trapezoidal pressures applied are larger than the resultant pressures calculated by ASCE 4-98 elastic solution based on J.H. Wood, 1973 and the enveloped of SASSI results.

Demands calculated from the response spectra and soil pressure analyses performed in ANSYS are combined on an absolute basis to produce the maximum demands for each direction of motion.

3KK.3 Seismic Analysis Results

Table 3KK-2 presents the natural frequencies of the UHSRS FE structural model used for the SASSI analysis. Table 3KK-3 presents a summary of SSI effects on the seismic response of the UHSRS. The maximum absolute nodal accelerations obtained from the SASSI analyses are presented in Table 3KK-4 for key UHSRS locations. The results envelope all site conditions considered. The maximum accelerations have been obtained by combining cross-directional contributions in accordance with RG 1.92 (Reference 3KK-6) using the square root sum of the squares (SRSS) method.

The dynamic horizontal soil pressure of the backfill on the basin walls varied depending on the soil case considered as the soil frequency approached that of the wall. The peak soil pressures varied along the height of the wall from values of approximately 0.5 ksf to almost 2ksf. The dynamic horizontal soil pressure used for design varied linearly from a value of 0.50ksf at the base slab to 1.5ksf at soil grade. ~~The base shear and moment demands on walls, calculated in SASSI calculated lateral dynamic soil pressures and equivalent pressure used for design analysis, were compared and the design pressure profile shown to be conservative.~~The peak dynamic soil pressure from each soil case was obtained from SASSI and compared with the dynamic soil pressure distribution applied in ANSYS. The resulting pressure distributions show that there is significant variability in the pressures determined from SASSI. The applied pressure RCOL2_03.08.04-28

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-20

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.2, "UHSRS", which references Appendix 3KK. In Appendix 3KK, Section 3KK.1, "Introduction," the second paragraph (Page 3KK-1) states that "Due to the low seismic response at the Comanche Peak Nuclear Power Plant site and lack of high frequency exceedances, the SASSI capability to consider incoherence of the input control motion is not implemented in the design of the UHSRS."

The applicant is requested to explain what are "high frequency exceedances". Is this a prerequisite for not considering the incoherence of the input control motion?

ANSWER:

The footprint dimensions of the foundation and the frequency content of the design ground motion are the main factors that determine the effects of the incoherency of the input ground motion on the seismic response of the buildings. The spatial variation of the ground motion across the foundation is significant for the portion of the ground motion that is characterized by high frequencies. The high frequency portion of the input design spectra represents the incoming seismic waves that have short wavelengths relative to the overall footprint dimensions of the foundation. FSAR Figure 3.7-201 shows the lack of high frequency exceedances at the CPNPP site. The site-specific FIRS (FIRS1 as shown in FSAR Figure 3.7-201) that define the design ground motion at the bottom elevation of the UHSRS foundation do not contain pronounced high frequency content since the FIRS are well below the 1/3 of the CSDRS at high frequencies. Therefore, the spatial variation of the input ground motion is deemed not significant for the design of the UHSRS. FSAR Section 3KK.1 has been adjusted to clarify this and similar adjustments have been made to FSAR Sections 3MM.1 and 3NN.1. See the response to Question 03.08.04-35 below for a discussion of incoherence with respect to the ESWPT.

High frequency exceedances are those exceedances of the standard plant CSDRS or site-specific FIRS that may occur in the range of 20 Hz or above, as discussed in RG 1.100 Revision 3. The presence of high frequency exceedances is not a prerequisite for considering incoherence of the input control motion. Inclusion of ground motion incoherency as permitted by USNRC ISG-01 Section 4 was considered for the site-specific analyses, but it was decided that this approach would not be used due to the low seismic response at the site and lack of high frequency exceedances. As stated in ASCE 4 Section 3.3.1.2:

> Vertically propagating shear and compression waves may be assumed for an SSI analysis provided that torsional effects due to non-vertically propagating waves are considered. The consideration of an accidental eccentricity of 5% of the structure's plan dimension, as discussed in Section 3.1.1, will fully account for torsional effects.

Therefore, any potential increases in design forces due to incoherence-related torsional components in the input motion are inherently addressed in the design by applying an accidental eccentricity of 5% of the structure's plan dimension in accordance with the provisions of ASCE 4 Section 3.1.1 (e). Accidental torsion is discussed further in DCD Subsection 3.7.2.11, which is incorporated by reference in the FSAR.

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

See attached marked-up FSAR Revision 1 pages 3KK-1, 3MM-1, and 3NN-1.

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

None.

<u>Impact on DCD</u>

None.

3KK MODEL PROPERTIES AND SEISMIC ANALYSIS RESULTS FOR UHSRS

3KK.1 Introduction

This Appendix discusses the seismic analysis of the ultimate heat sink related structures (UHSRSs), including the ultimate heat sink (UHS) Basin and its pump house. The computer program SASSI (Reference 3KK-1) serves as the platform for the soil-structure interaction (SSI) analyses. The three-dimensional (3D) finite element (FE) models of the UHSRS used in the SASSI analysis are generated from FE models with finer mesh patterns initially developed using the ANSYS computer program (Reference 3KK-2). The ~~SA~~coarser mesh SSI model is confirmed by comparing the structural frequencies between the ~~SA~~SSI model mesh and the fine mesh design model. The structural frequencies are calculated from modal analysis performed in ANSYS, and the similar results ensure compatibility between the two models and indicate that the ~~SA~~SSI model is acceptable. RCOL2_03.07.02-16 RCOL2_03.07.02-16

Dynamic analysis is performed in SASSI to obtain seismic responses including in-structure response spectra (ISRS), maximum accelerations, and dynamic soil pressures of the structure that includes SSI effects. Response spectra analyses are performed in ANSYS to obtain seismic ~~design~~ demands. used for design (Table 3KK-8 summarizes the analyses performed for calculating seismic demands) The SASSI analyses results for ~~maximum accelerations~~ISRS at the base slab and seismic soil pressures are used to verify the load demands assigned to the ANSYS structural design analysis that are included in the load combinations in accordance with the requirements of Section 3.8. The SASSI analysis ~~and results presented in this Appendix~~ include site-specific features such as the layering of the subgrade, embedment of the UHSRS, flexibility of the basemat and seismic motion scattering. Due to the low seismic response at the Comanche Peak Nuclear Power Plant site and lack of high-frequency exceedances, the spatial variation of the input ground motion is deemed not significant for the design of the UHSRS. Therefore, the SASSI capability to consider incoherence of the input control motion is not implemented in the ~~design~~analysis of the UHSRS. RCOL2_03.07.02-16 RCOL2_03.07.02-16 RCOL2_03.08.04-20 RCOL2_03.08.04-20

3KK.2 Model Description and Analysis Approach

The SASSI FE structural model for the UHSRS is shown in Figures 3KK-1. Table 3KK-1 presents the structural element material properties for the SASSI FE model. Detailed descriptions of the UHSRS are contained in Subsection 3.8.4. Figures 3.8-206 through 3.8-211 show detailed dimensions and layout of the UHSRS.

The fine mesh model, or ANSYS Design Model, is a three-dimensional finite element model of the UHSRS that is used for calculation of demands for design. The model includes all relevant structural details (walls, columns, beams, major openings, masses) with adequate mesh refinement to accurately calculate RCOL2_03.08.04-18

3MM MODEL PROPERTIES AND SEISMIC ANALYSIS RESULTS FOR PSFSVs

3MM.1 Introduction

This Appendix discusses the seismic analysis of the power source fuel storage vaults (PSFSVs). The computer program SASSI (Reference 3MM-1) serves as the platform for the soil-structure interaction (SSI) analyses. The three-dimensional (3D) finite element (FE) models used in the SASSI are condensed from FE models with finer mesh patterns initially developed using the ANSYS computer program (Reference 3MM-2). 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 with the ANSYS eigenvalues results ensures the accuracy of the translation.

The SASSI 3D FE model is dynamically analyzed to obtain seismic results including SSI effects. The SASSI model results including seismic soil pressures are used as input to the ANSYS models for performing the detailed structural design including loads and load combinations in accordance with the requirements of Section 3.8. The Table 3MM-8 summarizes the analyses performed for calculating seismic demands. The SASSI analysis and results presented in this Appendix include site-specific effects such as the layering of the subgrade, embedment of the PSFSVs, flexibility of the basemat and subgrade, and scattering of the input control design motion. Due to the low seismic response at the Comanche Peak Nuclear Power Plant site and lack of high-frequency exceedances, the spatial variation of the input ground motion is deemed not significant for the design of the PSFSVs. Therefore, the SASSI capability to consider incoherence of the input control motion is not implemented in the ~~design~~analysis of the PSFSVs.

RCOL2_03.07.02-16

RCOL2_03.08.04-20

RCOL2_03.08.04-20

3MM.2 Model Description and Analysis Approach

The SASSI FE model for the PSFSV is shown in Figure 3MM-1. Table 3MM-1 presents the properties assigned to the structural components of the SASSI FE model. Table 3MM-2 summarizes the SASSI FE model structural component dimensions and weights. Detailed descriptions and figures of the PSFSV are contained in Section 3.8.

RCOL2_03.07.02-16

The PSVSV is a simple shear wall structure with four exterior walls plus two interior shear walls. The walls must resist the out of plane flexure and shear due to transverse accelerations, soil pressures (for exterior walls) and flexure imparted on the wall from flexure in the roof slab. The roof slab resists vertical seismic demands as a continuous three span plate although there is some two-way response. Critical locations are therefore centers and edges of roof slabs and walls for flexure and bottom of walls for in-plane shear.

RCOL2_03.07.02-16

3NN ~~SASSI~~ MODEL PROPERTIES AND SEISMIC ANALYSIS RESULTS FOR R/B-PCCV-CONTAINMENT INTERNAL STRUCTURE RCOL2_03.08.04-60

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, <u>the spatial variation of the input ground motion is deemed not significant. Therefore,</u> the SASSI analyses do not consider incoherence of the input control motion. RCOL2_03.08.04-20

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.

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

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-21

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.2, "UHSRS", which references Appendix 3KK. In Appendix 3KK, Section 3KK.2, "Model Description and Analysis Approach," the second paragraph (Page 3KK-1) states that "Due to symmetry, soil-structure interaction (SSI) analysis is performed only on UHSRS B/D, and the responses are deemed applicable to the other UHSRS."

CPNPP COL FSAR Figure 3.8-201 shows the layout of the ultimate heat sink related structures (UHSRS) A, B, C, and D. UHSRS A and B are next to each other, and UHSRS C and D are next to each other. UHSRS A and B are separated from UHSRS C and D by a distance of about 58 ft. The applicant is requested to explain why the SSI analysis is performed on UHSRS B/D, and not UHSRS A/B or UHSRS C/D. Figure 3.8-201 shows that UHSRS A/B are perfectly symmetric with UHSRS C/D.

ANSWER:

Each SSI analysis is performed with only one UHSRS structure. The model used represents either B or D directly. Results for structures A and C are assumed to be the same because the structures are identical except that soil is adjacent to the east wall rather than the west wall. 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.

FSAR Section 3KK.2 has been revised to incorporate this response.

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

See attached marked-up FSAR Revision 1 page 3KK-2.

Impact on S-COLA

None.

Impact on DCD

None.

member demands at critical design locations. The model includes shell elements for walls and slabs, beam elements for columns and beams, mass elements for 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. RCOL2_03.08.04-18

The UHSRS model is developed and analyzed using methods and approaches consistent with ASCE 4 (Reference 3KK-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 UHSRS. The four UHSRS (per unit) are nearly ~~symmetric~~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. ~~Due to symmetry, s~~Since the structures are otherwise identical, soil-structure interaction (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. CTS-00922 RCOL2_03.07.02-16 RCOL2_03.08.04-21 RCOL2_03.07.02-16 RCOL2_03.08.04-27

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. RCOL2_03.08.04-23

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 (~~for the~~ lower bound case) RCOL2_03.07.02-16

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-22

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.2, "UHSRS", which references Appendix 3KK. In Appendix 3KK, Section 3KK.2, "Model Description and Analysis Approach," the third paragraph (Page 3KK-2) states that "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."

In CPNPP COL FSAR in Subsection 3.7.1.1, CP COL 3.7(5) presents Figure 3.7-201, which compares FIRS1, FIRS2, FIRS3, and FIRS4, with the certified seismic design response spectra (CSDRS) anchored at 0.1g. Also, Note 1 in the figure indicates that FIRS1 is the site-specific ground motion response spectra (GMRS).

The applicant is requested to:

(a) Provide information that explains how the strain-compatible backfill properties are obtained or computed. Appendix 3NN did not provide information for variations of shear modulus and damping ratio with shear strain level used in the calculation. Provide this information.

(b) Explain the relationship between FIRS and SSE. According to Appendix S to 10 CFR 50, the SSE should be used in the design. Provide the rationale and the technical basis to show that structures designed for FIRS can meet the SSE demands.

Furthermore, in US-APWR DCD Tier 2, Subsection 3.7.1.1, the second paragraph under "Site-Specific GMRS" on Page 3.7-4 states that "Site-specific GMRS are developed at a sufficient number of frequencies (at least 25) that adequately represent that local and regional seismic hazards using the site-specific geological, seismological, and geophysical input data."

In addition, the first paragraph under the title of "FIRS" on Page 3.7-4 in the US-APWR DCD states that "The site-specific GMRS serves as the basis for the development of FIRS that define the horizontal and vertical response spectra of the outcrop ground motion at the bottom elevation of the seismic category I and II basemats. Free-field outcrop spectra of site-specific horizontal ground motion are derived from the horizontal GMRS using site response analyses that consider only the wave propagation effects in materials that are below the control point elevation at the bottom of the basemat. The material present above the control point elevation can be excluded from the site response analysis."

The applicant is requested to explain:

a. Why the FIRS presented in CPNPP COL FSAR Figure 3.7-201 are defined by seven frequencies, not 25 frequencies, as stated in US-APWR DCD?

b. How are the FIRS derived from the GMRS.

c. Why FIRS are not scaled up to anchor at 0.1g before making the comparisons, in order to meet the minimum ground acceleration required by 10CFR, Appendix S to Part 5?

ANSWER:

Part 1

(a) Please refer to the response to RAI No. 2879 (CP RAI #60) Question 03.07.02-2 attached to Luminant letter TXNB-09073 dated November 24, 2009 (ML093340447) and to Question 03.08.04-53 below, which provide additional information for the FSAR.

(b) The design of the seismic category I structures are based on the 5% damping SSE design response spectra. Figure 3.7-201 is included in the FSAR to demonstrate that the 5% damping SSE design response spectra envelopes the 5% damping spectra at the FIRS locations across the entire range of pertinent frequencies and, thus, controls the design, as opposed to one of the FIRS, or a combination of spectra, controlling the design. See also the response to RAI No. 2879 (CP RAI #60) Question 03.07.02-11 attached to Luminant letter TXNB-09073 for a more complete discussion of the seismic analysis/design process for each of the seismic category I structures.

Part 2

a. As is described in FSAR Subsection 2.5.2.6.1.1, a seismic hazard calculation was made using the site amplification factors for the GMRS elevation, which is elevation 782 ft (top of Layer C). This calculation was made at the seven spectral frequencies at which ground motion equations were available from the 2004 EPRI study (Reference 2.5-401): 100 Hz, 25 Hz, 10 Hz, 5 Hz, 2.5 Hz, 1 Hz, and 0.5 Hz. The seismic hazard for horizontal motion was calculated by integrating the horizontal amplification factors shown in Figure 2.5.2-233 with the rock hazard and applying the CAV filter. Horizontal uniform hazard response spectra with its exceedance frequency of 10^{-5}/year and GMRS are calculated at 39 frequencies between 0.1 Hz and 100 Hz for the GMRS elevation. Because of the very flat appearance of the spectra at the seven spectral frequencies at which hazard calculations were made, log-log interpolation between available hazard values in the frequency range of 0.1 Hz to 100 Hz was used with the exception of between 1 Hz and 5 Hz and between 0.5 Hz to 0.1 Hz. Appropriate approximations were applied between 1 Hz and 5 Hz. and between 0.5 Hz to 0.1 Hz as explained in Subsection 2.5.2.6.1.1.

As described in FSAR Subsection 2.5.2.6.1.2, vertical GMRS and foundation input response spectra (FIRS) were developed using vertical-to-horizontal (V/H) ratios.

b. As described in FSAR Subsection 2.5.2.6.2, site response analyses were conducted for an additional four cases (FIRS 2, FIRS 3, FIRS 4_CoV30, and FIRS 4_CoV50) to consider foundation input response spectra for specific conditions different from the GMRS elevation. The seismic hazard for each FIRS case was calculated by integrating the horizontal amplification factors shown in FSAR Figures 2.5.2-235 through 2.5.2-238 with the rock hazard and applying the CAV filter. Smooth horizontal spectra for the four FIRS conditions (FIRS 1, FIRS 2, FIRS 3, FIRS4 and FIRS4_CoV50) were calculated in a similar way in which the smooth GMRS was calculated. This explanation on the derivation of the FIRS is provided in the response to RAI No. 2879 (CP RAI #60) Question 03.07.02-1 attached to Luminant letter TXNB-09073 dated November 24, 2009 (ML093340447). FSAR Subsection 2.5.2.6 has been revised in the supplemental response to RAI No. 1889 (CP RAI #11) Question 02.05.02-16 attached to Luminant letter TXNB-09084 dated December 14, 2009.

c. The FIRS were not scaled up because the theoretical FIRS that were developed were fully enveloped by the standard plant CSDRS anchored at 0.1g. Since full envelopment was achieved as demonstrated in FSAR Figure 3.7-201 and explained in note 2 of FSAR Figure 3.7-201, there was no need to scale the theoretical FIRS that were developed for the CPNPP site. FSAR Figure 3.7-201 demonstrates that FIRS1 and FIRS2, which are applicable to the CPNPP seismic category I building structures, are enveloped by a factor of 2 or more for every frequency in the design spectrum.

FSAR Appendix 3NN.2 has been revised to incorporate this response.

Reference

CEUS Ground Motion Project, Model Development and Results, Report No. 1008910, Electric Power Research Institute: Palo Alto, CA, 2004 (ML033580291).

Impact on R-COLA

See attached marked-up FSAR Revision 1 page 3NN-3.

Impact on S-COLA

None.

Impact on DCD

None.

Attachment

Marked-up FSAR Revision 1 page 3.7-2 from the responses to CP RAI # 55 Question 03.07.01-2 and CP RAI #60 Question 03.07.02-1

CP COL 3.7(22) Replace the last sentence of the ninth paragraph in DCD Subsection 3.7.1.1 with the following.

The CPNPP is not in a high seismic area, is not founded on hard rock, and the site-specific seismic GMRS and FIRS demonstrate that there are no high frequency exceedances of the CSDRS that could create damaging effects.

CP COL 3.7(5) Replace the last two sentences of the sixteenth paragraph in DCD Subsection 3.7.1.1 with the following.

The site-specific horizontal response spectra are obtained from site-specific response analyses performed in accordance with RG 1.208 (Reference 3.7-3) and account for upward propagation of the GMRS. ~~The nominal GMRS and horizontal response spectra~~The calculation of the GMRS and FIRS is outlined in Subsections 2.5.2.5 and 2.5.2.6, respectively. Subsections 2.5.2.5 and 2.5.2.6 document the site response methodology used, the soil properties used, and the methodology for calculating the GMRS. The nominal GMRS and FIRS for 5 percent damping resulting from these site-specific response analyses are shown in Figure 3.7-201. The spectra shown in Figure 3.7-201 represent nominal spectra for the following site-specific conditions: RCOL2_03.07.01-2 RCOL2_03.07.02-1

FIRS1 = the nominal GMRS, at the top of the stiff limestone (nominal elevation 782') described in ~~Chapter 2~~Subsections 2.5.2.5 and 2.5.2.6. The R/B-prestressed concrete containment vessel (PCCV)-containment internal structure, PS/Bs, UHSRS, PSFSVs, ESWPT, and A/B are founded directly on this limestone layer, have a thin layer of fill concrete placed between the top of limestone and bottom of mat foundation, and/or the fill concrete is analyzed in SASSI (Reference 3.7-17) as part of the seismic structural model. RCOL2_03.07.02-1

FIRS2 = the nominal response spectrum for structures located on a layer of fill concrete placed between the top of the limestone at nominal elevation 782' and bottom of the structure's foundation. Note that a comparison of FIRS1 and FIRS2 shows that the presence of several feet of fill concrete does not result in amplification of the ground motion seismic response, and is well below the minimum design earthquake.

FIRS3 = nominal response spectrum corresponding to typical plant grade elevation 822' for shallow-embedment structures founded on native, in-situ, undisturbed materials occurring below plant grade as described in ~~Chapter 2~~Subsections 2.5.2.5 and 2.5.2.6. FIRS3 does not apply currently to any plant structures. FIRS3 represents the free-field ground motion. RCOL2_03.07.02-1

surface of the rock subgrade at nominal elevation of 782 ft. The degradation curves presented in Figure 2.5.2-232, which are derived based on standard EPRI shear modulus reduction and damping curves for granular fill, were used to model the properties of the backfill, which are non-linear. The curves' values of the soil shear modulus and the damping as a function of shear strain are listed in Table 2.5.2-227. RCOL2_03.08.04-22 RCOL2_03.08.04-43 RCOL2_03.08.04-53

ACS SASSI SOIL calculated strain-compatible fill properties using 65% of the peak strain value for selection of effective soil strain. The results for the strain-compatible backfill properties obtained from the two horizontal site response analyses are averaged to obtain the backfill profiles used as the input for the site-specific SSI analyses.

The compression or P-wave velocity is developed for the rock and the backfill from the strain-compatible shear or S-wave velocity (Vs) and the measured value of the Poisson's ratio by using the following equation:~~.~~ RCOL2_03.07.02-2

$$Vp = Vs \cdot \sqrt{2 \cdot \frac{1-v}{1-2v}}$$

The SSI analyses use identical values for the shear S-wave and compression P-wave velocity damping. Figure 3NN-1, Figure 3NN-2 and Figure 3NN-3 present, respectively, the rock subgrade LB, BE and UB profiles for shear (S) wave velocity (Vs), compression (P) wave velocity (Vp) and material damping. Figure 3NN-4, Figure 3NN-5 and Figure 3NN-6 present in solid lines the results of the site response analyses for the profiles of strain-compatible backfill properties. The plots also show with dashed lines the backfill profiles that were modified to match the geometry of the mesh of the SASSI basement model. The presented input S and P wave profiles are modified using the equal arrival time averaging method. Table 3NN-16 provides the strain-compatible backfill properties, used for the SASSI analysis for LB, BE, UB, and HB embedment conditions. RCOL2_03.07.02-2

The minimum design spectra, tied to the shapes of the certified seismic design response spectra (CSDRS) and anchored at 0.1g, define the safe-shutdown earthquake (SSE) design motion for the seismic design of category I structures that is specified as outcrop motion at the top of the limestone at nominal elevation of 782 ft. Two statistically independent time histories H1 and H2 are developed compatible to the horizontal design spectrum, and a vertical acceleration time history V is developed compatible to the vertical design spectrum. The time step of the acceleration time histories used as input for the SASSI analysis is 0.005 seconds. The SASSI analysis requires the object motion to be defined as within-layer motion. ~~The site response analyses convert the design motion that is defined as outcrop motion (or motion at the free surface) to within-layer (or base motion) that depends on the properties of the backfill above the rock surface. The site response analyses provide for each considered backfill profile, two horizontal acceleration time histories of the design motion within the top limestone rock layer~~ RCOL2_03.08.04-54

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-23

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.2, "UHSRS", which references Appendix 3KK. In Appendix 3KK, Section 3KK.2, "Model Description and Analysis Approach," the 3rd paragraph, last two sentences (Page 3KK-2) state, in part, "To account for uncertainty in the site-specific properties, 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 applicant is requested to describe the values of the expected uncertainties in the backfill properties, and to reference the source of the data used to establish the uncertainty.

ANSWER:

The final backfill properties are unknown; therefore the soil cases are selected in order to cover a wide range of soil conditions for analysis. The coefficient of variation on shear modulus, Cv, is 0.69 for the lower and upper bound fill cases, and is based on the reference cited below. To account for additional uncertainty in the upper range, a Cv value of 1.25 was used for the high bound fill. To account for additional uncertainty in the lower range, analyses were also performed with no backfill. The "no-fill" condition and the Cv value of 1.25 for the high-bound condition provide conservative limits that exceed limits obtained using guidance for Cv values given in SRP 3.7.2.

Reference

Risk Engineering Inc., "Artificial Shear-Wave Velocity Profiles for Comanche Peak Units 2 and 3 Site Response Calculations" Record 0737-ACR-028 & 0737-ACR-029 Rev 1, 2/11/08. (Note that this title refers to Comanche Peak Units 2 and 3 but the intent was to provide information for Units 3 and 4.)

Impact on R-COLA

See attached marked-up FSAR Revision 1 page 3KK-2.

Impact on S-COLA

None.

Impact on DCD

None.

member demands at critical design locations. The model includes shell elements for walls and slabs, beam elements for columns and beams, mass elements for 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. RCOL2_03.08.04-18

The UHSRS model is developed and analyzed using methods and approaches consistent with ASCE 4 (Reference 3KK-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 UHSRS. The four UHSRS (per unit) are nearly ~~symmetric~~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. ~~Due to symmetry, s~~Since the structures are otherwise identical, soil-structure interaction (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. CTS-00922 RCOL2_03.07.02-16 RCOL2_03.08.04-21 RCOL2_03.07.02-16 RCOL2_03.08.04-27

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. RCOL2_03.08.04-23

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 (~~for the~~ lower bound case) RCOL2_03.07.02-16

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-24

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.2, "UHSRS", which references Appendix 3KK. In Appendix 3KK, Section 3KK.2, "Model Description and Analysis Approach," the fourth paragraph (Page 3KK-2) states that "The following SSI analyses and site profiles are used for calculating seismic responses of UHSRS:

- a surface foundation condition (without the presence of backfill) for the lower bound case
- 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 backfill separation is modeled by reducing the shear wave velocity by a factor of 10 for the soil elements adjacent to the structure that are determined to be separated. The potential for separation of backfill is determined using an iterative approach that compares the peak envelope soil pressure results for the best estimate (BE) case to the at-rest soil pressure."

The applicant is requested to provide the following information:

(a) Explain why in the first bullet, only the LB case is considered and in the second bullet, only the BE case is considered; whereas, for the third bullet, LB, BE, UB, and HB are considered.

(b) Provide the rationale for choosing a factor of 10 for reducing the shear wave velocity to model the backfill separation.

(c) Provide details that show how the interactive approach was done. Does this analysis correspond to the case of the third bullet? If yes, why is only the BE case considered in the iterative procedure to determine the potential of separation? In the third bullet statement, it is stated that all four soil profiles were considered.

(d) Once the separation condition is met, is the shear wave velocity reduced for the entire surrounding soil, or just one side of the soil? Justify the method of analysis if the shear wave velocity is reduced for the entire surrounding soil. In reality, when one side of the soil separates, the other side of the soil will not separate during the earthquake.

(e) Provide information that shows how the results of these analyses are used in design.

ANSWER:

(a) Soil embedment provides additional stiffness to the structure. Analysis with lower bound in-situ soil (limestone) and no backfill provides a bounding softest soil condition.

Analyses were performed with best estimate soil condition both for cases with soil separation and without separation. 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 using soil separation to produce the bounding maximum response.

(b) The reduction of properties was only performed on backfill elements modeled directly adjacent to the structure in the region of soil separation. The factor of 10 on shear wave velocity represents a factor of 100 on soil shear modulus and Young's modulus. This value was 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 will not be significantly influenced by the small pressures (see the figure included with the response to Question 03.08.04-28 below).

(c) The SSI peak soil pressures calculated in the SASSI best-estimate, non-separated case was compared to the at-rest calculated soil pressures. The SSI model is modified to model the soil separation for layers calculated to separate. The approach was not iterative and the best-estimate case was considered to be representative of the amount of soil separation for all soil cases.

(d) For separated soil case analyses, all of the soil elements directly adjacent to the structure within the separation depth are modified by reducing their shear wave velocity. For the UHSRS, the south and east or west sides have no adjacent soil due to a seismic isolation joint that separates the UHSRS from adjacent structures. Therefore the only way to model soil separation in this case is to separate the soil on all sides.

(e) The SSI analyses performed using SASSI produced in-structure response spectra and dynamic soil pressures. The calculation of the design demands (forces and moments) were performed using the program ANSYS. The inertial effects were calculated by response spectra analyses using design input response spectra input confirmed to be higher than the SSI calculated in-structure response spectra at the base slab. To calculate the design demands due to dynamic soil pressures, pressures were applied to the walls against soil. The dynamic soil pressures applied were calculated by the elastic solution of ASCE 4 (Wood method). The dynamic soil pressures applied were shown to produce greater demands than the SASSI calculated soil pressures. For design the effects due to inertial (RS) and seismic soil pressures are added on an absolute basis.

FSAR Section 3KK.2 has been revised to incorporate this response.

Impact on R-COLA

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

Impact on S-COLA

None.

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. RCOL2_03.08.04-24 RCOL2_03.07.02-16

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.

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-25

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.2, "UHSRS", which references Appendix 3KK. In Appendix 3KK, Section 3KK.2, "Model Description and Analysis Approach," the last paragraph on Page 3KK-2 states that "Shell elements are used to model the basemat and brick elements are used for the concrete fill that is present beneath basemat."

The applicant is requested to provide information that shows how the interface between the basemat and concrete fill is modeled. Are shell elements in contact with the brick elements directly? If yes, how is the shell element connected to the brick element?

ANSWER:

In the SSI model for analysis in SASSI, shell elements and solid (brick) elements are connected at their shared nodes. Shell elements represent the walls and slabs while brick elements are included to model the concrete fill beneath the structure and soil on the sides. Where the shell elements and brick elements are connected, the shell element is connected to overlap a face of the brick element. There are no locations in the models where shell elements are connected perpendicularly to the brick elements with the intention of transferring moments through nodal rotational degrees of freedom.

FSAR Section 3KK.2 has been revised to incorporate this response.

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

See attached marked-up FSAR Draft Revision 1 page 3KK-4.

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

None.

Impact on DCD

None.

The UHSRS analyses were verified by the following methods: RCOL2_03.07.02-16

- Comparison of eigenvalue analysis results between a coarser mesh (used for SASSI SSI analyses) and a finer mesh (used for ANSYS design analyses), the results are presented in Table 3KK-9. RCOL2_03.08.04-18

Review of SASSI transfer functions to verify that interpolation was reasonable and that expected structural responses were observed. All SASSI output results were compares between soil profiles to verify reasonably similar responses between the cases.

Operating-basis earthquake (OBE) structural damping values of Chapter 3 Table 3.7.1-3(b), such as 4 percent damping for reinforced concrete, are used in the site-specific SASSI analysis. This is consistent with the requirements of Section 1.2 of RG 1.61 (Reference 3KK-4) for structures on sites with low seismic responses where the analyses consider a relatively narrow range of site-specific subgrade conditions. The SASSI analyses produce results including peak accelerations, in-structure response spectra, and seismic soil pressures. All results from SSI analyses represent the envelope of the six soil conditions. The SASSI analyses results are used to produce the final response spectra and provide confirmation of the design spectra and seismic soil pressures used in ANSYS. RCOL2_03.07.02-11

Shell elements are used to model the basemat and brick elements are used for the concrete fill that is present beneath basemat and for the soil on the sides. RCOL2_03.08.04-25 Beam elements are used for the concrete beams, ~~that~~which support slabs and equipment in the structure, and for the concrete columns in the cooling towers. RCOL2_03.08.04-26 Beam elements are also used to model the steel members in the UHSRS. Shell elements are also used for the reinforced concrete walls and elevated slabs. RCOL2_03.08.04-25 Where shell elements and brick elements are connected, the shell element is connected to overlap a face of the brick element. There are no locations in the models where shell elements are connected perpendicularly to the brick elements with the intention of transferring moments through nodal rotational degrees of freedom. Walls are modeled using gross section properties at the centerline. All roof slabs and elevated slabs (pump room, fan slab, missile shield protection) are considered as cracked with an out-of-plane bending stiffness of ½ of the gross section stiffness in accordance with ASCE 43-05 (Reference 3KK-10). RCOL2_03.08.04-26 The properties assigned to the slab elements are modified to account for cracked out-of plane flexural stiffness and non-cracked in-plane axial and shear stiffness of the slabs as follows:

$$E_{cracked} = [1/(C_F)^{0.5}] \cdot E_{concrete}$$

$$t_{cracked} = (C_F)^{0.5} \cdot t$$

$$\gamma_{cracked} = [1/(C_F)^{0.5}] \cdot \gamma_{concrete}$$

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-26

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.2, "UHSRS", which references Appendix 3KK. In Appendix 3KK, Section 3KK.2, "Model Description and Analysis Approach," the paragraph at the top of Page 3KK-3 gives three equations used to modify the slab elements to account for the cracked out-of-plane flexural stiffness and non-cracked in-plane axial and shear stiffness of the slabs.

The applicant is requested to provide the technical basis for these equations and the reference to the source of the equations.

ANSWER:

All roof slabs and elevated slabs (pump room, fan slab, missile shield protection) are considered to be cracked with a bending stiffness of half of the gross section stiffness based on ASCE-43 Section 3.4.1. The slabs are considered uncracked for shear and axial loads. The equations to calculate the material properties for cracked concrete ($E_{cracked}$, $t_{cracked}$, and $\gamma_{cracked}$) are derived from fundamental mechanics to maintain the same total shear stiffness, axial stiffness, and mass while reducing the flexural stiffness by one half.

The equations as listed in FSAR Section 3KK.2 are:

$$E_{cracked} = \frac{1}{\sqrt{C_F}} \cdot E_{concrete}$$

$$t_{cracked} = \sqrt{C_F} \cdot t$$

$$\gamma_{cracked} = \frac{1}{\sqrt{C_F}} \cdot \gamma_{concrete}$$

Where E is the elastic modulus, t is the slab thickness, γ is the unit weight, and CF is the cracking factor and is equal to 0.5 (ASCE 43) for this case to produce half of the flexural stiffness in the cracked condition. The slab area for a unit width is equal to the slab thickness, t. The axial stiffness is equal to the elastic modulus times the axial area. The calculated axial area using cracked properties above is equal to uncracked axial stiffness as shown:

$$E_{cracked} \cdot t_{cracked} = \left(\frac{1}{\sqrt{C_F}} \cdot E_{concrete}\right) \cdot \left(\sqrt{C_F} \cdot t\right) = E_{concrete} \cdot t$$

A similar relationship holds true for shear since shear modulus is proportional to elastic modulus.

The flexural stiffness for the cracked case is intended to be half of the stiffness for the uncracked case. The flexural stiffness of a slab is proportional to the elastic modulus times the cube of the thickness. Performing a similar substitution we find:

$$E_{cracked} \cdot t_{cracked}^{3} = \left(\frac{1}{\sqrt{C_F}} \cdot E_{concrete}\right) \cdot \left(\sqrt{C_F} \cdot t\right)^3 = E_{concrete} \cdot t^3 \cdot C_F$$

Since C_F is defined as 0.5 for this case, the equation shows that the cracked flexural stiffness is half of the uncracked flexural stiffness.

Finally the slab needs to maintain the total weight. The weight for a unit length is equal to the area times the unit weight. The calculated weight using cracked properties is equal to the uncracked weight as shown:

$$t_{cracked} \cdot \gamma_{cracked} = \left(\sqrt{C_F} \cdot t\right) \cdot \left(\frac{1}{\sqrt{C_F}} \cdot \gamma_{concrete}\right) = t \cdot \gamma_{concrete}$$

FSAR Sections 3KK.2 and 3KK.5 have been revised to incorporate this response.

<u>Reference</u>

Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities, American Society of Civil Engineers, ASCE/SEI 43-05, Reston, Virginia, 2005.

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

See attached marked-up FSAR Revision 1 pages 3KK-4 and 3KK-10.

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

None.

Impact on DCD

None.

The UHSRS analyses were verified by the following methods: RCOL2_03.07.02-16

- Comparison of eigenvalue analysis results between a coarser mesh (used for SASSI SSI analyses) and a finer mesh (used for ANSYS design analyses), the results are presented in Table 3KK-9. RCOL2_03.08.04-18

Review of SASSI transfer functions to verify that interpolation was reasonable and that expected structural responses were observed. All SASSI output results were compares between soil profiles to verify reasonably similar responses between the cases.

Operating-basis earthquake (OBE) structural damping values of Chapter 3 Table 3.7.1-3(b), such as 4 percent damping for reinforced concrete, are used in the site-specific SASSI analysis. This is consistent with the requirements of Section 1.2 of RG 1.61 (Reference 3KK-4) for structures on sites with low seismic responses where the analyses consider a relatively narrow range of site-specific subgrade conditions. The SASSI analyses produce results including peak accelerations, in-structure response spectra, and seismic soil pressures. All results from SSI analyses represent the envelope of the six soil conditions. The SASSI analyses results are used to produce the final response spectra and provide confirmation of the design spectra and seismic soil pressures used in ANSYS. RCOL2_03.07.02-11

Shell elements are used to model the basemat and brick elements are used for the concrete fill that is present beneath basemat and for the soil on the sides. RCOL2_03.08.04-25 Beam elements are used for the concrete beams, ~~that~~which support slabs and equipment in the structure, and for the concrete columns in the cooling towers. RCOL2_03.08.04-26 Beam elements are also used to model the steel members in the UHSRS. Shell elements are also used for the reinforced concrete walls and elevated slabs. RCOL2_03.08.04-25 Where shell elements and brick elements are connected, the shell element is connected to overlap a face of the brick element. There are no locations in the models where shell elements are connected perpendicularly to the brick elements with the intention of transferring moments through nodal rotational degrees of freedom. Walls are modeled using gross section properties at the centerline. All roof slabs and elevated slabs (pump room, fan slab, missile shield protection) are considered as cracked with an out-of-plane bending stiffness of ½ of the gross section stiffness in accordance with ASCE 43-05 (Reference 3KK-10). RCOL2_03.08.04-26 The properties assigned to the slab elements are modified to account for cracked out-of plane flexural stiffness and non-cracked in-plane axial and shear stiffness of the slabs as follows:

$$E_{cracked} = [1/(C_F)^{0.5}] \cdot E_{concrete}$$

$$t_{cracked} = (C_F)^{0.5} \cdot t$$

$$\gamma_{cracked} = [1/(C_F)^{0.5}] \cdot \gamma_{concrete}$$

3KK-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.

3KK-5 *Seismic Design of Liquid-Containing Concrete Structures and Commentary*, ACI 350.3, American Concrete Institute, Farmington Hills, Michigan, 2006.

3KK-6 *Combining Responses and Spatial Components in Seismic Response Analysis*, Regulatory Guide 1.92, Rev. 2, U.S. Nuclear Regulatory Commission, Washington, DC, July 2006.

3KK-7 *Development of Floor Design Response Spectra for Seismic Design of Floor-supported Equipment or Components*, Regulatory Guide 1.122, Rev. 1, U.S. Nuclear Regulatory Commission, Washington, DC, February 1978.

3KK-8 Morante, R. and Wang, Y. *Reevaluation of Regulatory Guidance on Modal Response Combination Methods for Seismic Response Spectrum Analysis*, NUREG/CR-6645, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, DC, December 1999.

3KK-9 Seismic Subsystem Analysis, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, NUREG-0800, United States Nuclear Regulatory Commission Standard Review Plan 3.7.3, Revision 3, March 2007. RCOL2_03.07.03-1

3KK-10 Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities, American Society of Civil Engineers, ASCE/SEI 43-05, Reston, Virginia, 2005. RCOL2_03.08.04-26

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-27

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.2, "UHSRS", which references Appendix 3KK. In Appendix 3KK, Section 3KK.2, "Model Description and Analysis Approach," the last paragraph on Page 3KK-3 states that "The hydrodynamic effects of the water contained in the basins, cooling towers, and pump room of the UHS [ultimate heat sink] 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 [American Concrete Institute] 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 applicant is requested to provide the following information:

(a) The second sentence in the above quoted paragraph, "The water is separated into rectangular regions in which water sloshing can develop under horizontal seismic excitation," is confusing. Is water separated into rectangular regions so that water sloshing can develop? Is water sloshing a needed feature? Why?

(b) The meaning of the third sentence is not clear. Explain the meaning of "impulsive (fixed)" in this sentence. Does "fixed" mean fixed with respect to the ground? Is the flexibility of the tank wall considered?

(c) Is the possibility of water separating from the wall considered in the analysis?

(d) List the fundamental sloshing frequency, the structural frequency, and the soil frequency. Are the sloshing forces included in the design of walls? If yes, describe how they are considered. If not, explain the rationale for ignoring these sloshing effects.

(e) Are there any conditions where one of the basins is empty while the adjacent basin is filled with water? If so, summarize the results of the analysis for that condition. If not, provide the rationale for not considering those conditions.

ANSWER:

(a) The design of the UHS basin includes baffle walls that physically separate the water into regions while providing openings in the lower section of walls that allow for water flow. The hydrodynamic effects include the impulsive (rigid) and convective (sloshing) modes which must be considered based on SRP 3.7.3.II.14. In order to analyze and model these fluid modes, the basin areas needed to be broken up conceptually into compartments by the expected behavior of each compartment. These compartments are determined by the walls that separate the water regions. Impulsive and convective modes will primarily act and react within each region.

The FSAR was modified in the response to RAI No. 2883 (CP RAI#64) Question 03.07.03-2 attached to Luminant's letter TXNB-09060 dated October 30, 2009 (ML093090163) to state (in part):

> 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 development of dynamic demands in accordance with requirements of SRP 3.7.3. The hydrodynamic properties were calculated using the methodology specified in ACI 350.3-06 (Reference 3KK-5) and modeling was performed following the procedures of ASCE 4-98 (Reference 3KK-3). The properties calculated using ACI 350-06 has been shown to meet or exceed relevant requirements of SRP 3.7.3. For the purposes of hydrodynamic analysis, the water is separated into rectangular regions to calculate hydrodynamic properties per ACI 350.3-06.

(b) ASCE 4-98 and TID-7024 (both referenced by SRP 3.7.3) and ACI 350.03 separate the hydrodynamic fluid into impulsive and convective components. The impulsive mass of the water is the mass that acts rigidly with respect to the basin walls and is referred to as the "impulsive (aka fixed or rigid)" mass in the sentence indicated. The impulsive fluid mass is considered fixed with respect to the walls. This impulsive fluid mass is attached to the basin walls at the end of each hydrodynamic region using directional masses to include only mass activated by the wall motion (no fluid-wall friction). The fluid is not fixed with respect to the ground. The FSAR was modified to refer to hydrodynamic behavior as impulsive and convective, not "fixed", in the response to RAI No. 2883 (CP RAI #64) Question 03.07.03-2.

The tank wall flexibility is included in the response spectra analysis by modeling of walls by plate elements and applying the impulsive portion of the water mass to the walls as directional masses at the wall nodes corresponding to boundaries of each hydrodynamic zone.

(c) The effect of inclusion of the sloshing modes increases the hydrostatic pressure on one wall while simultaneously decreasing the hydrostatic pressure on the opposite wall. This is equivalent to an increase in water height on one side of the basin with simultaneous decrease in height on the other, similar to separation but physically representing wave modes.

(d) The frequency of sloshing in all regions except between the baffle walls in the pump room ranges between 0.16 to 0.31 Hz and the frequency of sloshing in between the baffle walls is approximately

0.66 Hz. Major structural frequencies exceed 4 Hz. The soil frequency in the horizontal direction ranges from 4 Hz for the lower-bound soil case to 8 Hz for the high-bound soil case.

Sloshing forces are calculated in the design model seismic response spectra analysis performed in ANSYS. The design model is a detailed finite element model of the UHSRS including basin walls represented by plate elements and sloshing modeled by a set of masses and springs system in accordance with the procedures of ASCE 4-98. The response spectra analysis is performed using a composite damping input spectra with a 5% damping (RG1.61) for frequencies above 1 Hz and 0.5% damping (SRP 3.7.3 and similar to Table 6 of RG 1.61) for hydrodynamic convective frequencies (all below 1 Hz). This method was used because all sloshing modes occur at frequencies less than 1 Hz and all major structural frequencies are above 4 Hz. This model generates the combined inertial effect seismic design forces, including sloshing effects, and these forces are used for design.

(e) For the adjacent UHS basins A and B or C and D: the basins are separated by an isolation gap so that the response of one basin does not directly influence the other. The soil structure interaction (SSI) analysis in SASSI calculated the response spectra at the basin slab. The SSI analysis demonstrated that the response spectra at the base slab of the basin is nearly the same as the design input response spectra, indicating that the SSI effects are small and the structures can be modeled independently. As a result, the UHSRS structures were modeled independently and the condition of one basin full and one empty did not need to be considered.

For separate components within a single UHS basin: the openings at the base of the wall dividing the basins of a single UHS maintain equal water level in the basins at all times, since there are sufficient openings in the lower part of all partition walls. No mechanism exists in the structural design for closing these openings and allowing unequal water level to be created. Unequal water levels were not considered for design.

FSAR Section 3KK.2 has been revised to incorporate this response.

FSAR Section 3KK.2 was revised in the response to RAI No. 2879 (CP RAI #60) Question 03.07.02-16 attached to Luminant letter TXNB-09073 dated November 24, 2009 (ML093340447) to clarify the layout of the UHSRS.

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

See attached marked-up FSAR Revision 1 pages 3KK-2 and 3KK-6.

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

None.

<u>Impact on DCD</u>

None.

member demands at critical design locations. The model includes shell elements for walls and slabs, beam elements for columns and beams, mass elements for 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. RCOL2_03.08.04-18

The UHSRS model is developed and analyzed using methods and approaches consistent with ASCE 4 (Reference 3KK-3), and accounting for the site-specific stratigraphy and subgrade conditions described in ~~Chapter 2~~Subsection 2.5.4, as CTS-00922 well as the backfill conditions around the embedded UHSRS. The four UHSRS (per unit) are nearly ~~symmetric~~identical with minor variations on backfill layout for RCOL2_03.07.02-16 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. RCOL2_03.08.04-21 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. ~~Due to symmetry, s~~Since the structures are otherwise identical, soil-structure interaction (SSI) analysis is performed only on UHSRS B/D, and the responses are deemed applicable to the other UHSRS. RCOL2_03.07.02-16 RCOL2_03.08.04-27 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.

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 RCOL2_03.08.04-23 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 (~~for the~~ lower bound case) RCOL2_03.07.02-16

into rectangular regions to calculate hydrodynamic properties per ACI 350.3-06. The rectangular regions shown in Figure 3KK-4 are chosen since they are bounded by structural walls such that their behavior conforms to the equations derived in the above referenced documents. The key hydrodynamic properties of each region are listed in Table 3KK-7. Due to the embedment, squat dimensions, and small intensity base excitations, uplifting of this structure is not considered in the UHSRS model. RCOL2_03.07.03-2

Following the recommended modeling procedures of ASCE 4-98 (Reference 3KK-3), the water mass within each region is separated into impulsive and convective components (W_i and W_c in Table 3KK-7). The impulsive mass of the water is applied to nodes of walls at each end of the rectangular region, in the direction perpendicular to the wall, and applied uniformly along the walls using directional masses from the bottom of the basin to a height of twice the impulsive pressure distribution (h_i, values in Table 3KK-7). The convective mass is included in the analysis using point masses and uni-directional springs which are attached to the end walls of each hydrodynamic region at the height of the convective pressure distribution centroid, hc (see Table 3KK-7). The mass is equal to the convective mass (W_c) noted in the attached table and the springs are assigned stiffness such that the mass-spring system has a frequency equal to the convective frequency (f_c) noted in the table. Separate mass-spring systems are provided for all hydrodynamic regions. The vertical mass of the water is distributed uniformly across the base mat using directional mass elements. Support flexibility is considered by enveloping demands of a fixed-base model and a model supported on flexible soil springs.

Response spectra analyses are performed in ANSYS (Reference 3KK-2) to obtain seismic design demands, which include all structural and hydrodynamic effects as described above. The impulsive hydrodynamic modes include the basin flexibility directly in the FE analysis. All structural and impulsive modes (frequencies > 1Hz) are assigned 5% damping. The convective modes are assigned 0.5% damping by increasing the input response spectrum for frequencies less than 1 Hz (only includes the convective modes). Modal combination is performed in accordance with RG 1.92 (Reference 3KK-6), using Combination Method B for combination of periodic and rigid modes, using the low frequency correction α=0 for frequencies below the peak of the spectra. Periodic modal response is combined using the grouping method. Spatial combination is performed using the Newmark 100-40-40 percent combination rule. RCOL2_03.08.04-32 RCOL2_03.07.03-2

The peak sloshing height in any hydrodynamic region is equal to 1.91 ft. This height includes spatial combination of sloshing in each region using the Newmark 100-40-40 percent directional combination rule. The nominal freeboard height to the top of the basin walls and underside of the pump house slab is not a concern since adequate clearance is provided to allow this amount of sloshing. RCOL2_03.08.04-27

The fine mesh ANSYS model is used for the calculation of both seismic and non-seismic demands for design. The seismic structural demands of the UHSRS RCOL2_03.07.02-11

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-28

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.2, "UHSRS", which references Appendix 3KK. In Appendix 3KK, Section 3KK.3, "Seismic Analysis Results," the second paragraph (Page 3KK-4) states that "The base shear and moment demands on walls, calculated in SASSI calculated lateral dynamic soil pressures and equivalent pressure used for design analysis, were compared and the design pressure profile shown to be conservative. The peak design vertical soil pressure calculated under the base slab is 11.7 ksf, which reduces away from edges. This value excludes the peak corner pressure of 23.0 ksf calculated on a single element, representing less than 0.2 percent of the total base slab area. The average peak vertical seismic pressure calculated under the base slab is 1.6 ksf."

The applicant is requested to:

(a) Revise first sentence in the above quoted paragraph as it seems confusing.

(b) Provide the definition for "equivalent pressure" that is used for design analysis. Also, provide technical information that shows how it is calculated.

(c) Provide information for the design pressure profile mentioned in the paragraph.

(d) Provide the technical rationale for excluding the 23.0 ksf for the corner pressure. Explain why the peak corner pressure of 23.0 ksf appears in the analysis. Why does this high stress only occur in one element?

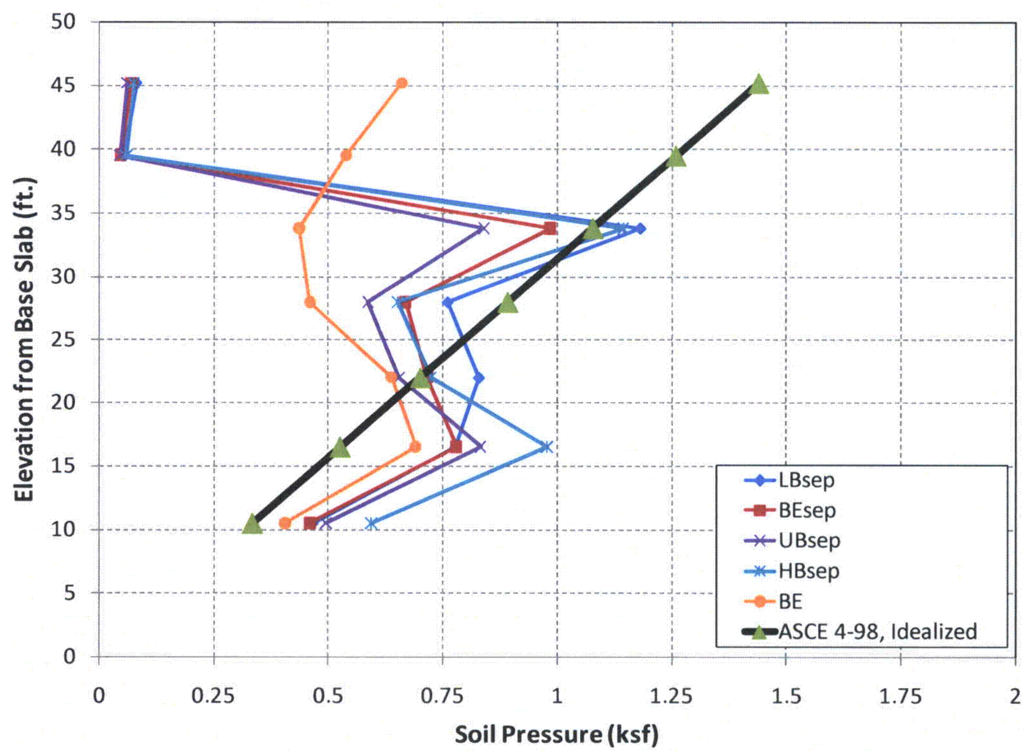
(e) Show the data for any comparisons made between demand and design loads that support the conclusion that the results are conservative.

ANSWER:

(a) The first sentence in the above quoted paragraph from FSAR Section 3KK.3 has been revised as shown on marked-up FSAR Revision 1 pages 3KK-7 and 3KK-8.

(b) The "equivalent pressure" in the sentence is referring to the static soil pressure applied to the ANSYS design model to represent the dynamic soil pressure. The pressure applied to the design model is based on ASCE 4-98 (Section 3.5.3.2) which determines a resultant force per unit length of wall and recommends application of a trapezoidal pressure distribution along the wall height (Section C3.5.3.2) with the resultant force at a height of 0.6 H (wall height) from the bottom of the wall. The pressure applied to the ANSYS design model was slightly greater with a resultant force at a height of 0.67 H. This was referred to as the "equivalent pressure." This soil pressure is shown to be conservative with respect to the SSI calculated peak dynamic soil pressures.

(c) The design pressure profile is based on ASCE 4-98 as described in the response to (b) above. The pressure used for design is shown in the figure below (ASCE 4-98, Idealized) along with dynamic soil pressure results from SASSI at the Basin West Wall.



Dynamic Soil Pressure Distribution along Height of West Wall and Static Pressure Distribution used in ANSYS

(d) The SASSI analysis uses a linear elastic structure and soil model. The high corner pressures represent a local high value at the extremes of the model and represent less than 0.2% of the model. The dynamic soil pressure is better represented by excluding this local peak element result. Both the extreme corner value and the more representative value were reported for completeness.

(e) Comparing the total base shear and overturning moments from the applied seismic soil pressure distribution in ANSYS to the controlling distribution from the SASSI SSI analyses shows that the applied seismic soil pressure distribution applied in ANSYS is conservative:

For West Wall (North of Pump Room)

- Base Shear – Design model = 34 kip/ft, SASSI = 30 kip/ft
- Base Moment – Design model = 673.2 kip-ft/ft, SASSI = 507 kip-ft/ft

For North Wall:

- Base Shear – Design model = 34 kip/ft, SASSI = 33 kip/ft
- Base Moment – Design model = 673.2 kip-ft/ft, SASSI = 414 kip-ft/ft

Impact on R-COLA

See attached marked-up FSAR Revision 1 pages 3KK-7 and 3KK-8.

Impact on S-COLA

None.

Impact on DCD

None.

are calculated from the seismic soil pressure and seismic inertia including hydrodynamic effects which are then added to all other design loads discussed in Section 3.8.4.3. Seismic inertial responses are calculated using response spectra analyses in ANSYS using the design input response spectra based on the standard plant CSDRS anchored to 0.10 g acceleration, which envelops the site-specific FIRS spectra. Hydrodynamic effects are included in the response spectra analysis as described above except that the convective mass is included in the analysis using point masses and uni-directional springs which are attached to the end walls of each hydrodynamic region at the height of the convective pressure distribution centroid, h_C (see Table 3KK-7). The mass is equal to the convective mass (W_C) noted in the table and the springs are assigned stiffness such that the mass-spring system has a frequency equal to the convective frequency (f_C) noted in the table. Separate mass-spring systems are provided for all hydrodynamic regions. RCOL2_03.07.02-11 RCOL2_03.08.04-19 RCOL2_03.08.04-31

For seismic soil pressure cases, analyzed statically in ANSYS, seismic soil pressure demands are applied to the structural elements as equivalent static pressures. The equivalent trapezoidal pressures applied are larger than the resultant pressures calculated by ASCE 4-98 elastic solution based on J.H. Wood, 1973 and the enveloped of SASSI results.

Demands calculated from the response spectra and soil pressure analyses performed in ANSYS are combined on an absolute basis to produce the maximum demands for each direction of motion.

3KK.3 Seismic Analysis Results

Table 3KK-2 presents the natural frequencies of the UHSRS FE structural model used for the SASSI analysis. Table 3KK-3 presents a summary of SSI effects on the seismic response of the UHSRS. The maximum absolute nodal accelerations obtained from the SASSI analyses are presented in Table 3KK-4 for key UHSRS locations. The results envelope all site conditions considered. The maximum accelerations have been obtained by combining cross-directional contributions in accordance with RG 1.92 (Reference 3KK-6) using the square root sum of the squares (SRSS) method.

The dynamic horizontal soil pressure of the backfill on the basin walls varied depending on the soil case considered as the soil frequency approached that of the wall. The peak soil pressures varied along the height of the wall from values of approximately 0.5 ksf to almost 2ksf. The dynamic horizontal soil pressure used for design varied linearly from a value of 0.50ksf at the base slab to 1.5ksf at soil grade. ~~The base shear and moment demands on walls, calculated in SASSI calculated lateral dynamic soil pressures and equivalent pressure used for design analysis, were compared and the design pressure profile shown to be conservative.~~The peak dynamic soil pressure from each soil case was obtained from SASSI and compared with the dynamic soil pressure distribution applied in ANSYS. The resulting pressure distributions show that there is significant variability in the pressures determined from SASSI. The applied pressure RCOL2_03.08.04-28

distribution used for design analyses (based on ASCE 4 elastic methods) produced conservative moments at the base of the basin walls and approximately equal base shear when compared to the pressures calculated in SASSI. The peak design vertical soil pressure calculated under the base slab is 11.7 ksf, which reduces away from edges. This value excludes the peak corner pressure of 23.0 ksf calculated on a single element, representing less than 0.2 percent of the total base slab area. The average peak vertical seismic pressure calculated under the base slab is 1.6 ksf. RCOL2_03.08.04-28

For design of the UHSRS per the loads and load combinations given in Section 3.8.4.3, response spectra analysis is performed in ANSYS to obtain seismic demands. The eigenvalue analysis of the UHS produced more than 400 modes below 40 Hz. The modes include 16 convective fluid modes ranging from 0.16 to 0.66 Hz and the peak sloshing height in any hydrodynamic region is equal to 1.91 ft. The first three structural modes are listed in Table 3KK-9. The response spectra analysis includes sloshing effects on the basins considering 0.5 percent damping, and follows the Lindley-Yow method (Reference 3KK-8) and 10 percent modal combination method. Note that the rigid response coefficient is set to zero for frequencies below the spectral peak acceleration (2.5 Hz for horizontal directions, 3.5 Hz for vertical direction) in accordance with RG 1.92 (Reference 3KK-6). Since the sloshing modes are well separated from all structural modes, the decreased level of damping is accounted for by increasing the spectrum for frequencies below 1.0Hz (all sloshing mode frequencies are below this value and all structural mode frequencies are above ~~this value~~4 Hz). The spectrum is increased by a factor of 1.57, which is equal to the ratio of 0.5% damped spectral values to 5 percent damped values ~~for the frequency range in which the sloshing modes act~~at 0.25 Hz based on the standard plant CSDRS (Table 3.7.1-1 of the DCD) and Table 1 of RG 1.60. An equivalent static acceleration equal to the ZPA (0.10g) which accounts for "missing mass" is also applied to the UHSRS, and the results are combined with the Lindley-Yow spectral response using SRSS. The spectra used for this approach (based on the standard plant CSDRS and RG 1.60 minimum spectra as described above) were confirmed to be higher than the enveloped base spectra calculated from the SASSI analysis. RCOL2_03.07.02-16 RCOL2_03.08.04-30 RCOL2_03.08.04-30 RCOL2_03.08.04-31

For structural design of members and components, the design seismic forces due to three different components of the earthquake are combined using the Newmark 100 percent - 40 percent – 40 percent combination method. The walls' shear forces were increased to account for 5 percent accidental torsion, and total base shear to be resisted by in-plane shear of the walls. Figure 3KK-2 presents the total adjusted wall seismic shear forces used for design.

The model used for response spectra seismic design analysis considered two bounding base slab behaviors; (a) flexible base slab – modeled with slab supported by using soil springs calculated using ASCE 4 (Reference 3KK-3) methodology as described in Section 3.8.4.4.3.2, and (b) rigid base slab – modeled by fixing the nodes across the base of the structure. The design analysis enveloped the demands from these two cases. RCOL2_03.08.04-32

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-29

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.2, "UHSRS", which references Appendix 3KK. In Appendix 3KK, Section 3KK.3, "Seismic Analysis Results," the third paragraph (Page 3KK-4) states that "The response spectra analysis includes sloshing effects on the basins considering 0.5 percent damping, and follows the Lindley-Yow method (Reference 3KK-8) and 10 percent modal combination method."

In CPNPP COL FSAR, Appendix 3KK, Section 3KK.2, "Model Description and Analysis Approach," the last paragraph (Page 3KK-3) states that "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 two statements above regarding the sloshing effect conflict. The first states the sloshing effect is included; whereas, the second states that the sloshing effect is not included. The applicant is requested to clarify this matter by clearly stating whether or not the sloshing effect is included in the analysis.

ANSWER:

Sloshing is included in the analysis. The statement in FSAR Section 3KK.2 implying that the sloshing mass is not included in the model is incorrect. This issue has been addressed in the response to RAI No. 2883 (CP RAI #64) Question 03.07.03-2 attached to Luminant letter TXNB-09060 dated October 30, 2009 (ML093090163). The FSAR markup submitted with that response corrects this sentence in FSAR Section 3KK.2 (attached).

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

None.

Impact on S-COLA

None.

Impact on DCD

None.

Attachment

Marked-up FSAR Revision 1 pages 3KK-3, 3KK-4, and 3KK-5 previously submitted in the response to RAI No. 2883 (CP RAI #64) Question 03.07.03-2 via Luminant letter TXNB-09060 dated October 30, 2009 (ML093090163).

properties at the centerline. All roof slabs and elevated slabs (pump room, fan slab, missile shield protection) are considered as cracked with an out-of-plane bending stiffness of ½ of the gross section stiffness. The properties assigned to the slab elements are modified to account for cracked out-of plane flexural stiffness and non-cracked in-plane axial and shear stiffness of the slabs as follows:

$$E_{cracked} = [1/(C_F)^{0.5}] \cdot E_{concrete}$$

$$t_{cracked} = (C_F)^{0.5} \cdot t$$

$$\gamma_{cracked} = [1/(C_F)^{0.5}] \cdot \gamma_{concrete}$$

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.

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~~ RCOL2_03.07.03-2

~~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 development of dynamic demands in accordance with requirements of SRP 3.7.3 (Reference 3KK-9). The hydrodynamic properties are calculated using the methodology specified in ACI 350.3-06 (Reference 3KK-5) and modeling is performed following the procedures of ASCE 4-98 (Reference 3KK-3). The properties calculated using ACI 350.3-06 meet or exceed relevant requirements of SRP 3.7.3. For the purposes of hydrodynamic analysis, the water is separated into rectangular regions to calculate hydrodynamic properties per ACI 350.3-06. The rectangular regions shown in Figure 3KK-4 are chosen since they are bounded by structural walls such that their behavior conforms to the equations derived in the above referenced documents. The key hydrodynamic properties of each region are listed in Table 3KK-7. Due to the embedment, squat dimensions, and small intensity base excitations, uplifting of this structure is not considered in the UHSRS model. RCOL2_03.07.03-2

Following the recommended modeling procedures of ASCE 4-98 (Reference 3KK-3), the water mass within each region is separated into impulsive and convective components (W_i and W_c in Table 3KK-7). The impulsive mass of the water is applied to nodes of walls at each end of the rectangular region, in the direction perpendicular to the wall, and applied uniformly along the walls using directional masses from the bottom of the basin to a height of twice the impulsive pressure distribution (h_i, values in Table 3KK-7). The convective mass is included in the analysis using point masses and uni-directional springs which are attached to the end walls of each hydrodynamic region at the height of the convective pressure distribution centroid, hc (see Table 3KK-7). The mass is equal to the convective mass (W_c) noted in the attached table and the springs are assigned stiffness such that the mass-spring system has a frequency equal to the convective frequency (f_c) noted in the table. Separate mass-spring systems are provided for all hydrodynamic regions. The vertical mass of the water is distributed uniformly across the base mat using directional mass elements. Support flexibility is considered by enveloping demands of a fixed-base model and a model supported on flexible soil springs.

Response spectra analyses are performed in ANSYS (Reference 3KK-2) to obtain seismic design demands, which include all structural and hydrodynamic effects as described above. The impulsive hydrodynamic modes include the basin flexibility directly in the FE analysis. All structural and impulsive modes (frequencies > 1Hz) are assigned 5% damping (although 7% is allowed by RG 1.61, Reference 3KK-4). The convective modes are assigned 0.5% damping by increasing the input response spectrum for frequencies less than 1 Hz (only includes the convective modes). Modal combination is performed in accordance with RG 1.92 (Reference 3KK-6), using Combination Method B for combination of periodic and rigid modes, using the low frequency correction α=0 for frequencies below the peak of the spectra. Periodic modal response is combined using the grouping method. Spatial combination is performed using the Newmark 100-40-40 percent combination rule. RCOL2_03.07.03-2

The peak sloshing height in any hydrodynamic region is equal to 1.91 ft. This height includes spatial combination of sloshing in each region using the Newmark 100-40-40 percent directional combination rule. The nominal freeboard height to the top of the basin walls and underside of the pump room slab is equal to 4 feet. Therefore, loss of water or uplifting pressures on the pump house slab is not a concern since adequate clearance is provided to allow this amount of sloshing.

3KK.3 Seismic Analysis Results

Table 3KK-2 presents the natural frequencies of the UHSRS FE structural model used for the SASSI analysis. Table 3KK-3 presents a summary of SSI effects on the seismic response of the UHSRS. The maximum absolute nodal accelerations obtained from the SASSI analyses are presented in Table 3KK-4 for key UHSRS locations. The results envelope all site conditions considered. The maximum accelerations have been obtained by combining cross-directional contributions in accordance with RG 1.92 (Reference 3KK-6) using the square root sum of the squares (SRSS) method.

The dynamic horizontal soil pressure of the backfill on the basin walls varied depending on the soil case considered as the soil frequency approached that of the wall. The peak soil pressures varied along the height of the wall from values of approximately 0.5 ksf to almost 2ksf. The dynamic horizontal soil pressure used for design varied linearly from a value of 0.50ksf at the base slab to 1.5ksf at soil grade. The base shear and moment demands on walls, calculated in SASSI calculated lateral dynamic soil pressures and equivalent pressure used for design analysis, were compared and the design pressure profile shown to be conservative. The peak design vertical soil pressure calculated under the base slab is 11.7 ksf, which reduces away from edges. This value excludes the peak corner pressure of 23.0 ksf calculated on a single element, representing less than 0.2 percent of the total base slab area. The average peak vertical seismic pressure calculated under the base slab is 1.6 ksf.

For design of the UHSRS per the loads and load combinations given in Section 3.8, response spectra analysis is performed to obtain seismic demands. The response spectra analysis includes sloshing effects on the basins considering 0.5 percent damping, and follows the Lindley-Yow method (Reference 3KK-8) and 10 percent modal combination method. Note that the rigid response coefficient is set to zero for frequencies below the spectral peak acceleration (2.5 Hz for horizontal directions, 3.5 Hz for vertical direction) in accordance with RG 1.92 (Reference 3KK-6). Since the sloshing modes are well separated from all structural modes, the decreased level of damping is accounted for by increasing the spectrum for

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-30

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.2, "UHSRS", which references Appendix 3KK. In Appendix 3KK, Section 3KK.3, "Seismic Analysis Results," the third paragraph (Page 3KK-4) states that "The spectrum is increased by a factor of 1.57, which is equal to the ratio of 0.5% damped spectral values to 5 percent damped values for the frequency range in which the sloshing modes act."

The applicant is requested to provide the technical basis for using the factor of 1.57 in the analyses.

ANSWER:

The concrete structure is considered to have 5% damping for calculation of seismic demands for the design. The convective fluid modes are considered to have 0.5% damping based on SRP 3.7.3 and similar to Table 6 of RG 1.61. The sloshing modes exist below 1 Hz and are well separated from all structural modes which exist above 4 Hz. The decreased level of damping in sloshing modes is accounted for by increasing the design input response spectrum for frequencies below 1.0 Hz to represent the 0.5% damping spectra. The spectrum is increased by a factor of 1.57 which is equal to the ratio of 0.5% damped spectral values to 5% damped values at 0.25 Hz (Table 3.7.1-1 in the DCD and Table 1 of RG 1.60).

FSAR Section 3KK.3 has been revised to incorporate this response.

Impact on R-COLA

See attached marked-up FSAR Revision 1 page 3KK-8.

Impact on S-COLA

None.

Impact on DCD

None.

distribution used for design analyses (based on ASCE 4 elastic methods) produced conservative moments at the base of the basin walls and approximately equal base shear when compared to the pressures calculated in SASSI. The peak design vertical soil pressure calculated under the base slab is 11.7 ksf, which reduces away from edges. This value excludes the peak corner pressure of 23.0 ksf calculated on a single element, representing less than 0.2 percent of the total base slab area. The average peak vertical seismic pressure calculated under the base slab is 1.6 ksf. RCOL2_03.08.04-28

For design of the UHSRS per the loads and load combinations given in Section 3.8.4.3, response spectra analysis is performed in ANSYS to obtain seismic demands. The eigenvalue analysis of the UHS produced more than 400 modes below 40 Hz. The modes include 16 convective fluid modes ranging from 0.16 to 0.66 Hz and the peak sloshing height in any hydrodynamic region is equal to 1.91 ft. The first three structural modes are listed in Table 3KK-9. The response spectra analysis includes sloshing effects on the basins considering 0.5 percent damping, and follows the Lindley-Yow method (Reference 3KK-8) and 10 percent modal combination method. Note that the rigid response coefficient is set to zero for frequencies below the spectral peak acceleration (2.5 Hz for horizontal directions, 3.5 Hz for vertical direction) in accordance with RG 1.92 (Reference 3KK-6). Since the sloshing modes are well separated from all structural modes, the decreased level of damping is accounted for by increasing the spectrum for frequencies below 1.0Hz (all sloshing mode frequencies are below this value and all structural mode frequencies are above ~~this value~~4 Hz). The spectrum is increased by a factor of 1.57, which is equal to the ratio of 0.5% damped spectral values to 5 percent damped values ~~for the frequency range in which the sloshing modes act~~at 0.25 Hz based on the standard plant CSDRS (Table 3.7.1-1 of the DCD) and Table 1 of RG 1.60. An equivalent static acceleration equal to the ZPA (0.10g) which accounts for "missing mass" is also applied to the UHSRS, and the results are combined with the Lindley-Yow spectral response using SRSS. The spectra used for this approach (based on the standard plant CSDRS and RG 1.60 minimum spectra as described above) were confirmed to be higher than the enveloped base spectra calculated from the SASSI analysis. RCOL2_03.07.02-16 RCOL2_03.08.04-30 RCOL2_03.08.04-30 RCOL2_03.08.04-31

For structural design of members and components, the design seismic forces due to three different components of the earthquake are combined using the Newmark 100 percent - 40 percent – 40 percent combination method. The walls' shear forces were increased to account for 5 percent accidental torsion, and total base shear to be resisted by in-plane shear of the walls. Figure 3KK-2 presents the total adjusted wall seismic shear forces used for design.

The model used for response spectra seismic design analysis considered two bounding base slab behaviors; (a) flexible base slab – modeled with slab supported by using soil springs calculated using ASCE 4 (Reference 3KK-3) methodology as described in Section 3.8.4.4.3.2, and (b) rigid base slab – modeled by fixing the nodes across the base of the structure. The design analysis enveloped the demands from these two cases. RCOL2_03.08.04-32

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-31

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.2, "UHSRS", which references Appendix 3KK. In Appendix 3KK, Section 3KK.3, "Seismic Analysis Results," the last sentence of the third paragraph (Page 3KK-4) states that "The spectra used for this approach were confirmed to be higher than the enveloped base spectra calculated from the SASSI analysis."

How were the spectra mentioned in the above quoted sentence obtained? Provide information for the structural model, the input motions, and the method of analysis used to obtain the spectra.

ANSWER:

The standard plant CSDRS anchored to 0.1g PGA, which envelope the site-specific FIRS spectra, are used in the ANSYS response spectra analyses. The input design ground motion used in the SASSI analyses also matches the standard plant CSDRS anchored to 0.1g peak ground acceleration, which envelopes the site-specific FIRS spectra. Composite damping spectra were used in the ANSYS response spectra analyses to account for the differing levels of damping required for structural modes and convective fluid modes. For structural modes a 5% damping was selected to be conservative based on Table 1 of RG 1.61. The convective fluid modes are considered to have 0.5% damping based on SRP 3.7.3 and similar to Table 6 of RG 1.61. Structural and convective modes are well separated with convective modes occurring at less than 1 Hz and structural modes occurring at more than 4 Hz. The design input spectra used for development of inertial design demands was a combination of a 0.5% damped spectra for frequencies less than 1 Hz and 5% damped spectra for the remainder. A response spectra analysis was performed using the design model of the UHS to calculate seismic force/moment demands that are used for the design evaluation of the UHS.

The frequency domain soil-structure interaction analysis performed in SASSI used a 3-D finite element model of the UHS structure that included plate representations of the walls and slabs, beam elements for columns and beams, and mass elements representing equipment and impulsive fluid mass. The model used 4% damping for concrete elements for development of in-structure response spectra in accordance with RG 1.61 Section 1.2 and Table 2, and is conservative for SSE motions when obtaining design forces. The soil layering used various profiles to model uncertainty in the soil with cases representing the lower bound, best estimate, and upper bound soil and fill cases as well as a high bound fill, and a lower bound case with no fill.

The design input time history motion input to the SASSI analyses matched the design input response spectra that is the standard plant CSDRS (DCD Table 3.7.1-1 and 3.7.1-2) anchored to 0.1g peak ground acceleration that envelopes the site-specific FIRS spectra. The analysis was run in SASSI for three orthogonal directions of input motion. The co-directional terms of the output response spectra for the three directions of input motion were combined on an SRSS basis within each soil profile. The final spectra are the envelope of all soil cases. This final enveloped in-structure response spectra at the base slab is the spectra that is compared to the design input spectra used for calculating the design seismic force and moments demands in the first paragraph of this response.

FSAR Sections 3KK.2 and 3KK.3 have been revised to incorporate this response.

Impact on R-COLA

See attached marked-up FSAR Revision 1 pages 3KK-7 and 3KK-8.

Impact on S-COLA

None.

Impact on DCD

None.

are calculated from the seismic soil pressure and seismic inertia including hydrodynamic effects which are then added to all other design loads discussed in Section 3.8.4.3. Seismic inertial responses are calculated using response spectra analyses in ANSYS using the design input response spectra based on the standard plant CSDRS anchored to 0.10 g acceleration, which envelops the site-specific FIRS spectra. Hydrodynamic effects are included in the response spectra analysis as described above except that the convective mass is included in the analysis using point masses and uni-directional springs which are attached to the end walls of each hydrodynamic region at the height of the convective pressure distribution centroid, h_c (see Table 3KK-7). The mass is equal to the convective mass (W_c) noted in the table and the springs are assigned stiffness such that the mass-spring system has a frequency equal to the convective frequency (f_c) noted in the table. Separate mass-spring systems are provided for all hydrodynamic regions. RCOL2_03.07.02-11 RCOL2_03.08.04-19 RCOL2_03.08.04-31

For seismic soil pressure cases, analyzed statically in ANSYS, seismic soil pressure demands are applied to the structural elements as equivalent static pressures. The equivalent trapezoidal pressures applied are larger than the resultant pressures calculated by ASCE 4-98 elastic solution based on J.H. Wood, 1973 and the enveloped of SASSI results.

Demands calculated from the response spectra and soil pressure analyses performed in ANSYS are combined on an absolute basis to produce the maximum demands for each direction of motion.

3KK.3 Seismic Analysis Results

Table 3KK-2 presents the natural frequencies of the UHSRS FE structural model used for the SASSI analysis. Table 3KK-3 presents a summary of SSI effects on the seismic response of the UHSRS. The maximum absolute nodal accelerations obtained from the SASSI analyses are presented in Table 3KK-4 for key UHSRS locations. The results envelope all site conditions considered. The maximum accelerations have been obtained by combining cross-directional contributions in accordance with RG 1.92 (Reference 3KK-6) using the square root sum of the squares (SRSS) method.

The dynamic horizontal soil pressure of the backfill on the basin walls varied depending on the soil case considered as the soil frequency approached that of the wall. The peak soil pressures varied along the height of the wall from values of approximately 0.5 ksf to almost 2ksf. The dynamic horizontal soil pressure used for design varied linearly from a value of 0.50ksf at the base slab to 1.5ksf at soil grade. ~~The base shear and moment demands on walls, calculated in SASSI calculated lateral dynamic soil pressures and equivalent pressure used for design analysis, were compared and the design pressure profile shown to be conservative.~~The peak dynamic soil pressure from each soil case was obtained from SASSI and compared with the dynamic soil pressure distribution applied in ANSYS. The resulting pressure distributions show that there is significant variability in the pressures determined from SASSI. The applied pressure RCOL2_03.08.04-28

distribution used for design analyses (based on ASCE 4 elastic methods) produced conservative moments at the base of the basin walls and approximately equal base shear when compared to the pressures calculated in SASSI. The peak design vertical soil pressure calculated under the base slab is 11.7 ksf, which reduces away from edges. This value excludes the peak corner pressure of 23.0 ksf calculated on a single element, representing less than 0.2 percent of the total base slab area. The average peak vertical seismic pressure calculated under the base slab is 1.6 ksf. RCOL2_03.08.04-28

For design of the UHSRS per the loads and load combinations given in Section 3.8.4.3, response spectra analysis is performed in ANSYS to obtain seismic demands. The eigenvalue analysis of the UHS produced more than 400 modes below 40 Hz. The modes include 16 convective fluid modes ranging from 0.16 to 0.66 Hz and the peak sloshing height in any hydrodynamic region is equal to 1.91 ft. The first three structural modes are listed in Table 3KK-9. The response spectra analysis includes sloshing effects on the basins considering 0.5 percent damping, and follows the Lindley-Yow method (Reference 3KK-8) and 10 percent modal combination method. Note that the rigid response coefficient is set to zero for frequencies below the spectral peak acceleration (2.5 Hz for horizontal directions, 3.5 Hz for vertical direction) in accordance with RG 1.92 (Reference 3KK-6). Since the sloshing modes are well separated from all structural modes, the decreased level of damping is accounted for by increasing the spectrum for frequencies below 1.0Hz (all sloshing mode frequencies are below this value and all structural mode frequencies are above ~~this value~~4 Hz). The spectrum is increased by a factor of 1.57, which is equal to the ratio of 0.5% damped spectral values to 5 percent damped values ~~for the frequency range in which the sloshing modes act~~at 0.25 Hz based on the standard plant CSDRS (Table 3.7.1-1 of the DCD) and Table 1 of RG 1.60. An equivalent static acceleration equal to the ZPA (0.10g) which accounts for "missing mass" is also applied to the UHSRS, and the results are combined with the Lindley-Yow spectral response using SRSS. The spectra used for this approach (based on the standard plant CSDRS and RG 1.60 minimum spectra as described above) were confirmed to be higher than the enveloped base spectra calculated from the SASSI analysis. RCOL2_03.07.02-16 RCOL2_03.08.04-30 RCOL2_03.08.04-30 RCOL2_03.08.04-31

For structural design of members and components, the design seismic forces due to three different components of the earthquake are combined using the Newmark 100 percent - 40 percent – 40 percent combination method. The walls' shear forces were increased to account for 5 percent accidental torsion, and total base shear to be resisted by in-plane shear of the walls. Figure 3KK-2 presents the total adjusted wall seismic shear forces used for design.

The model used for response spectra seismic design analysis considered two bounding base slab behaviors; (a) flexible base slab – modeled with slab supported by using soil springs calculated using ASCE 4 (Reference 3KK-3) methodology as described in Section 3.8.4.4.3.2, and (b) rigid base slab – modeled by fixing the nodes across the base of the structure. The design analysis enveloped the demands from these two cases. RCOL2_03.08.04-32

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-32

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.2, "UHSRS", which references Appendix 3KK. In Appendix 3KK, Section 3KK.3, "Seismic Analysis Results," the second paragraph on Page 3KK-5 states that "The model used for response spectra seismic design analysis considered two bounding base slab behaviors; (a) flexible base slab – modeled with slab supported by using soil springs calculated using ASCE 4 (Reference 3KK-3) methodology, and (b) rigid base slab – modeled by fixing the nodes across the base of the structure."

The applicant is requested to provide the following information:

(a) In case (a) above for the flexible base slab, the applicant states that the soil springs of ASCE 4 were used in the model. However, the soil springs of ASCE 4 assume the massless rigid base slab. Provide justification for using these springs for the flexible base slab.

(b) The model for a structure with soil springs of ASCE is a non-classical damped system that does not have the classical vibration modes. Provide the technical basis and information that shows how CPNPP COL FSAR solved the non-classical damped system and then performed the response spectrum analysis. What is the damping value used in the analysis?

ANSWER:

(a) The spring stiffness calculated using ASCE 4 reflects the soil spring for a surface founded structure with rigid base slab, which is not required to be a massless slab. The flexible springs are used (in part) to include the frequency shift resulting from the SSI flexibility as discussed in part (b) of this response. The ASCE 4 springs are used to calculate the lower bound of the SSI frequency, since the soil springs for the embedded foundation is higher than the equivalent surface founded structure.

(b) The soil springs used in the ANSYS design model were assigned to represent soil flexibility per ASCE 4 soil stiffness. The additional soil damping recommended by ASCE 4 was not included in the analysis. The stiffness of the horizontal and vertical springs were assigned to reflect the base flexibility to (1) allow calculation of the base mat design demands (not possible with a fixed base analysis model), (2) consider support flexibility that alters the force distribution around the base of the structure, and (3) include the frequency shift resulting from the increased SSI flexibility (but not including the increased damping). The analysis uses a classical damping, since the lumped soil damping is not used in the model. Response spectra analyses were performed using a fixed-base model of the structure and a model of the structure supported by soil springs. The seismic forces/moments demands calculated from these two cases were enveloped for use in design.

The response spectra analysis was performed using the ANSYS design model. The input spectra for the response spectra analysis was the 5% damped site-specific design response spectra except for frequencies below 1 Hz where the spectra was increased to values representing the 0.5% damping to account for the lower damping value of hydrodynamic modes as required by SRP 3.7.3.

The response to this question has been incorporated in FSAR Subsection 3.8.4.4.3.2 in response to RAI No. 2994 (CP RAI #108) Question 03.08.04-12 via Luminant Letter TXNB-09078 dated December 10, 2009), and FSAR Section 3KK.2 and 3KK.3 have been revised to incorporate this response.

Impact on R-COLA

See attached marked-up FSAR Revision 1 pages 3.8-11, 3KK-6, and 3KK-8.

Impact on S-COLA

None.

Impact on DCD

None.

the soil compaction pressure. The dynamic soil pressures are described in Appendix 3LL. ~~in accordance with ASCE 4-98 (Reference 3.8-34).~~ RCOL2_03.08.04-11

3.8.4.4.3.2 UHSRS

The UHSRS are designed to withstand the loads specified in Subsection 3.8.4.3. The structural design of the UHSRS is performed using the computer program ANSYS (Reference 3.8-14). The seismic analysis and the computer programs used for the seismic analysis are addressed in Appendix 3KK.

The seismic responses for the design are calculated using a two step analysis method as defined in ASCE 4-98 (Reference 3.8-34). Step 1 is the SSI analysis using the program SASSI and step 2 is calculating the seismic demands for the design using the program ANSYS as described below. RCOL2_03.08.04-12

The ANSYS design analysis models for the UHSRS were placed on soil springs calculated by methods provided in ASCE 4-98 (Reference 3.8-34) to provide localized flexibility at the base of the structure. The flexibility of the base allows for calculation of the base slab demands. The effects of embedment are included in the SSI analysis. The seismic lateral pressure and inertia loads applied to the ANSYS design model represent the total seismic loading from the SSI analysis.

ANSYS analyses are performed based on two support conditions: (1) flexible rock subgrade by applying soil springs across all base slab nodes and (2) rigid base by applying fixed restraints across all base slab nodes. All results from these two conditions are enveloped for design. ~~on the model placed on soil springs at the bottom of the base slab, with the springs representing the stiffness of the rock subgrade. To address the sensitivity of the structural response on the subgrade stiffness, an additional set of analyses simulating a fixed base condition is performed on the model.~~ The stiffness of the subgrade springs is calculated using the methodology in ASCE-4 Section 3.3.4.2 (Reference 3.8-34) for vibration of a rectangular foundation resting on an elastic half space. The springs were included to provide localized flexibility at the base of the structure to calculate base slab demands. The soil adjacent to the UHSRS is not included in the design model in order to transfer the total seismic load through the structure down to the base slab. Embedment effects are included in the SSI model from which the seismic lateral soil pressures and inertia loads are based. The evaluation of subgrade stiffness considers the best estimate properties of the layers above elevation 393 ft. Since the support below the structure will not exhibit long-term settlement effects, the subgrade stiffness calculated from ASCE-4 Section 3.3.4.2 is used for analysis of both static and seismic loads. RCOL2_03.08.04-19 RCOL2_03.08.04-32 RCOL2_03.08.04-12 RCOL2_03.08.04-32

The equivalent shear modulus for the ASCE spring calculations is based on the equivalent shear wave velocity which is determined using the equivalent shear wave travel time method described in Appendix 3NN. The equivalent Poisson's ratio and density are based on the weighted average with respect to layer thickness. The springs are included in the model using three individual, uncoupled uni-directional spring elements that are attached to each node of the base mat. The sum of all nodal springs in each of the three orthogonal directions are equal to the corresponding generalized structure-foundation stiffness in the same RCOL2_03.08.04-15 into rectangular regions to calculate hydrodynamic properties per ACI 350.3-06. The rectangular regions shown in Figure 3KK-4 are chosen since they are bounded by structural walls such that their behavior conforms to the equations derived in the above referenced documents. The key hydrodynamic properties of each region are listed in Table 3KK-7. Due to the embedment, squat dimensions, and small intensity base excitations, uplifting of this structure is not considered in the UHSRS model. RCOL2_03.07.03-2

Following the recommended modeling procedures of ASCE 4-98 (Reference 3KK-3), the water mass within each region is separated into impulsive and convective components (W_i and W_c in Table 3KK-7). The impulsive mass of the water is applied to nodes of walls at each end of the rectangular region, in the direction perpendicular to the wall, and applied uniformly along the walls using directional masses from the bottom of the basin to a height of twice the impulsive pressure distribution (h_i, values in Table 3KK-7). The convective mass is included in the analysis using point masses and uni-directional springs which are attached to the end walls of each hydrodynamic region at the height of the convective pressure distribution centroid, hc (see Table 3KK-7). The mass is equal to the convective mass (W_c) noted in the attached table and the springs are assigned stiffness such that the mass-spring system has a frequency equal to the convective frequency (f_c) noted in the table. Separate mass-spring systems are provided for all hydrodynamic regions. The vertical mass of the water is distributed uniformly across the base mat using directional mass elements. Support flexibility is considered by enveloping demands of a fixed-base model and a model supported on flexible soil springs.

Response spectra analyses are performed in ANSYS (Reference 3KK-2) to obtain seismic design demands, which include all structural and hydrodynamic effects as described above. The impulsive hydrodynamic modes include the basin flexibility directly in the FE analysis. All structural and impulsive modes (frequencies > 1Hz) are assigned 5% damping. The convective modes are assigned 0.5% damping by increasing the input response spectrum for frequencies less than 1 Hz (only includes the convective modes). Modal combination is performed in accordance with RG 1.92 (Reference 3KK-6), using Combination Method B for combination of periodic and rigid modes, using the low frequency correction α=0 for frequencies below the peak of the spectra. Periodic modal response is combined using the grouping method. Spatial combination is performed using the Newmark 100-40-40 percent combination rule. RCOL2_03.08.04-32 RCOL2_03.07.03-2

The peak sloshing height in any hydrodynamic region is equal to 1.91 ft. This height includes spatial combination of sloshing in each region using the Newmark 100-40-40 percent directional combination rule. The nominal freeboard height to the top of the basin walls and underside of the pump house slab is not a concern since adequate clearance is provided to allow this amount of sloshing. RCOL2_03.08.04-27

The fine mesh ANSYS model is used for the calculation of both seismic and non-seismic demands for design. The seismic structural demands of the UHSRS RCOL2_03.07.02-11

distribution used for design analyses (based on ASCE 4 elastic methods) produced conservative moments at the base of the basin walls and approximately equal base shear when compared to the pressures calculated in SASSI. The peak design vertical soil pressure calculated under the base slab is 11.7 ksf, which reduces away from edges. This value excludes the peak corner pressure of 23.0 ksf calculated on a single element, representing less than 0.2 percent of the total base slab area. The average peak vertical seismic pressure calculated under the base slab is 1.6 ksf. RCOL2_03.08.04-28

For design of the UHSRS per the loads and load combinations given in Section 3.8.4.3, response spectra analysis is performed in ANSYS to obtain seismic demands. The eigenvalue analysis of the UHS produced more than 400 modes below 40 Hz. The modes include 16 convective fluid modes ranging from 0.16 to 0.66 Hz and the peak sloshing height in any hydrodynamic region is equal to 1.91 ft. The first three structural modes are listed in Table 3KK-9. The response spectra analysis includes sloshing effects on the basins considering 0.5 percent damping, and follows the Lindley-Yow method (Reference 3KK-8) and 10 percent modal combination method. Note that the rigid response coefficient is set to zero for frequencies below the spectral peak acceleration (2.5 Hz for horizontal directions, 3.5 Hz for vertical direction) in accordance with RG 1.92 (Reference 3KK-6). Since the sloshing modes are well separated from all structural modes, the decreased level of damping is accounted for by increasing the spectrum for frequencies below 1.0Hz (all sloshing mode frequencies are below this value and all structural mode frequencies are above ~~this value~~4 Hz). The spectrum is increased by a factor of 1.57, which is equal to the ratio of 0.5% damped spectral values to 5 percent damped values ~~for the frequency range in which the sloshing modes act~~at 0.25 Hz based on the standard plant CSDRS (Table 3.7.1-1 of the DCD) and Table 1 of RG 1.60. An equivalent static acceleration equal to the ZPA (0.10g) which accounts for "missing mass" is also applied to the UHSRS, and the results are combined with the Lindley-Yow spectral response using SRSS. The spectra used for this approach (based on the standard plant CSDRS and RG 1.60 minimum spectra as described above) were confirmed to be higher than the enveloped base spectra calculated from the SASSI analysis.

RCOL2_03.07.02-16
RCOL2_03.08.04-30
RCOL2_03.08.04-30
RCOL2_03.08.04-31

For structural design of members and components, the design seismic forces due to three different components of the earthquake are combined using the Newmark 100 percent - 40 percent – 40 percent combination method. The walls' shear forces were increased to account for 5 percent accidental torsion, and total base shear to be resisted by in-plane shear of the walls. Figure 3KK-2 presents the total adjusted wall seismic shear forces used for design.

The model used for response spectra seismic design analysis considered two bounding base slab behaviors; (a) flexible base slab – modeled with slab supported by using soil springs calculated using ASCE 4 (Reference 3KK-3) methodology as described in Section 3.8.4.4.3.2, and (b) rigid base slab – modeled by fixing the nodes across the base of the structure. The design analysis enveloped the demands from these two cases.

RCOL2_03.08.04-32

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DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-33

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.2, "UHSRS", which references Appendix 3KK. In Appendix 3KK, Section 3KK.4, "In-Structure Response Spectra (ISRS)," the last sentence of the paragraph (Page 3KK-5) states that "For the design of seismic category I and II subsystems and components mounted to the UHSRS walls, it is required to account for the effects of out-of-plane wall flexibility."

The applicant is requested to provide information that shows how the effects of out-of-plane wall flexibility are considered in the analyses.

ANSWER:

The out-of-plane wall flexibility is included in the 3D SASSI model because the walls and slabs are directly modeled using plate elements. The in-structure response spectra used for design of subsystems and components therefore include the effects due to out-of-plane wall flexibility. Out-of-plane flexibility also influences seismic anchor motions considered in subsystem design. Seismic anchor motions are taken into consideration for all seismic analysis methods used in the design of seismic category I and seismic category II SSCs, as stated in DCD Subsection 3.7.2.1 and discussed in DCD Subsections 3.7.3.1.7.1, 3.9.2.2.8, and 3.12.3.2.6. These DCD subsections are incorporated by reference in the FSAR. Further, any additional flexibility in the subsystem and components or their supports, possibly resulting in an increased spectral response, will be evaluated in the detailed design phase when procurement specifications are developed and their supports are designed.

The statement in FSAR Section 3KK.4 quoted above has been revised to clarify that effects of out-of-plane flexibility include seismic anchor motions. Similar statements in FSAR Section 3LL.2 and 3MM.4 have also been revised accordingly.

Impact on R-COLA

See attached marked-up FSAR Revision1 pages 3KK-9, 3LL-6, and 3MM-6.

Impact on S-COLA

None.

Impact on DCD

None.

A comparison of the SASSI generated site-specific in-structure response spectra at the base slab to the ANSYS input spectra confirms that the input used for the ANSYS analyses is conservative. A comparison of the SASSI generated soil pressures with the soil pressures used for the seismic soil pressure analyses performed in ANSYS confirms that the applied loading used for design exceeds that calculated in the SASSI analyses. RCOL2_03.07.02-16 CTS-00922

The seismic design forces and moments resulting from the design analysis are presented in Table 3KK-5 at key UHSRS locations. The force and moment values represent the enveloped results for the seismic demands for all soil cases considered in the SASSI analyses.

Table 3KK-6 summarizes the resulting maximum displacements for enveloped seismic loading conditions at key UHSRS locations obtained from the seismic analysis.

3KK.4 In-Structure Response Spectra (ISRS)

The enveloped broadened in-structure response spectra (ISRS) calculated in SASSI are presented in Figure 3KK-3 for the UHSRS base slab, pump room elevated slab, pump room roof slab, and cooling tower fan support slab for each of the three orthogonal directions (east-west, north-south, vertical) for 0.5 percent, 2 percent, 3 percent, 4 percent, 5 percent, 7 percent, 10 percent and 20 percent damping. The ISRS for each orthogonal direction are resultant spectra, which have been combined using SRSS to account for cross-directional coupling effects in accordance with RG 1.122 (Reference 3KK-7). The ISRS include the envelope of the ~~6~~six site conditions (BE, LB, UB, and HB, ~~with and~~ BE without backfill separation from the structure, and the no-fill surface foundation condition with LB subgrade conditions). All results have been broadened by 15 percent and all valleys removed. ~~It is permitted to perform 15 percent peak clipping of the spectra presented herein in accordance with ASCE 4 (Reference 3KK-3) for spectra with less than 10 percent damping.~~ For the design of seismic category I and II subsystems and components mounted to the UHSRS walls and slab, it is required to account for the effects of out-of-plane ~~wall~~ flexibility, including seismic anchor moments. RCOL2_03.07.02-15 RCOL2_03.08.04-33

3KK.5 References

3KK-1 *An Advanced Computational Software for 3D Dynamic Analysis Including Soil Structure Interaction,* ACS SASSI Version 2.2, Ghiocel Predictive Technologies, Inc., July 23, 2007.

3KK-2 ANSYS Release 11.0, SAS IP, Inc. 2007.

3KK-3 *Seismic Analysis of Safety-Related Nuclear Structures,* American Society of Civil Engineers, ASCE 4-98, Reston, Virginia, 2000.

~~model for structural design of members and components~~demands produced from ANSYS seismic analyses. These results include the combined demands from seismic intertia and seismic soil pressure and the combinations of all directions of input motion. For structural design, the accidental torsion load case results in increased shear in the outer walls, which is included in the values reported in Tables 3LL-9, 3LL-10, and 3LL-11. Note that addition of the torsion by scaling the seismic demands results in shear demand in the outer walls that meets or exceeds the accidental torsion requirements for design. RCOL2_03.07.02-13

Displacements provided in Table 3LL-12 ~~summarizes the resulting maximum displacements for enveloped seismic loading conditions for each of the three segments of the ESWPT~~are the peak displacements of the nodes calculated in the ANSYS seismic analyses representing the deflection calculated using the combined seismic intertia and seismic soil pressure. RCOL2_03.07.02-13

Table 3LL-13 presents the maximum pressures below the basemat of the ESWPT calculated from SASSI analyses.

3LL.4 In-Structure Response Spectra (ISRS)

The enveloped broadened ISRS calculated in SASSI are presented in Figures 3LL-7, 3LL-8, and 3LL-9 for ESWPT Segments 1, 2, and 3, respectively. The spectra are presented for the horizontal and vertical directions for the ESWPT base slab and roof for 0.5 percent, 2 percent, 3 percent, 4 percent, 5 percent, 7 percent, 10 percent, and 20 percent damping. The ISRS for the roof of the PSFSV access tunnels are also presented in Figure 3LL-9. The ISRS are resultant spectra, which have been combined using SRSS to account for cross-directional coupling effects in accordance with RG 1.122 (Reference 3LL-6). The ISRS include the envelope of the four site conditions (BE, LB, UB, and HB) with and without backfill separation (if applicable) from the structure. All results have been broadened by 15 percent and all valleys removed. The shape of the spectra presented herein can be simplified by further enveloping of peaks for the design of seismic category I and II subsystems and components housed within or mounted to the ESWPT and PSFSV access tunnels. ~~It is permitted to perform 15 percent peak clipping of the spectra presented herein in accordance with ASCE 4 (Reference 3LL-3) during the design process for spectra with damping values less than 10 percent.~~ For the design of seismic category I and II subsystems and components mounted to the ESWPT walls and slabs, it is required to account for the effects of out-of-plane ~~wall~~ flexibility, including seismic anchor motions. RCOL2_03.07.02-13 RCOL2_03.07.02-13 RCOL2_03.07.02-15 RCOL2_03.08.04-33

3LL.5 References

3LL-1 *An Advanced Computational Software for 3D Dynamic Analysis Including Soil Structure Interaction,* ACS SASSI Version 2.2, Ghiocel Predictive Technologies, Inc., July 23, 2007.

3LL-2 ANSYS Release 11.0, SAS IP, Inc. 2007.

The seismic design forces and moments based on the ANSYS analysis are presented in Table 3MM-6. The force and moment values represent the enveloped seismic results for all site conditions considered in the analysis. These results are calculated from ANSYS design model subjected to the enveloped of accelerations and dynamic lateral soil pressure from all calculated SASSI analyses. Accidental torsion is accounted by increasing the wall shears given in Table 3MM-6. The walls seismic base shear was increased to account for accidental torsion and total seismic base shear to be resisted by in plane shear of walls. The total adjusted wall shear forces used for design are presented in Figure 3MM-2. The forces presented in the figure are not symmetrical due to model non-symmetry including the sizes of the exterior walls and openings in the north wall. For structural design of members and components, the design seismic forces due to three different components of the earthquake are combined using the Newmark 100% - 40% – 40% method.

RCOL2_03.07.02-11
RCOL2_03.08.04-49

The PSFSV displacements due to seismic loading are less than 0.07 inch. Table 3MM-7 summarizes the resulting maximum displacements for enveloped seismic loading conditions.

3MM.4 In-Structure Response Spectra (ISRS)

The enveloped broadened ISRS calculated in SASSI are presented in Figure 3MM-3 for the PSFSV base slab and roof for each of the three orthogonal directions (east-west, north-south, vertical) for 0.5 percent, 2 percent, 3 percent, 4 percent, 5 percent, 7 percent, 10 percent and 20 percent damping. The ISRS for each orthogonal direction are resultant spectra which have been combined using SRSS to account for cross-directional coupling effects in accordance with RG 1.122 (Reference 3MM-6). The ISRS include the envelope of the 11 site conditions (BE, LB, UB, and HB with and without backfill separation from the structure, and the no-fill surface foundation condition with BE, LB, and UB subgrade conditions). All results have been broadened by 15 percent and all valleys removed. The spectra ~~can be~~are used for the design of seismic category I and II subsystems and components housed within or mounted to the PSFSV. ~~It is permitted to perform 15 percent peak clipping of the spectra for damping values below 10 percent in accordance with ASCE 4 (Reference 3MM-3).~~ For the design of seismic category I and II subsystems and components mounted to the PSFSV walls and slabs, it is required to account for the effects of out-of-plane wall flexibility, including seismic anchor motions.

RCOL2_03.07.02-11
RCOL2_03.08.04-50
RCOL2_03.07.02-15
RCOL2_03.08.04-33

3MM.5 References

3MM-1 *An Advanced Computational Software for 3D Dynamic Analysis Including Soil Structure Interaction,* ACS SASSI Version 2.2, Ghiocel Predictive Technologies, Inc., July 23, 2007.

3MM-2 ANSYS Release 11.0, SAS IP, Inc. 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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-34

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.1, "ESWPT", which references Appendix 3LL. In Appendix 3LL, "Model Properties and Seismic Analysis Results for ESWPT," section 3LL.1, "Introduction", the paragraph (Page 3LL-1) states that "The computer program SASSI (Reference 3LL-1) serves as the platform for the soil-structure interaction (SSI) analyses. The three-dimensional (3D) finite element (FE) models used in SASSI are condensed from FE models with finer mesh patterns initially developed using the ANSYS computer program (Reference 3LL-2). The dynamic analysis of the SASSI 3D FE model in the frequency domain provides results for the ESWPT seismic response that include SSI effects. The SASSI model results for maximum accelerations and seismic soil pressures are used as input to the ANSYS models for performing the detailed structural design, including loads and load combinations in accordance with the requirements of Section 3.8."

The applicant is requested to:

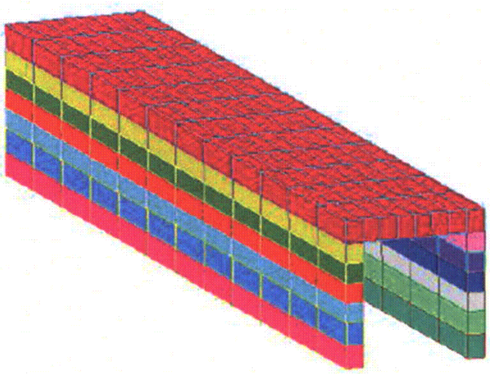
(a) Provide a description, including figures, that shows how the surrounding soil was modeled in the SASSI SSI analysis. What are the assumed boundary conditions? Address the location where the input motions were applied to the model. Were the input motions in time domain or in the form of response spectra? What is the damping ratio assumed for the input motions?

(b) Explain how the SASSI model results for maximum accelerations are used as input to the ANSYS model. List the locations of these maximum accelerations. If the results of SASSI SSI analysis are in time domain, explain how maximum accelerations at different locations are obtained from different time histories.

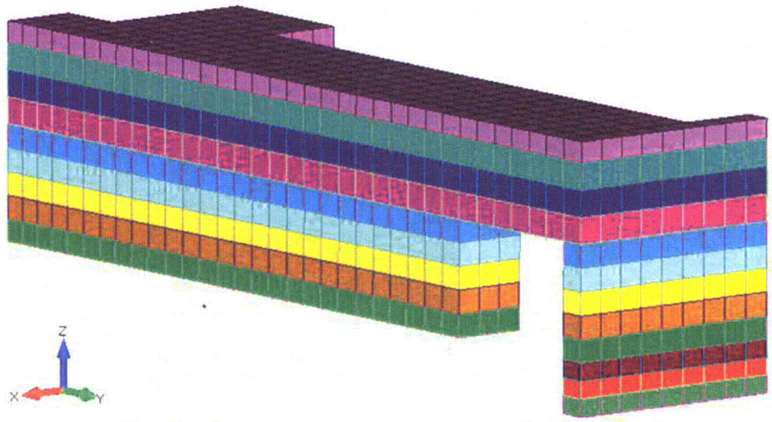
ANSWER:

(a) The computer program SASSI internally performs frequency domain calculations of the soil structure interaction problems for modeling of a layered soil site. The program requires input for the soil properties of each soil layer of the site, including shear wave velocity, compression wave velocity, density, and soil damping for compression waves and shear waves. Soil is modeled to a depth of over 700 feet below grade. At the bottom of the soil layering, a 10 layer half-space is used. The program also requires input for the structural finite element model including plate, beam, solid, and mass elements. Where the structure interfaces with the soil layers, the structural nodes are designated as interaction nodes. Where structures are embedded or buried, the user must define the solid structure representing excavation elements which create the region of soil to be removed. The SASSI program assembles the stiffness/impedance matrix representing the combined soil layers minus the excavated soil elements plus the structural matrix. For the ESWPT the soil is present on all sides of and above the tunnel where the tunnel is below grade except where the tunnel is seismically isolated from the soil or adjacent structure. At Tunnel Segment 2, the north side is separated from the UHSRS basin wall by a seismic isolation joint, and the tunnel is therefore not connected to the soil on this face. At Tunnel Segment 3, the tunnel is separated from the PSFSV and the power source building. SASSI does not provide soil pressures at interaction nodes. To allow calculation of soil pressures on the structure, elements of soil surrounding the tunnel were explicitly modeled as part of the structure using solid (brick) elements. Additional soil elements were explicitly modeled above tunnel 2 and 3 primarily for ease of model generation. These elements are shown in the figures below.

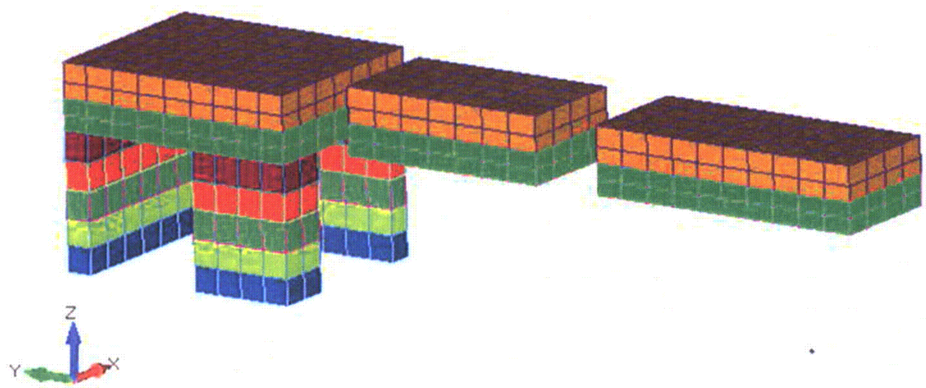
The input motions are applied to the model at the top of the limestone (bottom of backfill) at the far-field, effectively meaning at a sufficient distance from the structure to not be influenced by soil structure interaction effects. Input motions are applied as time history accelerations (time domain) with a time step of 0.005 seconds. The damping for the model is not input as part of the time history accelerations but rather as material damping within the soil layer model and structural materials. The concrete materials were assigned 4% material damping in accordance with RG 1.61 Table 2 for use in generation of in-structure response spectra.



Tunnel Segment 1 SASSI Explicitly Modeled Soil Elements



Tunnel Segment 2 SASSI Explicitly Modeled Soil Elements



Tunnel Segment 3 SASSI Explicitly Modeled Soil Elements

(b) SASSI is an analysis program that performs frequency domain calculations to obtain transfer functions and subsequently calculates time history responses including nodal accelerations. For each soil case and for each direction of input motion, peak accelerations are calculated for all three directions of output motion. These peak accelerations represent the maximum absolute acceleration for all time steps. The co-directional accelerations from each direction of input are combined using SRSS and then enveloped over all soil cases. Calculation of the seismic inertia effect for design demands (forces and moments) for Tunnel Segments 1 and 3 was performed by a lateral equivalent acceleration loading in ANSYS. Maximum accelerations calculated in SASSI were enveloped for each region/component (roof, exterior wall, interior wall, or base slab) and applied to the various region/components in the ANSYS model. Tables 3LL-6, 3LL-7, and 3LL-8 indicate the maximum accelerations for each region/component.

FSAR Sections 3LL.2 and 3LL.3 have been revised to incorporate this response.

Impact on R-COLA

See attached marked-up FSAR Revision 1 pages 3LL-2, 3LL-3, 3LL-4, and 3LL-5.

Impact on S-COLA

None.

Impact on DCD

None.

Attachments

Marked-up FSAR Revision 1 Tables 3LL-6 and 3LL-8 previously submitted in the response to RAI No. 2879 (CP RAI #60) Question 03.07.02-12 via Luminant letter TXNB-09073 dated November 24, 2009 (ML093340447).

Table 3LL-6

ESWPT Segment 1 SASSI FE Model Component Peak Accelerations(1) (g)

Component	Transverse Direction	Longitudinal Direction	Vertical Direction
Base Slab	0.12	0.12	0.15
Roof Slab	0.24	0.14	0.19
Interior Walls	0.26	0.13	0.17
Exterior Walls	0.24	0.14	0.16

Notes:

1) For structural design using the loads and load combinations in Section 3.8, the seismic demands are calculated in ANSYS by applying these peak accelerations as statically equivalent loads across the entire component and combining with the demands calculated in ANSYS by applying an equivalent static seismic soil pressure.~~loads are obtained by applying to the ESWPT segment a statically equivalent uniform acceleration that envelopes the above accelerations and a dynamic soil pressure.~~ RCOL2_03.07.02-12

Table 3LL-8

ESWPT Segment 3 SASSI FE Model Component Peak Accelerations(4) (g)

Component	Transverse Direction	Longitudinal Direction	Vertical Direction
Base Slab	0.12(1)	0.12(1)	0.13(1)
Roof Slab	0.50(1)	0.16(1)	0.21(1)
Interior Walls	0.50(3)	0.19	0.20
Exterior Walls	0.50(3)	0.16	0.15
PSFSV Service Tunnel Walls	0.32(2)	0.38(2)	0.15
PSFSV Service Tunnel Roof	0.32(2)	0.38(2)	0.16

Notes:

1) The transverse direction for the base slab and roof is the north-south direction; the longitudinal direction is the east-west direction.
2) The transverse direction for the PSFSV service tunnel walls and roof is the east-west direction; the longitudinal direction is the north south direction.
3) For interior and exterior walls, the transverse direction is the out-of-plane direction.
4) For structural design using the loads and load combinations in Section 3.8, the seismic demands are calculated in ANSYS using the peak accelerations as statically equivalent loads and combining them with the demands calculated in ANSYS by applying an equivalent static seismic soil pressure.~~loads are obtained by applying to the ESWPT segment a statically equivalent uniform acceleration that envelopes the above accelerations, and a dynamic soil pressure.~~ RCOL2_03.07.02-12

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.

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 ~~using an iterative approach that compares~~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 RCOL2_03.07.02-11 RCOL2_03.07.02-11 range of backfill properties and conditions in combination with the site-specific supporting media conditions.

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, and soil pressures are compared between the various soil profiles used in analyses to verify that the responses are reasonably similar between these cases except for the expected trends due to soil frequency changes. RCOL2_03.07.02-16

Operating-basis earthquake (OBE) structural damping values of Chapter 3 Table 3.7.1-3(b), such as 4 percent damping for reinforced concrete, are used in the site-specific SASSI analysis. This is consistent with the requirements of Section 1.2 of RG 1.61 (Reference 3LL-4) for structures on sites with low seismic responses where the analyses consider a relatively narrow range of site-specific subgrade conditions. 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 the envelope of the soil conditions. The SASSI analysis results are used to produce the final response spectra and provide confirmation of the inputs to the ANSYS design model. RCOL2_03.07.02-11

ANSYS analyses are used to calculate the structural demands of the ESWPT to seismic soil pressure and seismic inertia which are then added to all other design loads discussed in Section 3.8.

The seismic inertia demand of segment 2 are calculated using ANSYS, response spectra analyses with the site specific 5% damped design response spectra. The design response spectra is based on the standard plant CSDRS anchored to a zero period acceleration of 0.10 g that is shown to envelope the site specific FIRS and the in-structure response spectra calculated at the base slab in SASSI. Modal combination is performed in accordance with RG 1.91 Combination Method B. Analysis of the ESWPT produced 40 modes below 50 Hz. Table 3LL-15 lists five major structural frequencies for each direction of motion organized by mass participation. RCOL2_03.08.04-44 RCOL2_03.07.02-16

The seismic inertia demand of segments 1 and 3 are calculated using an equivalent static lateral load based on the enveloped peak accelerations calculated in SASSI for all soil cases that are shown in Tables 3LL-6 and 3LL-8. RCOL2_03.07.02-11 RCOL2_03.08.04-34

The seismic soil pressure demands are calculated statically in ANSYS. The seismic soil pressure demands are applied on the structural elements as equivalent static pressures. The pressures applied are of larger magnitude compared to the calculated elastic solution used in ASCE 4-98 based on J.H. Wood, 1973 and the enveloped SASSI results. Soil above the tunnel is accounted for in two ways: (1) a shear force was applied at the interface of the tunnel roof and the soil above where the shear value is shown to be higher than that calculated in SASSI SSI analyses and (2) the density of the tunnel roof slab is increased in regions of the tunnel where a balanced soil condition does not exist. This second method accounts for an assumed load path of bringing the entire soil mass into the roof slab through shear. RCOL2_03.08.04-8

Demands calculated from the response spectra and soil pressure analyses performed in ANSYS for segment 2 are combined on an absolute basis to produce the maximum demands for each direction of motion and these directions RCOL2_03.07.02-11 are then combined spatially by 100-40-40 percent combination rule (Eq. 13 of RG 1.92). Calculations of the design forces and moments use the 100-40-40 percent combination rule because the design of concrete elements includes the effects of the interaction of different components, such as interaction of axial forces with the moments or axial forces with shear. Since the direction of input motion that results in the maximum axial force may be different from that producing the maximum moment or shear, the 100-40-40 method produces more accurate design demands. RCOL2_03.07.02-11 RCOL2_03.08.04-41

Demands calculated from the equivalent static accelerations and soil pressure analyses performed in ANSYS for segments 1 and 3 are combined to produce the maximum demands in each direction. The maximum demands for each direction of motion and these directions are then combined spatially by 100-40-40 percent combination rule (Eq. 13 of RG 1.92). RCOL2_03.07.02-11

To confirm the design input and results from the ANSYS model of tunnel segment 2 used for response spectra analysis, the enveloped in-structure response spectra at the base slab calculated in the SASSI analysis are compared to the input spectra. The enveloped soil pressures from SASSI are compared to the soil pressures used as input to the ANSYS model, and the plate stresses from SASSI are compared to those calculated in ANSYS. The comparisons show that the seismic loads used for design exceeded those based on results of the SASSI analysis.

3LL.3 Seismic Analysis Results

Table 3LL-4 presents the natural frequencies and descriptions of the associated modal responses obtained from the fixed-base ANSYS analysis of the straight portion of the ESWPT (Segment 1 Model). These frequencies were compared to the frequencies calculated from the transfer functions for the SASSI model to confirm adequacy of the coarser mesh SASSI model to represent dynamic behavior of the tunnels. Table 3LL-5 presents a summary of SSI effects on the seismic response of the ESWPT segments.

The maximum absolute nodal accelerations obtained from the ~~time-history~~SASSI SSI analyses of the ESWPT models are presented in Tables 3LL-6 to 3LL-8. The results are presented for each of the major ESWPT components and envelope all backfill conditions described above. The maximum accelerations have been obtained by combining cross-directional contributions (i.e. X-response due to X-input, X-response due to Y-input, and X-response due to Z-input) in accordance with RG 1.92 (Reference 3LL-5) using the square root sum of the squares (SRSS) method. RCOL2_03.07.02-13 RCOL2_03.08.04-34 RCOL2_03.08.04-41

The forces and moments in Tables 3LL-9, 3LL-10, and 3LL-11 represent ~~the maximum~~ seismic ~~design forces and moments that represent the envelope of the results for all considered site conditions. The forces and moments are obtained by combination of the three orthogonal directions used in the model by the Newmark 100%-40%-40% method. The seismic design forces are applied to the ANSYS~~ RCOL2_03.07.02-13

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-35

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.1, "ESWPT", which references Appendix 3LL. In Appendix 3LL, "Model Properties and Seismic Analysis Results for ESWPT," section 3LL.1, "Introduction", the last sentence of the paragraph (Page 3LL-1) states that "Due to the low seismic response at the Comanche Peak Nuclear Power Plant site and the lack of high-frequency exceedances, the SASSI capability to consider incoherence of the input control motion is not implemented in the design of the ESWPT."

The response of underground tunnels is produced primarily by the ground deformations under free-field conditions; therefore, the wave passage, including non-vertically propagating waves, and the wave incoherence effects may be important in the response calculation. The applicant is requested to address the issue, "Are the effects of the seismic wave passage on the tunnel considered in the analysis?" If yes, provide a description of the wave fields considered and the impinging angles assumed. If not, provide the technical justification for not considering the wave passage effects. Also, provide the technical justification for not considering the wave incoherence effects.

ANSWER:

The effects of the seismic wave passage on the tunnel are not directly considered in the SASSI or ANSYS dynamic analyses of the tunnel. The wave passage effects are considered to be small because the tunnel foundation is supported by a stiff limestone layer which will experience low strains under the fairly low seismic motion at the site. FSAR Section 3LL.1 has been revised to incorporate this response.

Impact on R-COLA

See attached marked-up FSAR Revision 1 page 3LL-1.

Impact on S-COLA

None.

Impact on DCD

None.

3LL MODEL PROPERTIES AND SEISMIC ANALYSIS RESULTS FOR ESWPT

3LL.1 Introduction

This Appendix discusses the seismic analysis of the essential service water pipe tunnel (ESWPT). The computer program SASSI (Reference 3LL-1) serves as the platform for the soil-structure interaction (SSI) analyses. The three-dimensional (3D) finite element (FE) models used in SASSI are condensed from FE models with finer mesh patterns initially developed using the ANSYS computer program (Reference 3LL-2). The dynamic analysis of the SASSI 3D FE model in the frequency domain provides results for the ESWPT seismic response that include SSI effects. The SASSI model results for maximum accelerations, ~~and~~ seismic soil pressures and base response spectra are used as input to the ANSYS models for performing the detailed structural design, including loads and load combinations in accordance with the requirements of Section 3.8. Table 3LL-14 summarizes the analyses performed for calculating seismic demands. The SASSI analysis and results presented in this Appendix include site-specific SSI effects such as the layering of the subgrade, flexibility, and embedment of the ESWPT structure, and scattering of the input control design motion. Due to the low seismic response at the Comanche Peak Nuclear Power Plant site and the lack of high-frequency exceedances, the SASSI capability to consider incoherence of the input control motion is not implemented in the ~~design~~analysis of the ESWPT. Wave passage effects are considered small and not included in the analysis because the tunnel foundation is supported by a stiff limestone layer, which will experience low strains under the fairly low seismic motion at the site.

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RCOL2_03.07.02-16
RCOL2_03.08.04-35

3LL.2 Model Description and Analysis Approach

The ESWPT is modeled with three separate models, each model representing a physical portion of the ESWPT, which are separated by expansion joints (see Subsection 3.8.1.6) that prevent any significant interaction of segments at the interface. Tunnel Segment 1 represents a typical straight north-south tunnel segment buried in backfill soil. Tunnel Segment 2 represents east-west segments adjacent to the ultimate heat sink related structures (UHSRS). Two tornado missile shields extend from the top of this segment to protect the essential service water (ESW) piping and openings into the ultimate heat sink (UHS). The FE model for Segment 3 represents east-west segments adjacent to the power source fuel storage vault (PSFSV) and includes elements representing the fuel pipe access tunnels that extend across the top of the ESWPT. The SSI analyses for all tunnel segments considered soil on all sides in which soil is in contact including the top and bottom of the tunnel.

RCOL2_03.08.04-36
RCOL2_03.07.02-16
RCOL2_03.08.04-40

The ~~FE~~SSI models for each of the three ESWPT segments are shown in Figures 3LL-1 through 3LL-6 as overall and cutaway views. Tables 3LL-1, 3LL-2, and 3LL-3 present the properties assigned to the structural components of the SASSI FE models for Segments 1, 2, and 3, respectively. Detailed descriptions and figures of the ESWPT including actual dimensions are contained in Section 3.8. Shell elements model the roof, interior, and exterior walls, and basemat. Brick

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-36

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.1, "ESWPT", which references Appendix 3LL. In Appendix 3LL, "Model Properties and Seismic Analysis Results for ESWPT," section 3LL.2, "Model Description and Analysis Approach," the first sentence of the first paragraph (Page 3LL-1) states that "The ESWPT is modeled with three separate models, each model representing a physical portion of the ESWPT."

The applicant is requested to provide a description for the boundary conditions assumed for the interfaces of three segments and provide technical justification for the assumptions.

Also, expansion joints are provided near the corner junctions of the intersecting ESWPT segments, as well as those located within the straight portion of the segments away from the intersections. The applicant is requested to address the following issues:

a. How were the analyses performed so that they account for the seismic behavior of the tunnel walls at the corner junctions of these intersecting segments? Provide a description of the results of this analysis.

b. Also, describe the nature of the design of these expansion joints and provide data regarding their properties and behavior over time.

ANSWER:

Free boundary conditions are applied at the nodes at the tunnel interfaces. The expansion joints described in response (b) below allow the expansion joints to be modeled as complete separation between adjacent structures in seismic structural analyses. Only one structure is modeled for these analyses, with the expansion joint modeled as a lack of soil or adjacent structure on the isolated sides. This is appropriate for the material considered in the joint.

(a) Expansion joints separate the tunnel into segments. There are three different types of tunnel segments. The calculations include an analysis of a representative segment of each type including:

- Tunnel Segment 1 - representative of typical fully buried straight tunnel segments with fill on both sides and top.
- Tunnel Segment 2 – representative of segments adjacent to the Ultimate Heat Sink (UHS) structures. This tunnel segment has two tornado missile shields that extend from the top of this segment to protect the pipe as it transitions from the tunnel to the UHS.
- Tunnel Segment 3 – representative of segments adjacent to the Power Source Fuel Storage Vault with fuel pipe access tunnels extending from the top.

All the tunnel segment models are 3-D representations of the tunnel geometries. As can be observed in the site plan (FSAR Figure 3.8-201), Tunnel Segments 2 and 3 include 90 degree corners. This corner condition is modeled in the SSI and design analysis models, and the results for this analysis are calculated in a manner similarly to the results for the non-corner portions of the tunnel. The SSI analysis were done using program SASSI for calculating in-structure response spectra and dynamic soil pressure. The design models that are more refined than the SSI models were used to calculate seismic force/moment demands that were used for the design of each segment. The soil pressure, accelerations and/or input design spectra used for the design model were confirmed to be conservative compared to the corresponding responses from SASSI SSI analyses. Increased force and moment demands at the corners were observed and accounted for in the design.

(b) A site-specific specification for the expansion/separation joint that provides performance requirements for material or system used will be prepared prior to the start of procurement. Performance requirements for an elastomeric material joint or sealer will include requirements bounding the allowable stress-strain properties, durability requirements, and specification for a material testing program. The material considered for this stage of design of the UHSRS is ETHAFOAM 220 produced by Sealed Air Corporation. This material was considered because it has a tri-linear stress-strain curve. Its initial stiffness property allows placement of about 10 feet of concrete lift directly against the material while entering the second flat segment of the curve. During the seismic event, the material will act as an isolation gap since the stress-strain curve is flat beyond the strain levels induced during concrete placement. The separation joint material such as ETHAFOAM will have specifications prepared that include long-term durability as part of detailed design prior to procurement.

The expansion joints are modeled as a complete separation between adjacent structures in the seismic structural analyses. For these analyses only one structure is modeled, with the expansion joint modeled as a lack of soil or adjacent structure on the isolated sides. This is appropriate for the material considered in the joint.

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

See attached marked-up FSAR Revision 1 page 3LL-1.

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

None.

Impact on DCD

None.

3LL MODEL PROPERTIES AND SEISMIC ANALYSIS RESULTS FOR ESWPT

3LL.1 Introduction

This Appendix discusses the seismic analysis of the essential service water pipe tunnel (ESWPT). The computer program SASSI (Reference 3LL-1) serves as the platform for the soil-structure interaction (SSI) analyses. The three-dimensional (3D) finite element (FE) models used in SASSI are condensed from FE models with finer mesh patterns initially developed using the ANSYS computer program (Reference 3LL-2). The dynamic analysis of the SASSI 3D FE model in the frequency domain provides results for the ESWPT seismic response that include SSI effects. The SASSI model results for maximum accelerations, ~~and~~ seismic soil pressures and base response spectra are used as input to the ANSYS models for performing the detailed structural design, including loads and load combinations in accordance with the requirements of Section 3.8. Table 3LL-14 summarizes the analyses performed for calculating seismic demands. The SASSI analysis and results presented in this Appendix include site-specific SSI effects such as the layering of the subgrade, flexibility, and embedment of the ESWPT structure, and scattering of the input control design motion. Due to the low seismic response at the Comanche Peak Nuclear Power Plant site and the lack of high-frequency exceedances, the SASSI capability to consider incoherence of the input control motion is not implemented in the ~~design~~analysis of the ESWPT. Wave passage effects are considered small and not included in the analysis because the tunnel foundation is supported by a stiff limestone layer, which will experience low strains under the fairly low seismic motion at the site.

RCOL2_03.07.02-16
RCOL2_03.07.02-16
RCOL2_03.08.04-35

3LL.2 Model Description and Analysis Approach

The ESWPT is modeled with three separate models, each model representing a physical portion of the ESWPT, which are separated by expansion joints (see Subsection 3.8.1.6) that prevent any significant interaction of segments at the interface. Tunnel Segment 1 represents a typical straight north-south tunnel segment buried in backfill soil. Tunnel Segment 2 represents east-west segments adjacent to the ultimate heat sink related structures (UHSRS). Two tornado missile shields extend from the top of this segment to protect the essential service water (ESW) piping and openings into the ultimate heat sink (UHS). The FE model for Segment 3 represents east-west segments adjacent to the power source fuel storage vault (PSFSV) and includes elements representing the fuel pipe access tunnels that extend across the top of the ESWPT. The SSI analyses for all tunnel segments considered soil on all sides in which soil is in contact including the top and bottom of the tunnel.

RCOL2_03.08.04-36
RCOL2_03.07.02-16
RCOL2_03.08.04-40

The ~~FE~~SSI models for each of the three ESWPT segments are shown in Figures 3LL-1 through 3LL-6 as overall and cutaway views. Tables 3LL-1, 3LL-2, and 3LL-3 present the properties assigned to the structural components of the SASSI FE models for Segments 1, 2, and 3, respectively. Detailed descriptions and figures of the ESWPT including actual dimensions are contained in Section 3.8. Shell elements model the roof, interior, and exterior walls, and basemat. Brick

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-37

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.1, "ESWPT", which references Appendix 3LL. In Appendix 3LL, "Model Properties and Seismic Analysis Results for ESWPT," section 3LL.2, "Model Description and Analysis Approach," the last sentence of the first paragraph (Page 3LL-1) states that "Shell elements model the roof, interior, and exterior walls, and basemat. Brick elements model the backfill and fill concrete below the ESWPT basemat."

The shell element has six degrees of freedom per node; whereas, the brick element has only three degrees of freedom per node. The applicant is requested to explain how shell elements are connected to the brick elements.

ANSWER:

The shell element used has five degrees of freedom per node (three translational degrees, two bending degrees and no drilling degree of freedom). In the SSI model for analysis in SASSI, shell elements and solid (brick) elements are connected at their shared nodes. The tunnel structure is modeled with shell elements which represent the walls and slabs, while brick elements are included to model the concrete fill beneath the structure and soil on the sides. Where the shell elements and brick elements are connected, the shell element is connected to overlap the face of the brick element. There are no locations in the models where shell elements are connected perpendicularly to the bricks with the intention of transferring moments through nodal rotational degrees of freedom.

The design model in ANSYS does not model the concrete fill.

FSAR Section 3LL.2 has been revised to incorporate this response.

Impact on R-COLA

See attached marked-up FSAR Revision 1 page 3LL-2.

Impact on S-COLA

None.

Impact on DCD

None.

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.

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 ~~using an iterative approach that compares~~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 RCOL2_03.07.02-11 RCOL2_03.07.02-11

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-38

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.1, "ESWPT", which references Appendix 3LL. In Appendix 3LL, "Model Properties and Seismic Analysis Results for ESWPT," section 3LL.2, "Model Description and Analysis Approach," the second paragraph (Page 3LL-1) states that "Site-specific strain-compatible backfill and rock properties are used in determining the within-layer motion."

The applicant is requested to provide information for the soil shear modulus and soil material (hysteretic) damping ratio as a function of soil shear strain used in the analysis to obtain the site-specific strain-compatible soil properties.

ANSWER:

The backfill material shear modulus and damping ratio values as a function of soil shear strain are listed in the table below and are shown in FSAR Figure 2.5.2-232. These properties were used for calculating the compatible backfill properties using convolution analysis using the SOIL module of ACS SASSI (which is similar to the program SHAKE). Low-strain rock properties were used and therefore rock strain-dependant properties were not required.

Fill Dynamic Degradation Properties

	Top 20 ft		20 - 40 ft		Top 20 ft		20 - 40 ft	
Value No.	% Strain	G/Gmax	% Strain	G/Gmax	% Strain	Damping Ratio	% Strain	Damping Ratio
1	0.00010	1.00000	0.00010	1.00000	0.00010	0.01475	0.00010	0.01096
2	0.00044	0.99294	0.00017	1.00000	0.00026	0.01475	0.00026	0.01053
3	0.00077	0.98824	0.00030	1.00000	0.00043	0.01559	0.00043	0.01138
4	0.00132	0.97177	0.00052	1.00000	0.00071	0.01728	0.00071	0.01264
5	0.00172	0.96000	0.00092	0.99294	0.00117	0.01980	0.00114	0.01475
6	0.00226	0.94353	0.00156	0.97882	0.00191	0.02317	0.00188	0.01728
7	0.00365	0.89882	0.00264	0.95059	0.00306	0.02823	0.00304	0.02107
8	0.00566	0.84235	0.00433	0.91294	0.00496	0.03539	0.00492	0.02612
9	0.00865	0.77882	0.00710	0.86353	0.00796	0.04424	0.00796	0.03287
10	0.01267	0.71294	0.01101	0.80941	0.01225	0.05562	0.01256	0.04171
11	0.01779	0.63765	0.01613	0.74353	0.01853	0.06952	0.01966	0.05309
12	0.02496	0.56235	0.02329	0.67059	0.02733	0.08553	0.02949	0.06826
13	0.03504	0.48941	0.03316	0.60000	0.03865	0.10281	0.04278	0.08343
14	0.04988	0.41647	0.04721	0.52471	0.05419	0.12177	0.06100	0.10155
15	0.07101	0.34118	0.06626	0.44941	0.07535	0.14073	0.08625	0.11966
16	0.10254	0.27059	0.09432	0.37647	0.10476	0.15927	0.12094	0.13778
17	0.15234	0.20706	0.13429	0.30588	0.14442	0.17865	0.16957	0.15674
18	0.23955	0.15059	0.19391	0.23529	0.20250	0.19761	0.23576	0.17612
19	0.38758	0.10824	0.28807	0.16941	0.28393	0.21657	0.32503	0.19424
20	0.86875	0.07059	1.02995	0.08235	1.04315	0.28020	0.90357	0.25070

Impact on R-COLA

None.

Impact on S-COLA

None.

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-39

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.1, "ESWPT", which references Appendix 3LL. In Appendix 3LL, "Model Properties and Seismic Analysis Results for ESWPT," section 3LL.2, "Model Description and Analysis Approach," the first paragraph on Page 3LL-2 states that "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, as well as the backfill conditions around the embedded portions of the ESWPT."

The applicant is requested to provide information for the exact section number(s) of ASCE 4 that were used in the ESWPT analysis.

ANSWER:

The guidance provided by ASCE 4-98 (see reference below) provisions were followed in general for analysis of the ESWPT including portions of the following sections:

- Section 2.1 Seismic Ground Motions
- Section 2.2 Response Spectra
- Section 2.3 Time Histories
- Section 3.1 Modeling of Structures
  - 3.1.1 General Requirements
  - 3.1.2 Structural Material Properties
  - 3.1.3 Modeling of Stiffness
  - 3.1.4 Modeling of Mass
  - 3.1.5 Modeling of Damping

3.1.8.3 Requirements for Shear-Wall Structures

Section 3.2 Analysis of Structures

3.2.1 General Requirements

3.2.4 Complex Frequency Response Method

Section 3.3 Soil-Structure Interaction Modeling and Analysis

Section 3.4 Input for Subsystem Seismic Analysis

Section 3.5 Special Structures

Section 3.5.3 Earth-Retaining Walls

Reference:

Seismic Analysis of Safety Related Nuclear Structures and Commentary on Seismic Analysis of Safety Related Structures, ASCE Standard 4-98, American Society of Civil Engineers, 1998.

Impact on R-COLA

None.

Impact on S-COLA

None.

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-40

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.1, "ESWPT", which references Appendix 3LL. In Appendix 3LL, "Model Properties and Seismic Analysis Results for ESWPT," section 3LL.3, "Seismic Analysis Results," the first paragraph (Page 3LL-2) states that "Table 3LL-4 presents the natural frequencies and descriptions of the associated modal responses obtained from the fixed-base ANSYS analysis of the straight portion of the ESWPT (Segment 1 Model). These frequencies were compared to the frequencies calculated from the transfer functions for the SASSI model to confirm adequacy of the coarser mesh SASSI model to represent dynamic behavior of the tunnels. Table 3LL-5 presents a summary of SSI effects on the seismic response of the ESWPT segments."

Provide the following information:
(a) Essential service water pipe tunnel (ESWPT) is an underground structure. The surrounding soil should be included in the analysis. The approach used in the CPNPP COL FSAR in which, first, the natural frequencies of the structure in its fixed-base condition are computed ignoring the surrounding soil, and then the response spectra analysis is performed, which does not seem to have a valid technical basis. The applicant is requested to provide the technical justification for this approach used in the analyses.

(b) Provide the technical information that shows how the natural frequencies were calculated from the transfer functions for the SASSI model. Provide plots for these transfer functions. Is the surrounding soil included in the SASSI model? What criteria are used to confirm the adequacy of the coarser mesh SASSI model?

ANSWER:

(a) The dynamic analysis of the ESWPT was performed using two analysis models: (1) a seismic soil structure interaction (SSI) analysis using the computer program SASSI to determine the dynamic response of the tunnel including the in-structure response spectra, dynamic soil loads, and peak accelerations, and (2) a design analysis model using the computer program ANSYS to calculate non-seismic and seismic loading demands. The seismic demands for the structural design were calculated by applying loads that represent seismic inertia loads and equivalent dynamic lateral soil pressures. The fixed based frequencies calculated using the ANSYS design model were used to verify the mesh refinement of the modeling as discussed in Answer (b) below.

The SSI analyses of the ESWPT using the program SASSI considered soil on all sides of the tunnels including the top and bottom. The ANSYS design model represented the seismic inertial loads and dynamic soil pressure loads acting on the tunnel. The ANSYS model did not include the modeling of the soil in any way that would allow the soil to reduce the loads on the tunnel.

The ANSYS design model was used to calculate seismic demand forces and moments for the design of the ESWPT using two steps. The first step was to calculate the seismic demands due to inertial effects of the tunnel structure and the second step was to account for dynamic lateral forces exerted by the soil onto the tunnel.

The inertia part of the seismic demands was calculated as follows: (1) for Tunnel Segments 1 and 3, equivalent static acceleration loading was applied to the model. The applied accelerations enveloped the acceleration values calculated in the SSI SASSI analysis and thus inherently including the embedment effect. (2) For Tunnel Segment 2, a response spectra analysis was performed using the design input response spectra shown to be more conservative than the SSI spectra calculated at the base slab. The tunnel frequencies without the stiffness of the soil on the south side were higher than the frequencies of the peak of the spectra. Therefore, not including the soil stiffness on the south side softened the structural response and increased the seismic inertial demands of the tunnel.

The seismic soil pressures on the sides of the tunnels were accounted for by applying seismic soil pressure demands from the elastic solution (Wood method) ASCE 4-98 Section 3.5.3.2. The applied soil pressures were confirmed to envelope the SSI soil pressures calculated in the SASSI analyses.

Soil above the tunnel was accounted for in two ways: (1) a shear force was applied at the interface of the tunnel roof and the soil above where the shear value is shown to be higher than that calculated in SASSI SSI analyses, and (2) the density of the tunnel roof slab was increased in regions of the tunnel where a balanced soil condition does not exist. The second method accounts for an assumed load path of bringing the entire soil mass into the roof slab through shear.

The total dynamic demands were calculated by summing the inertial and dynamic soil pressure demands on an absolute basis from the two design analyses.

(b) Natural frequencies were not calculated from the SASSI transfer functions to confirm adequate model mesh size. For confirmation of adequate mesh size of the ESWPT, a modal analysis was performed in ANSYS for Tunnel 1 with a fine mesh model and with a coarse mesh model that matches the SASSI model mesh. Less than a 10% difference between the frequencies of the major modes was observed, indicating that the simplification is acceptable. The surrounding soil is not included in the fixed base verification SASSI model so that a direct comparison can be made to the fixed base ANSYS design model modal results.

FSAR Section 3LL.2 has been revised to reflect this answer.

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

See attached marked-up FSAR Revision 1 pages 3LL-1 and 3LL-3.

Impact on S-COLA

None.

Impact on DCD

None.

Attachments

Marked-up FSAR Revision 1 pages 3LL-1, 3LL-2, 3LL-3, and 3LL-4 previously submitted in the response to RAI No. 2879 (CP RAI #60) Question 03.07.02-16 via Luminant letter TXNB-09073 dated November 24, 2009 (ML093340447).

3LL MODEL PROPERTIES AND SEISMIC ANALYSIS RESULTS FOR ESWPT

3LL.1 Introduction

This Appendix discusses the seismic analysis of the essential service water pipe tunnel (ESWPT). The computer program SASSI (Reference 3LL-1) serves as the platform for the soil-structure interaction (SSI) analyses. The three-dimensional (3D) finite element (FE) models used in SASSI are condensed from FE models with finer mesh patterns initially developed using the ANSYS computer program (Reference 3LL-2). The dynamic analysis of the SASSI 3D FE model in the frequency domain provides results for the ESWPT seismic response that include SSI effects. The SASSI model results for maximum accelerations, ~~and~~ seismic soil pressures and base response spectra are used as input to the ANSYS models for performing the detailed structural design, including loads and load combinations in accordance with the requirements of Section 3.8. Table 3LL-14 summarizes the analyses performed for calculating seismic demands. The SASSI analysis and results presented in this Appendix include site-specific SSI effects such as the layering of the subgrade, flexibility, and embedment of the ESWPT structure, and scattering of the input control design motion. Due to the low seismic response at the Comanche Peak Nuclear Power Plant site and the lack of high-frequency exceedances, the SASSI capability to consider incoherence of the input control motion is not implemented in the design of the ESWPT. RCOL2_03.07.02-16 RCOL2_03.07.02-16

3LL.2 Model Description and Analysis Approach

The ESWPT is modeled with three separate models, each model representing a physical portion of the ESWPT. Tunnel Segment 1 represents a typical straight north-south tunnel segment buried in backfill soil. Tunnel Segment 2 represents east-west segments adjacent to the ultimate heat sink related structures (UHSRS). Two tornado missile shields extend from the top of this segment to protect the essential service water (ESW) piping and openings into the ultimate heat sink (UHS). The FE model for Segment 3 represents east-west segments adjacent to the power source fuel storage vault (PSFSV) and includes elements representing the fuel pipe access tunnels that extend across the top of the ESWPT.

The ~~FE~~SSI models for each of the three ESWPT segments are shown in Figures 3LL-1 through 3LL-6 as overall and cutaway views. Tables 3LL-1, 3LL-2, and 3LL-3 present the properties assigned to the structural components of the SASSI FE models for Segments 1, 2, and 3, respectively. Detailed descriptions and figures of the ESWPT including actual dimensions are contained in Section 3.8. Shell elements model the roof, interior, and exterior walls, and basemat. Brick elements model the backfill and fill concrete below the ESWPT basemat. RCOL2_03.07.02-16

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. 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 for the site-specific stratigraphy and subgrade conditions described in Chapter 2, as well as the backfill conditions around the embedded portions of the ESWPT.

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.

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 ~~using an iterative approach that compares~~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 combination with the site-specific supporting media conditions. RCOL2_03.07.02-11 RCOL2_03.07.02-11

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 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 RCOL2_03.07.02-16 the frequency of analysis and it is divided by the selected number of layers in the half-space. RCOL2_03.07.02-16

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.

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 interaction 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.

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, and soil pressures are compared between the various soil profiles used in analyses to verify that the responses are reasonably similar between these cases except for the expected trends due to soil frequency changes.

Operating-basis earthquake (OBE) structural damping values of Chapter 3 Table 3.7.1-3(b), such as 4 percent damping for reinforced concrete, are used in the site-specific SASSI analysis. This is consistent with the requirements of Section 1.2 of RG 1.61 (Reference 3LL-4) for structures on sites with low seismic responses where the analyses consider a relatively narrow range of site-specific subgrade conditions. The SASSI analyses produce results including peak RCOL2_03.07.02-11 accelerations, in-structure response spectra, seismic element demands, and seismic soil pressures. All results from SSI analyses represent the envelope of the soil conditions. The SASSI analysis results are used to produce the final response spectra and provide confirmation of the inputs to the ANSYS design model. RCOL2_03.07.02-11

ANSYS analyses are used to calculate the structural demands of the ESWPT to seismic soil pressure and seismic inertia which are then added to all other design loads discussed in Section 3.8.

The seismic inertia demand of segment 2 are calculated using ANSYS, response spectra analyses with the site specific 5% damped design response spectra. Modal combination is performed in accordance with RG 1.91 Combination Method B. Analysis of the ESWPT produced 40 modes below 50 Hz. Table 3LL-15 lists five major structural frequencies for each direction of motion organized by mass participation. RCOL2_03.07.02-16

The seismic inertia demand of segments 1 and 3 are calculated using an equivalent static lateral load based on the enveloped peak accelerations calculated in SASSI for all soil cases. RCOL2_03.07.02-11

The seismic soil pressure demands are calculated statically in ANSYS. The seismic soil pressure demands are applied on the structural elements as equivalent static pressures. The pressures applied are of larger magnitude compared to the calculated elastic solution used in ASCE 4-98 based on J.H. Wood, 1973 and the enveloped SASSI results.

Demands calculated from the response spectra and soil pressure analyses performed in ANSYS for segment 2 are combined on an absolute basis to produce the maximum demands for each direction of motion and these directions are then combined spatially by 100-40-40 percent combination rule (Eq. 13 of RG 1.92).

Demands calculated from the equivalent static accelerations and soil pressure analyses performed in ANSYS for segments 1 and 3 are combined to produce the maximum demands in each direction. The maximum demands for each direction of motion and these directions are then combined spatially by 100-40-40 percent combination rule (Eq. 13 of RG 1.92).

To confirm the design input and results from the ANSYS model of tunnel segment 2 used for response spectra analysis, the enveloped in-structure response spectra at the base slab calculated in the SASSI analysis are compared to the input spectra. The enveloped soil pressures from SASSI are compared to the soil pressures used as input to the ANSYS model, and the plate stresses from SASSI are compared to those calculated in ANSYS. The comparisons show that the seismic loads used for design exceeded those based on results of the SASSI analysis.

3LL MODEL PROPERTIES AND SEISMIC ANALYSIS RESULTS FOR ESWPT

3LL.1 Introduction

This Appendix discusses the seismic analysis of the essential service water pipe tunnel (ESWPT). The computer program SASSI (Reference 3LL-1) serves as the platform for the soil-structure interaction (SSI) analyses. The three-dimensional (3D) finite element (FE) models used in SASSI are condensed from FE models with finer mesh patterns initially developed using the ANSYS computer program (Reference 3LL-2). The dynamic analysis of the SASSI 3D FE model in the frequency domain provides results for the ESWPT seismic response that include SSI effects. The SASSI model results for maximum accelerations, ~~and~~ seismic soil pressures and base response spectra are used as input to the ANSYS models for performing the detailed structural design, including loads and load combinations in accordance with the requirements of Section 3.8. Table 3LL-14 summarizes the analyses performed for calculating seismic demands. The SASSI analysis and results presented in this Appendix include site-specific SSI effects such as the layering of the subgrade, flexibility, and embedment of the ESWPT structure, and scattering of the input control design motion. Due to the low seismic response at the Comanche Peak Nuclear Power Plant site and the lack of high-frequency exceedances, the SASSI capability to consider incoherence of the input control motion is not implemented in the ~~design~~analysis of the ESWPT. Wave passage effects are considered small and not included in the analysis because the tunnel foundation is supported by a stiff limestone layer, which will experience low strains under the fairly low seismic motion at the site.

RCOL2_03.07.02-16
RCOL2_03.07.02-16
RCOL2_03.08.04-35

3LL.2 Model Description and Analysis Approach

The ESWPT is modeled with three separate models, each model representing a physical portion of the ESWPT, which are separated by expansion joints (see Subsection 3.8.1.6) that prevent any significant interaction of segments at the interface. Tunnel Segment 1 represents a typical straight north-south tunnel segment buried in backfill soil. Tunnel Segment 2 represents east-west segments adjacent to the ultimate heat sink related structures (UHSRS). Two tornado missile shields extend from the top of this segment to protect the essential service water (ESW) piping and openings into the ultimate heat sink (UHS). The FE model for Segment 3 represents east-west segments adjacent to the power source fuel storage vault (PSFSV) and includes elements representing the fuel pipe access tunnels that extend across the top of the ESWPT. The SSI analyses for all tunnel segments considered soil on all sides in which soil is in contact including the top and bottom of the tunnel.

RCOL2_03.08.04-36
RCOL2_03.07.02-16
RCOL2_03.08.04-40

The ~~FE~~SSI models for each of the three ESWPT segments are shown in Figures 3LL-1 through 3LL-6 as overall and cutaway views. Tables 3LL-1, 3LL-2, and 3LL-3 present the properties assigned to the structural components of the SASSI FE models for Segments 1, 2, and 3, respectively. Detailed descriptions and figures of the ESWPT including actual dimensions are contained in Section 3.8. Shell elements model the roof, interior, and exterior walls, and basemat. Brick

range of backfill properties and conditions in combination with the site-specific supporting media conditions.

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, and soil pressures are compared between the various soil profiles used in

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-41

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.1, "ESWPT", which references Appendix 3LL. In Appendix 3LL, "Model Properties and Seismic Analysis Results for ESWPT," section 3LL.3, "Seismic Analysis Results," the second paragraph (Page 3LL-3) states that "The maximum accelerations have been obtained by combining cross-directional contributions in accordance with RG 1.92 (Reference 3LL-5) using the square root sum of the squares (SRSS) method." The third paragraph (CP FSAR Page 3LL-3) states that "Tables 3LL-9, 3LL-10, and 3LL-11 present the maximum seismic design forces and moments that represent the envelope of the results for all considered site conditions. The forces and moments are obtained by combination of the three orthogonal directions used in the model by the Newmark 100%-40%-40% method. The seismic design forces are applied to the ANSYS model for structural design of members and components."

The applicant is requested to:

(a) Explain what "cross-directional contributions" means in the first quoted sentence above.

(b) Provide a rationale on why SRSS is used for combining accelerations; whereas, the Newmark 100%-40%-40% method is used for combining forces and moments.

(c) Provide a description for the ANSYS model. If the mesh of ANSYS model is different from that of SASSI model, provide a detailed description that shows how the seismic design forces obtained from the SASSI model are mapped to the ANSYS model.

ANSWER:

(a) For each peak nodal acceleration output, the peak nodal acceleration in a particular direction (e.g., X-direction) is influenced by input seismic motions from the X, Y, and Z-directions. Cross-directional contributions for X-direction response are: X-direction output due to X-direction input motion, X-direction output due to Y-direction input motion, and X-direction output due to Z-direction input motion. The total X-direction peak is the SRSS of these three responses since the three input motions in X, Y, and Z-directions are statistically independent.

(b) Combination by SRSS or Newmark 100-40-40 methods are acceptable methods of combining co-directional responses per RG 1.92. The SRSS method produces peak responses for all components in one step while the Newmark method calculates peak responses using three combination steps. For calculations of acceleration, only the peak values are required and therefore the SRSS method is preferred. Design forces and moments are treated differently because the design of concrete based elements includes the effects of the interaction of different components, such as axial forces with moments or axial forces with shear. Since the direction of input motion that results in the maximum axial force may be different than that producing the maximum moment or shear, the Newmark method produces the more accurate design demands.

(c) As described in FSAR Section 3LL.2, the ANSYS model uses plate elements to represent tunnel walls and slabs. The mesh refinement is sufficient to obtain design demands at critical design sections. The ANSYS model uses a finer mesh than the SASSI model.

Seismic design forces were calculated directly within the ANSYS design model as discussed in the response to Part (a) of Question 03.08.04-40 above; therefore no mapping of forces from the SASSI model to the ANSYS model was required.

FSAR Section 3LL.2 has been revised to incorporate this response.

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

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

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

None.

<u>Impact on DCD</u>

None.

are then combined spatially by 100-40-40 percent combination rule (Eq. 13 of RG 1.92). Calculations of the design forces and moments use the 100-40-40 percent combination rule because the design of concrete elements includes the effects of the interaction of different components, such as interaction of axial forces with the moments or axial forces with shear. Since the direction of input motion that results in the maximum axial force may be different from that producing the maximum moment or shear, the 100-40-40 method produces more accurate design demands. RCOL2_03.07.02-11 RCOL2_03.08.04-41

Demands calculated from the equivalent static accelerations and soil pressure analyses performed in ANSYS for segments 1 and 3 are combined to produce the maximum demands in each direction. The maximum demands for each direction of motion and these directions are then combined spatially by 100-40-40 percent combination rule (Eq. 13 of RG 1.92). RCOL2_03.07.02-11

To confirm the design input and results from the ANSYS model of tunnel segment 2 used for response spectra analysis, the enveloped in-structure response spectra at the base slab calculated in the SASSI analysis are compared to the input spectra. The enveloped soil pressures from SASSI are compared to the soil pressures used as input to the ANSYS model, and the plate stresses from SASSI are compared to those calculated in ANSYS. The comparisons show that the seismic loads used for design exceeded those based on results of the SASSI analysis.

3LL.3 Seismic Analysis Results

Table 3LL-4 presents the natural frequencies and descriptions of the associated modal responses obtained from the fixed-base ANSYS analysis of the straight portion of the ESWPT (Segment 1 Model). These frequencies were compared to the frequencies calculated from the transfer functions for the SASSI model to confirm adequacy of the coarser mesh SASSI model to represent dynamic behavior of the tunnels. Table 3LL-5 presents a summary of SSI effects on the seismic response of the ESWPT segments.

The maximum absolute nodal accelerations obtained from the ~~time history~~SASSI SSI analyses of the ESWPT models are presented in Tables 3LL-6 to 3LL-8. The results are presented for each of the major ESWPT components and envelope all backfill conditions described above. The maximum accelerations have been obtained by combining cross-directional contributions (i.e. X-response due to X-input, X-response due to Y-input, and X-response due to Z-input) in accordance with RG 1.92 (Reference 3LL-5) using the square root sum of the squares (SRSS) method. RCOL2_03.07.02-13 RCOL2_03.08.04-34 RCOL2_03.08.04-41

The forces and moments in Tables 3LL-9, 3LL-10, and 3LL-11 represent ~~the maximum~~ seismic ~~design forces and moments that represent the envelope of the results for all considered site conditions. The forces and moments are obtained by combination of the three orthogonal directions used in the model by the Newmark 100% 40% 40% method. The seismic design forces are applied to the ANSYS~~ RCOL2_03.07.02-13

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-42

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.1, "ESWPT", which references Appendix 3LL. In Appendix 3LL, "Model Properties and Seismic Analysis Results for ESWPT," Table 3LL-1, "ESWPT Segment 1 FE Model Component Properties," there are two notes, 1 and 2, presented at the bottom of the table. The first note is referred in the fifth column. The second note, however, is not referred in the Table. The applicant is requested to correct this oversight.

ANSWER:

Note 2 corresponds to the "Width or Height x Thickness" column of FSAR Table 3LL-1, which has been revised to include the reference to Note 2.

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

See attached marked-up FSAR Revision 1 page 3LL-8.

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

None.

<u>Impact on DCD</u>

None.

Table 3LL-1

ESWPT Segment 1 FE Model Component Properties

Components	Material	E (ksi)	Poisson's Ratio	Unit Weight (kcf)	Damping Ratio	Width or Height x Thickness[(2)] (ft)	Element type
Roof	5,000 psi concrete	4,030	0.17	0.225[(1)]	0.04	23 x 2	Shell
Base slab	5,000 psi concrete	4,030	0.17	0.200[(1)]	0.04	23 x 2	Shell
Exterior Walls	5,000 psi concrete	4,030	0.17	0.175[(1)]	0.04	16.67 x 2	Shell
Interior Walls	5,000 psi concrete	4,030	0.17	0.250[(1)]	0.04	16.67 x 1	Shell
Fill Concrete	3,000 psi concrete	3,125	0.17	0.15	0.04	23 x 10.08	Brick

RCOL2_03.08.04-42

Notes:

1) The unit weight includes equivalent dead loads due to piping and other supported components, and 25% of applicable live load for dynamic analysis purposes. A pipe load of 150 psf is considered on the roof slab and 50 psf is considered on all other interior surfaces. The applicable floor live load is 200 psf.
2) The width or height of the component is adjusted from actual dimensions to suit the mesh pattern used for the FE model. The adjustments are minor and do not affect the accuracy of the analysis results. Actual component dimensions are shown in Section 3.8 Figure 3.8-203 and 3.8-205.

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-43

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.1, "ESWPT", which references Appendix 3LL. In Appendix 3LL, "Model Properties and Seismic Analysis Results for ESWPT," Table 3LL-5, "SASSI Results for ESWPT Seismic Response" (Page 3LL-9), the first sentence under "Backfill" states, "The properties of the backfill determine the overall response of the buried ESWPT structure." Later, the backfill soil frequency ranges are provided.

The applicant is requested to provide a description of the material properties required for the engineered backfill used for the ESWPT. This discussion should address current industry activities evaluating backfill properties issues under the direction of the Nuclear Energy Institute (NEI), and possible implications on seismic analyses performed on the ESWPT and as-built properties of the engineered backfill.

ANSWER:

The response to RAI No. 2879 (CP RAI #60) Question 03.07.02-2 attached to Luminant letter TXNB-09073 dated November 24, 2009 (ML093340447) provides a discussion of how strain-compatible properties of the backfill were obtained and includes a table that presents those properties. Construction procedures will be developed to measure in-situ Vs values either as part of a test fill program or for verification purposes once the production fill has been completed. The response to Question 03.08.04-52 below provides a discussion on the testing methods of the engineered backfill for CPNPP Units 3 and 4, including discussion of industry (NEI) activities related to evaluating backfill properties. FSAR Sections 3NN.2 and 3NN.3 have been revised to incorporate this response.

Impact on R-COLA

See attached mark-up of FSAR Revision 1 pages 2.5-190, 3NN-3, 3NN-5, and 3NN-6.

Impact on S-COLA

None.

Impact on DCD

None.

Attachment

Marked-up FSAR Revision 1 FSAR Table 3NN-16 previously submitted in the response to RAI No. 2879 (CP RAI #60) Question 03.07.02-2 attached to Luminant letter TXNB-09073 dated November 24, 2009 (ML093340447).

RCOL2_03.
7.02-2

Table 3NN-16

Backfill Strain Compatible Properties

Elevation (ft)	Unit Weight (pcf)	Poisson's Ratio	S-Wave Velocity (fps)				P-Wave Velocity (fps)				Damping Ratio (%)			
			LB	LB	UB	HB	LB	BE	UB	HB	LB	BE	UB	HB
822	125	0.35	475	633	834	969	990	1317	1740	2017	3.00	2.40	2.00	1.80
819	125	0.35	540	739	999	1174	1125	1539	2080	2444	4.75	3.65	2.70	2.25
815	125	0.35	477	691	958	1143	994	1438	1993	2379	7.45	5.15	3.70	3.00
811	125	0.35	425	649	925	1113	885	1351	1926	2316	10.05	6.55	4.45	3.55
806	125	0.35	383	618	900	1088	797	1287	1874	2265	12.45	7.55	5.10	4.05
802	125	0.35	623	890	1213	1431	1296	1854	2526	2978	6.25	4.10	3.00	2.50
797	125	0.35	603	871	1199	1419	1256	1814	2497	2954	7.00	4.60	3.25	2.70
792	125	0.35	587	855	1188	1409	1223	1779	2473	2932	7.60	4.95	3.50	2.90
787	125	0.35	576	842	1180	1400	1199	1753	2456	2915	8.10	5.25	3.70	3.00
782	Top of Limestone (Foundation Bottom)													

table condition can be controlled by having sumps and pumps installed at key locations in the excavations.

Other than "perched" water, localized water bearing layers or lenses, no groundwater was encountered in the primary Glen Rose Limestone. Therefore only normal pumping equipment and procedures are required to remove storm runoff and concrete curing water that could enter the open excavations.

During construction of CPNPP Units 1 and 2, only small and localized seeps were reportedly observed in foundation excavations that extended to deeper levels (and lower elevations) than at CPNPP Units 3 and 4.

2.5.4.5.4 Backfill Material

Backfill is required between the foundation excavation sidewalls and lower structural walls of seismic category I and II facilities, the main power block structures, and the UHS. The volume of backfill is minimized by using steep or vertical excavation cuts.

No exclusions are placed on the use of limestone or sandstone derived from the mass grading to develop plant grade or foundation excavations. The total volume of excavation in the Units 3 and 4 power block and UHS areas greatly exceeds the volume of required backfill. Shale materials are not acceptable for backfill material in structural areas because of their fine-grained nature, high plasticity, and expansion potential. Testing of limestone and shale samples is discussed in Subsection 2.5.4.2. Dynamic properties assigned to engineered backfill are discussed in Subsection 2.5.4.7.4. The source of backfill to be used adjacent to category I structures will be the limestone and sandstone removed from the excavation and that there will be sufficient quantity of material from the excavation for that purpose. The acceptance criteria, test method, and frequency of verification for fill placement are provided for each fill application in Subsection 2.5.4.5.4.8. Continuous geotechnical engineering observation and inspection of all fill is required to certify and ensure that the fill is properly placed and compacted ~~in accordance with project plans and specifications~~as discussed in Subsection 2.5.4.5.4.2. RCOL2_03.08.04-43

Clean sand may be used as a select granular backfill material around the buried structure walls. A discussion of the materials for engineered fill is provided in Subsection 2.5.4.5.4.1.1. All major seismic category I and II buildings and structure are founded directly on solid limestone or fill concrete (subsection 3.7.1.3). Recommendations for concrete fill under power block structure foundations are provided in Subsection 2.5.4.5.4.1.2.

Concrete fill may be used as backfill to replace unsuitable rock removed below elevation 782 ft as part of foundation preparations. The concrete fill foundation details are shown on Figure 2.5.4-217.

surface of the rock subgrade at nominal elevation of 782 ft. The degradation curves presented in Figure 2.5.2-232, which are derived based on standard EPRI shear modulus reduction and damping curves for granular fill, were used to model the properties of the backfill, which are non-linear. The curves' values of the soil shear modulus and the damping as a function of shear strain are listed in Table 2.5.2-227. RCOL2_03.08.04-22 RCOL2_03.08.04-43 RCOL2_03.08.04-53

ACS SASSI SOIL calculated strain-compatible fill properties using 65% of the peak strain value for selection of effective soil strain. The results for the strain-compatible backfill properties obtained from the two horizontal site response analyses are averaged to obtain the backfill profiles used as the input for the site-specific SSI analyses.

The compression or P-wave velocity is developed for the rock and the backfill from the strain-compatible shear or S-wave velocity (Vs) and the measured value of the Poisson's ratio by using the following equation: ~~.~~ RCOL2_03.07.02-2

$$Vp = Vs \cdot \sqrt{2 \cdot \frac{1-v}{1-2v}}$$

The SSI analyses use identical values for the shear S-wave and compression P-wave velocity damping. Figure 3NN-1, Figure 3NN-2 and Figure 3NN-3 present, respectively, the rock subgrade LB, BE and UB profiles for shear (S) wave velocity (Vs), compression (P) wave velocity (Vp) and material damping. Figure 3NN-4, Figure 3NN-5 and Figure 3NN-6 present in solid lines the results of the site response analyses for the profiles of strain-compatible backfill properties. The plots also show with dashed lines the backfill profiles that were modified to match the geometry of the mesh of the SASSI basement model. The presented input S and P wave profiles are modified using the equal arrival time averaging method. Table 3NN-16 provides the strain-compatible backfill properties, used for the SASSI analysis for LB, BE, UB, and HB embedment conditions. RCOL2_03.07.02-2

The minimum design spectra, tied to the shapes of the certified seismic design response spectra (CSDRS) and anchored at 0.1g, define the safe-shutdown earthquake (SSE) design motion for the seismic design of category I structures that is specified as outcrop motion at the top of the limestone at nominal elevation of 782 ft. Two statistically independent time histories H1 and H2 are developed compatible to the horizontal design spectrum, and a vertical acceleration time history V is developed compatible to the vertical design spectrum. The time step of the acceleration time histories used as input for the SASSI analysis is 0.005 seconds. The SASSI analysis requires the object motion to be defined as within-layer motion. ~~The site response analyses convert the design motion that is defined as outcrop motion (or motion at the free surface) to within-layer (or base motion) that depends on the properties of the backfill above the rock surface. The site response analyses provide for each considered backfill profile, two horizontal acceleration time histories of the design motion within the top limestone rock layer~~ RCOL2_03.08.04-54

reproduce the rigid link behavior present in the standard plant lumped mass stick models. RCOL2_03.08.04-57

The major coordinates that define the geometry of the FE basement model are listed in Table 3NN-2 to Table 3NN-5. 3NN-6 presents the types of SASSI finite elements used to model the different structural members in the basement model. The table also presents the ~~stiffness and mass inertia~~material properties (modulus of elasticity and weight density) assigned to each group of finite elements. The ~~stiffness and damping~~ properties assigned to each material of the SASSI model are listed in Table 3NN-7. The site-specific SASSI analysis uses the operating-basis earthquake (OBE) damping values of Chapter 3, Table 3.7.1-3(b), which is consistent with the requirements of Section 1.2 of RG 1.61 (Reference 3NN-4) for structures on sites with low seismic responses where the analyses consider a relatively narrow range of site-specific subgrade conditions. RCOL2_03.08.04-58

SASSI solid FE elements, shown in Figure 3NN-9, model the stiffness and mass inertia properties of the building basemat. The modeling of the thick central part of the basemat supporting the PCCV and containment internal structure is simplified to minimize the size of the SASSI model as shown in Figure 3NN-10. Rigid shell elements connect the thick portion of the basemat with the floor slabs at the ground elevation. Rigid 3D beam elements connect the PCCV and containment internal structure lumped-mass stick models to the rigid shell elements as shown in Figure 3NN-13 and Figure 3NN-14. Massless shell elements are added at the top of the basemat solid element to accurately model the bending stiffness of the central part of the mat. Figure 3NN-11 shows the solid FE elements representing the stiffness and mass inertia of the fill concrete placed under the central elevated part of the basemat and under the surface mat at the northeast corner of the building.

SASSI 3D shell elements model the basement shear walls, the surface mat under the northeast corner of the R/B, and the R/B slabs at ground floor elevation. The elastic modulus and unit weight assigned to the material of the shell elements modeling the R/B basement shear walls shown in Figure 3NN-12 are adjusted to account for the different height of walls and reductions of stiffness due to the openings. Table 3NN-8 lists the adjusted material properties assigned to the shell elements of the walls with openings.

Rigid 3D beam elements connect the top of the basement shear walls with lumped-mass stick model representing the above ground portion of the R/B and FH/A. This modeling approach enables the R/B-FH/A to be connected to the flexible part of the building basement and decoupled from the thick central part that serves as foundation to the PCCV and containment internal structure part of the building.

The layering of the backfill profiles is modified in order to match the geometry of the mesh of the SASSI basemat model described above. The S-wave and P-wave velocities of the backfill (Vs and Vp) are adjusted using an equivalent arrival time methodology as follows: RCOL2_03.08.04-43 RCOL2_03.08.04-53

$$Vs = \frac{D}{\sum d_i / Vs_i} \quad \text{and} \quad Vp = \frac{D}{\sum d_i / Vp_i}$$

RCOL2_03.08.04-43
RCOL2_03.08.04-53

where:

D is the thickness of the backfill layer in SASSI, d_i is the thickness of each backfill layer in the site-response analysis model, and Vs_i and Vp_i are the strain-compatible S-wave and P-wave velocities corresponding to the layering of the site response model.

The P-wave damping (Dp) of the rock and backfill is set equal to the S-wave damping. The S-wave damping (Ds) of the rock and backfill layers is calculated as a weighted average using the following formula:

$$Ds = Dp = \frac{\sum d_i \cdot Ds_i}{D}$$

where Ds_i is the S-wave damping value of each backfill layer.

In addition to the weights assigned to the lumped-mass-stick models of the US-APWR standard plant summarized in Table 3H.2-10 of Appendix 3H, the SASSI model used for site specific analyses includes the weight of 47,085 kips pertaining to the fill concrete placed beneath the building basemat. The combined total weight of the R/B, containment internal structure, and PCCV including the basemat and the fill concrete is 781,685 kips. The equivalent uniform pressure under the building foundation is 11.86 ksf. In the SASSI model of the basement, unit mass weight is assigned only to the 3D shell elements modeling the shear walls of R/B and to the portion of the basemat represented by 3D brick elements. Table 3NN-9 presents the weights assigned to the elements of the basement structural members. The remaining weight of the basement is lumped at a single node that, as shown in Figure 3NN-10, is connected to the central portion of the foundation by rigid beams. As shown in Table 3NN-10, the magnitude and the location of the lumped mass are calculated such that, when combined with the mass inertia properties of the mat and walls, the FE model duplicates the overall lumped mass inertia properties assigned to the standard plant lumped mass stick model at basement node BS01.

Four layers of SASSI solid elements, shown Figure 3NN-15, are used to represent the stiffness and the mass inertia of the excavated backfill soil. Figure 3NN-4, Figure 3NN-5, and Figure 3NN-6 show in dashed lines the input strain-compatible properties assigned to the different layers of excavated soil elements.

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-44

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.1, "ESWPT", which references Appendix 3LL. In Appendix 3LL, "Model Properties and Seismic Analysis Results for ESWPT," Table 3LL-7, "ESWPT Segment 2 SASSI FE Model Component Peak Accelerations" (Page 3LL-11), the third note at the bottom of the table states that "For structural design using the loads and load combinations in Section 3.8, design accelerations are determined separately using a response spectra analysis of the Segment 2 ANSYS FE model using as input the enveloped accelerations shown above, and a dynamic soil pressure."

The applicant is requested to:

a. Provide details that show how the response spectra analysis mentioned in the above quoted paragraph was performed.

b. Show how the accelerations in the table are used as inputs.

c. Describe the locations of "a dynamic soil pressure" and discuss how it is used as input for the response spectra analysis.

ANSWER:

(a) For the seismic motion demand calculation of Segment 2, the response spectra analyses were performed in ANSYS using the site-specific 5% damped design response spectra. The design response spectra is the standard plant CSDRS (DCD Table 3.7.1-1 and 3.7.1-2) anchored to a 0.10 g peak ground acceleration, which envelopes the site-specific FIRS spectra and the in-structure response spectra calculated at the base slab in SASSI. Modal combination was performed in accordance with RG 1.92 Combination Method B. .

(b) For the seismic inertial demand calculation of Tunnel Segments 1 and 3, an equivalent static lateral load was applied based on the peak accelerations calculated in SASSI which are shown in FSAR Tables 3LL-6 and 3LL-8. The accelerations presented in the tables represent the maximum accelerations across the wall or slab for all soil cases considered in the SASSI analysis. These maximum accelerations were conservatively applied across the entire wall or slab for the design.

(c) For all tunnel segments, seismic soil pressure was applied as a static pressure in ANSYS. The pressures are not input to the response spectra analysis; however the effects of the seismic soil pressures and response spectra analysis are combined on an absolute basis. The seismic soil 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.

FSAR Section 3LL.2 has been revised to reflect this response.

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

See attached marked-up FSAR Revision 1 page 3LL-4.

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

None.

<u>Impact on DCD</u>

None.

<u>Attachments</u>

Marked-up FSAR Revision 1 Tables 3LL-6 and 3LL-8 previously submitted in the response to RAI No. 2879 (CP RAI #60) Question 03.07.02-12 attached to Luminant letter TXNB-09073 dated November 24, 2009 (ML093340447)

Table 3LL-6

ESWPT Segment 1 SASSI FE Model Component Peak Accelerations(1) (g)

Component	Transverse Direction	Longitudinal Direction	Vertical Direction
Base Slab	0.12	0.12	0.15
Roof Slab	0.24	0.14	0.19
Interior Walls	0.26	0.13	0.17
Exterior Walls	0.24	0.14	0.16

Notes:

1) For structural design using the loads and load combinations in Section 3.8, the seismic demands are calculated in ANSYS by applying these peak accelerations as statically equivalent loads across the entire component and combining with the demands calculated in ANSYS by applying an equivalent static seismic soil pressure.~~loads are obtained by applying to the ESWPT segment a statically equivalent uniform acceleration that envelopes the above accelerations and a dynamic soil pressure.~~ RCOL2_03.07.02-12

Table 3LL-8

ESWPT Segment 3 SASSI FE Model Component Peak Accelerations(4) (g)

Component	Transverse Direction	Longitudinal Direction	Vertical Direction
Base Slab	0.12(1)	0.12(1)	0.13(1)
Roof Slab	0.50(1)	0.16(1)	0.21(1)
Interior Walls	0.50(3)	0.19	0.20
Exterior Walls	0.50(3)	0.16	0.15
PSFSV Service Tunnel Walls	0.32(2)	0.38(2)	0.15
PSFSV Service Tunnel Roof	0.32(2)	0.38(2)	0.16

Notes:

1) The transverse direction for the base slab and roof is the north-south direction; the longitudinal direction is the east-west direction.
2) The transverse direction for the PSFSV service tunnel walls and roof is the east-west direction; the longitudinal direction is the north south direction.
3) For interior and exterior walls, the transverse direction is the out-of-plane direction.
4) For structural design using the loads and load combinations in Section 3.8, the seismic demands are calculated in ANSYS using the peak accelerations as statically equivalent loads and combining them with the demands calculated in ANSYS by applying an equivalent static seismic soil pressure.~~loads are obtained by applying to the ESWPT segment a statically equivalent uniform acceleration that envelopes the above accelerations, and a dynamic soil pressure.~~ RCOL2_03.07.02-12

analyses to verify that the responses are reasonably similar between these cases except for the expected trends due to soil frequency changes. RCOL2_03.07.02-16

Operating-basis earthquake (OBE) structural damping values of Chapter 3 Table 3.7.1-3(b), such as 4 percent damping for reinforced concrete, are used in the site-specific SASSI analysis. This is consistent with the requirements of Section 1.2 of RG 1.61 (Reference 3LL-4) for structures on sites with low seismic responses where the analyses consider a relatively narrow range of site-specific subgrade conditions. 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 the envelope of the soil conditions. The SASSI analysis results are used to produce the final response spectra and provide confirmation of the inputs to the ANSYS design model. RCOL2_03.07.02-11

ANSYS analyses are used to calculate the structural demands of the ESWPT to seismic soil pressure and seismic inertia which are then added to all other design loads discussed in Section 3.8.

The seismic inertia demand of segment 2 are calculated using ANSYS, response spectra analyses with the site specific 5% damped design response spectra. The design response spectra is based on the standard plant CSDRS anchored to a zero period acceleration of 0.10 g that is shown to envelope the site specific FIRS and the in-structure response spectra calculated at the base slab in SASSI. Modal combination is performed in accordance with RG 1.91 Combination Method B. Analysis of the ESWPT produced 40 modes below 50 Hz. Table 3LL-15 lists five major structural frequencies for each direction of motion organized by mass participation. RCOL2_03.08.04-44 RCOL2_03.07.02-16

The seismic inertia demand of segments 1 and 3 are calculated using an equivalent static lateral load based on the enveloped peak accelerations calculated in SASSI for all soil cases that are shown in Tables 3LL-6 and 3LL-8. RCOL2_03.07.02-11 RCOL2_03.08.04-34

The seismic soil pressure demands are calculated statically in ANSYS. The seismic soil pressure demands are applied on the structural elements as equivalent static pressures. The pressures applied are of larger magnitude compared to the calculated elastic solution used in ASCE 4-98 based on J.H. Wood, 1973 and the enveloped SASSI results. Soil above the tunnel is accounted for in two ways: (1) a shear force was applied at the interface of the tunnel roof and the soil above where the shear value is shown to be higher than that calculated in SASSI SSI analyses and (2) the density of the tunnel roof slab is increased in regions of the tunnel where a balanced soil condition does not exist. This second method accounts for an assumed load path of bringing the entire soil mass into the roof slab through shear. RCOL2_03.08.04-8

Demands calculated from the response spectra and soil pressure analyses performed in ANSYS for segment 2 are combined on an absolute basis to produce the maximum demands for each direction of motion and these directions RCOL2_03.07.02-11

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-45

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.1, "ESWPT", which references Appendix 3LL. In Appendix 3LL, "Model Properties and Seismic Analysis Results for ESWPT," Table 3LL-13, "Bearing Pressures Below ESWPT (ksf)" (Page 3LL-17).

The applicant is requested to provide the allowable soil bearing pressure in the table.

ANSWER:

The response to RAI No. 2999 (CP RAI #115) Question 03.08.05-5 attached to Luminant letter TXNB-09067 dated November 13, 2009 (ML093230704) provided a discussion of the allowable bearing pressures and a revision to FSAR Table 3.8-202 that added allowable bearing capacities and the capacity-to-demand ratios for bearing pressure for each of the seismic category I facilities. FSAR Table 3.8-202 is attached to this response.

FSAR Table 3LL-13 has been revised to provide allowable bearing pressures.

FSAR Table 3.8-202 has been revised in response to RAI No. 2999 (CP RAI #115) Question 03.08.05-5 attached to Luminant letter TXNB-09067 dated November 13, 2009 (ML093230704).

Impact on R-COLA

See attached marked-up FSAR Revision 1 page 3LL-20.

Impact on S-COLA

None.

Impact on DCD

None.

Attachment:

Marked-up FSAR Draft Revision 1 Table 3.8-202 included in the response to Question 03.08.05-5

CP COL 3.7(7)

Table 3.8-202

Summary of Bearing Pressures and Factor of Safety

RCOL2_03.08.05-5 CTS-00603

Building	Bearing Pressures (lb/ft^2)		Ultimate Bearing Capacity (lb/ft^2)	Available Factor of Safety (Based on Ultimate Bearing Capacity)		Allowable Bearing Capacity (lb/ft^2)		Ratio of Allowable Bearing Capacity to Bearing Pressure	
	Static Case	Seismic Case(1),(2)		Static Case	Seismic Case	Static Case	Seismic Case	Static Case	Seismic Case
R/B	11,300	18,900	146,000	~~12,900~~ 12.9	~~7,700~~7.7	48,700	73,000	4.3	3.9
T/B	5,900	7,400	146,000	~~24,700~~ 24.7	~~19,700~~19.7	48,700	73,000	8.3	9.9
A/B	6,600	10,800	146,000	~~22,100~~ 22.1	~~13,500~~13.5	48,700	73,000	7.4	6.8
PS/Bs	4,300	7,400	146,000	~~34,000~~34	~~19,700~~19.7	48,700	73,000	11.3	9.9
PSFSVs	2,900(3)	5,100(3)	146,000	~~50,300~~ 50.3	~~28,600~~28.6	48,700	73,000	16.8	14.3
UHSRS	4,500(4)	16,200(4)	146,000	~~32,400~~ 32.4	~~9,000~~9	48,700	73,000	10.8	4.5
ESWPT	3,600(5)	12,400(5)	146,000	~~40,600~~ 40.6	~~11,800~~11.8	48,700	73,000	13.5	5.9

CTS-00603

CTS-00603

Notes:

1) All seismic case bearing pressures are based on the site-specific FIRS with 0.1 g PGA as described in Subsection 3.7.1.
2) Seismic case bearing pressures shown above include static bearing pressures.
3) The pressure shown includes bearing pressure due to full fuel oil tanks.
4) The pressure shown includes bearing pressure due to full reservoirs.
5) The maximum bearing pressures occur underneath the portion of the ESWPT supporting the air intake missile shields adjacent to the UHSRS.

Table 3LL-13

Bearing Pressures Below ESWPT (ksf)

	Peak Single Element(1)	Peak Design(2)	Average Dynamic(3)	Allowable Bearing Capacity(4)	
				Static Case	Dynamic Case
Segment 1	4.4	4.4	2.1	48.7	73.0
Segment 2	16.6	8.8	2.2	48.7	73.0
Segment 3	17.5	5.7	2.5	48.7	73.0

RCOL2_03.0 8.04-45

Notes:

1) Peak single element pressure represents corner pressures on elements representing less than 1% of the slab area.
2) Peak design pressure is the edge envelope pressure excluding the corner peaks, to be used for design.
3) Average dynamic pressure is the average of peak values for every element below the base slab.
4) Allowable bearing capacities are taken from Table 3.8-202.

RCOL2_03.0 8.04-45

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-46

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.3, "PSFSVs", which references Appendix 3MM. In Appendix 3MM, "Model Properties and Seismic Analysis Results for PSFSVs," Section 3MM.1, "Introduction," the second paragraph (Page 3MM-1) states that "The SASSI model results including seismic soil pressures are used as input to the ANSYS models for performing the detailed structural design including loads and load combinations in accordance with the requirements of Section 3.8."

The applicant is requested to:

(a) Provide the detailed technical information that shows how the SASSI results, including seismic soil pressure, are used as input to the ANSYS models. Is the SASSI result at every node used as input?

(b) Provide descriptions for the ANSYS models. How many ANSYS models are there? Why use more than one model?

ANSWER:

(a) The seismic design loads applied in ANSYS included seismic inertial loads applied as equivalent static accelerations and seismic soil pressures applied as equivalent static soil pressures. The SASSI analysis produced peak nodal accelerations. These nodal accelerations were enveloped for each component (exterior wall, interior wall, base slab, roof slab) and this peak enveloped acceleration for each component was applied as the equivalent static acceleration (Table 3MM-5). The equivalent lateral soil pressure applied to the PSFSV was calculated based on the elastic solution (Wood method). Peak soil pressure calculated in SASSI was used to confirm that the soil pressure applied to the design model was conservative. Further explanation of how SASSI results are used as input to ANSYS is provided in the response to RAI No. 2879 (CP RAI #60) Question 03.07.02-11 attached to Luminant letter TXNB-09073 dated November 24, 2009.

(b) A single ANSYS model is used for seismic force calculations and is similar to the SASSI model except that it has a finer mesh. The ANSYS model consists of plate elements representing the walls and slabs, and stiff beams and masses representing the fuel tanks and the mass of the fuel contained within. The model was analyzed for two conditions: (1) including the concrete roof to account for behavior in service under various loadings including seismic loading, and (2) excluding the concrete roof to account for earth load where the backfill has been installed but the roof has not yet been cast because access is required to install the fuel tanks. FSAR Section 3MM.2 has been revised to remove the reference to multiple ANSYS models.

Impact on R-COLA

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

Impact on S-COLA

None.

Impact on DCD

None.

Transfer functions are examined for each analysis to verify that the interpolation was reasonable and that the expected structural responses are observed. Transfer functions, spectra, accelerations, and soil pressures are compared between the various soil profiles used in analyses to verify that the responses were reasonably similar between these cases except for the expected trends due to soil frequency changes. RCOL2_03.07.02-16

Operating-basis earthquake (OBE) structural damping values of Chapter 3 Table 3.7.1-3(b), such as 4 percent damping for reinforced concrete, are used in the site-specific SASSI analysis. This is consistent with the requirements of Section 1.2 of RG 1.61 (Reference 3MM-4) for structures on sites with low seismic responses where the analyses consider a relatively narrow range of site-specific subgrade conditions.

The SASSI analyses produce results including peak accelerations, in-structure response spectra, and seismic soil pressures. All results from SSI analyses represent the envelope of the nine soil conditions. The SASSI analysis results are used to produce the final response spectra and provide confirmation of the ANSYS design input and output demands. RCOL2_03.07.02-11

ANSYS analyses are used to calculate the structural demands of the PSFSV to seismic soil pressure and seismic inertia which are then added to the effects of all other design loads discussed in Section 3.8.4.3. Seismic inertia is analyzed in ANSYS by applying equivalent static lateral loads. The equivalent static lateral loads applied are based on the enveloped peak accelerations calculated in SASSI (provided in Table 3MM-5 and discussed in the following section). For reference, the modal properties of the ANSYS design model are provided in Table 3MM-9. RCOL2_03.08.04-46

The seismic soil pressure is analyzed statically in ANSYS. The seismic soil pressure demands are applied on the structural elements as equivalent static pressures. The pressures applied are shown to be conservative when compared to the calculated elastic solution used in ASCE 4-98 based on J.H. Wood, 1973 and the enveloped SASSI results.

Demands from the equivalent static accelerations and soil pressure analyses performed in ANSYS are combined on an absolute basis to produce the maximum demand in each direction.

3MM.3 Seismic Analysis Results

Table 3MM-4 presents a summary of SSI effects on the seismic response of the PSFSV. The maximum absolute nodal accelerations obtained from the ~~time-history~~SASSI analyses of the PSFSV models are presented in Table 3MM-5. The results are presented for each of the major PSFSV components and envelope all site conditions described above. The maximum accelerations have been obtained by combining cross-directional contributions in accordance with RG 1.92 (Reference 3MM-5) using the square root sum of the squares (SRSS) method. RCOL2_03.07.02-11

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-47

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.3, "PSFSVs", which references Appendix 3MM. In Appendix 3MM, "Model Properties and Seismic Analysis Results for power source fuel storage vaults (PSFSVs)," Section 3MM.2, "Model Description and Analysis Approach," the second paragraph (Page 3MM-1) states that "Shell elements are used for the roof, interior and exterior walls, brick elements are used for the base mat, and beam elements are used to represent the emergency power fuel oil tanks and their supports, which are connected to the basemat."

Provide the technical justification for using beam elements to model the fuel oil tank and their supports. Is the case of the tanks not filled with fuel oil included in the analyses? If yes, provide a description how it is modeled. If not, provide the rationale for not considering this case.

ANSWER:

The fuel oil tanks and their supports are considered to be rigid; therefore, the beam elements were included only to represent the fuel oil tank mass at its center of gravity.

Only the case of the fuel oil tanks completely full is included in the analysis. Varying levels of fuel oil in the fuel oil storage tanks were not considered because:

- The power source fuel storage vaults are supposed to be kept full prior to an emergency or other critical event such as an SSE. Therefore, full tanks is the normal operating fuel level for the tanks.
- The SSI analyses performed in SASSI demonstrated that the design input response spectra at the top of limestone and the in-structure spectra at the top of the base slab are nearly the same indicating that the SSI effects are not large. The SSI analyses were used to determine maximum accelerations for a range of soil conditions representing the uncertainty in soil

properties.

- Since the tanks are assumed rigid, the tank seismic inertial forces applied to the base slab were obtained by equivalent static analysis using lateral seismic accelerations of 0.25g, which is more than twice the PSFSV base slab ZPA acceleration of 0.12g. The design acceleration was increased from the base slab ZPA acceleration in order to estimate the potential increase in demands due to hydrodynamic effects. For the global design of the PSFSV, a lower mass in the tank (including sloshing effects) is expected to result in lower design forces. Therefore, a fuel oil level less than full was not considered.

For the detailed design, the steel tank properties will be specified and seismic behavior including hydrodynamic effects will be performed to design tank supports, tank support attachment to the slab, and local reinforcement in the tank slab.

FSAR Section 3MM.2 has been revised to incorporate this response.

Impact on R-COLA

See attached marked-up FSAR Revision 1 page 3MM-2.

Impact on S-COLA

None.

Impact on DCD

None.

Shell elements are used for the roof, interior and exterior walls, brick elements are used for the base mat, and stiff beam elements are used to represent the emergency power fuel oil tanks and their supports, which are connected to the basemat. The three tanks are considered to be rigid, and full with a total weight of 1155 kips each, which corresponds to the normal operating fuel level. The steel tank mass and stiffness properties, and seismic behavior including hydrodynamic effects, will be accounted for in the design of tank supports, tank support attachments to the slab, and local reinforcement in the tank slab. Walls are modeled using gross section properties at the centerline. The tapered east wall of the vault is modeled at the centerline of the top portion of the wall. The change in thickness is modeled using the average thickness of the wall at each element layer. RCOL2_03.08.04-4 RCOL2_03.08.04-4 RCOL2_03.08.04-47 RCOL2_03.07.02-16

The materials and properties of the roof slab are changed to reflect the cracked concrete properties for out of plane bending. The cracked concrete properties are modeled for one-half of the uncracked flexural stiffness of the roof. Un-cracked properties are considered for the in-plane stiffness ~~and the mass of the roof~~ (Reference 3MM-3). Therefore, to achieve 1/2 flexural out-of-plane stiffness of the slab without reducing its in-plane stiffness or mass, the following element properties are assigned: RCOL2_03.07.02-16 RCOL2_03.07.02-16

$$t_{cracked} = (C_F)^{0.5} \cdot t$$

$$E_{cracked} = [1/(C_F)^{0.5}] \cdot E_{concrete}$$

$$\gamma_{cracked} = [1/(C_F)^{0.5}] \cdot \gamma_{concrete}$$

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.

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-48

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.3, "PSFSVs", which references Appendix 3MM. In Appendix 3MM, "Model Properties and Seismic Analysis Results for PSFSVs," Section 3MM.2, "Model Description and Analysis Approach," the second paragraph on Page 3MM-3 states that, "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 potential for separation of backfill is determined using an iterative approach that compares the peak envelope soil pressure results to the at-rest soil pressure."

The applicant is requested to:

(a) Provide justification for using a factor of 10 to reduce the shear wave velocity for those layers of backfill that are to be separated.

(b) Provide a detailed description for the iterative approach used while running the SASSI program. If the shear wave velocity of a layer is reduced by 10, would that layer stay with the reduced shear wave velocity, or would it go back to the original shear wave velocity once the dynamic soil pressure is less than the at-rest soil pressure?

ANSWER:

(a) The reduction of properties was only performed on backfill elements modeled directly adjacent to the structure in the region of soil separation. The factor of 10 on shear wave velocity represents a factor of 100 on soil shear modulus and Young's modulus. This value was 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 as compared to pressure at elevations where separation was not modeled (see the figure included with the response to Question 03.08.04-28 above).

(b) The SSI peak soil pressures calculated in the SASSI best-estimate, non-separated case was compared to the at-rest calculated soil pressures. The SSI model is modified to model the soil separation for layers calculated to separate. The approach was not iterative and the best-estimate case was considered to be representative of the amount of soil separation for all soil cases. The SSI peak soil pressures calculated in SASSI were compared to the at-rest calculated soil pressures. The SSI model is modified using a reduced shear wave velocity in all soil elements adjacent to the structure within the separation depth to model the soil separation. SASSI is a linear analysis program that cannot update material properties (such as shear wave velocity) based on the time varying response (nonlinear behavior). Therefore, the shear wave velocity reduction is applicable for the entire dynamic analysis.

Results are enveloped for the non-separated and separated soil cases, bounding the potential peak response.

FSAR Section 3MM.2 has been revised to incorporate this response.

Impact on R-COLA

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

Impact on S-COLA

None.

Impact on DCD

None.

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 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 RCOL2_03.07.02-11 RCOL2_03.08.04-48 RCOL2_03.07.02-11

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

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QUESTION NO.: 03.08.04-49

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.3, "PSFSVs", which references Appendix 3MM. In Appendix 3MM, "Model Properties and Seismic Analysis Results for PSFSVs," Section 3MM.3, "Seismic Analysis Results," the second paragraph (Page 3MM-3) states that "The total adjusted wall shear forces used for design are presented in Figure 3MM-2."

The applicant is requested to explain why these shear forces presented in Figure 3MM-2 are not symmetric? Seismic may come in any direction. Provide a rationale for not using symmetric forces in the design.

ANSWER:

FSAR Figure 3.8-201 shows the general layout of the east and west PSFSVs. FSAR Figure 3MM-2 shows seismic shear forces for the west PSFSV. The forces presented in the figure are not symmetric because the soil and structure system is not symmetric. Soil exists only on two sides of the west PSFSV (south and west sides of the west PSFSV) with seismic isolation joints existing on the other two sides to separate the PSFSV from adjacent structures. The north side and east side of the west PSFSV are each separated by an isolation joint and therefore are not connected to the free field soil. The west wall of the west PSFSV is tapered from 2.5 ft to 4.5 ft at the base to allow the structure to resist the soil load on this long span wall. All other exterior walls are 2.5 ft thick and all interior walls are 1.5 ft thick and therefore lighter. The north wall contains openings, reducing its total mass relative to the south wall. This causes the non-symmetrical load distribution shown in FSAR Figure 3MM-2 for the west PSFSV.

FSAR Section 3MM.3 and Figure 3MM-2 have been revised to incorporate this response.

Impact on R-COLA

See attached marked-up FSAR Revision 1 pages 3MM-6 and 3MM-19.

Impact on S-COLA

None.

Impact on DCD

None.

The seismic design forces and moments based on the ANSYS analysis are presented in Table 3MM-6. The force and moment values represent the enveloped seismic results for all site conditions considered in the analysis. These results are calculated from ANSYS design model subjected to the enveloped of accelerations and dynamic lateral soil pressure from all calculated SASSI analyses. Accidental torsion is accounted by increasing the wall shears given in Table 3MM-6. The walls seismic base shear was increased to account for accidental torsion and total seismic base shear to be resisted by in plane shear of walls. The total adjusted wall shear forces used for design are presented in Figure 3MM-2. The forces presented in the figure are not symmetrical due to model non-symmetry including the sizes of the exterior walls and openings in the north wall. For structural design of members and components, the design seismic forces due to three different components of the earthquake are combined using the Newmark 100% - 40% – 40% method. RCOL2_03.07.02-11 RCOL2_03.08.04-49

The PSFSV displacements due to seismic loading are less than 0.07 inch. Table 3MM-7 summarizes the resulting maximum displacements for enveloped seismic loading conditions.

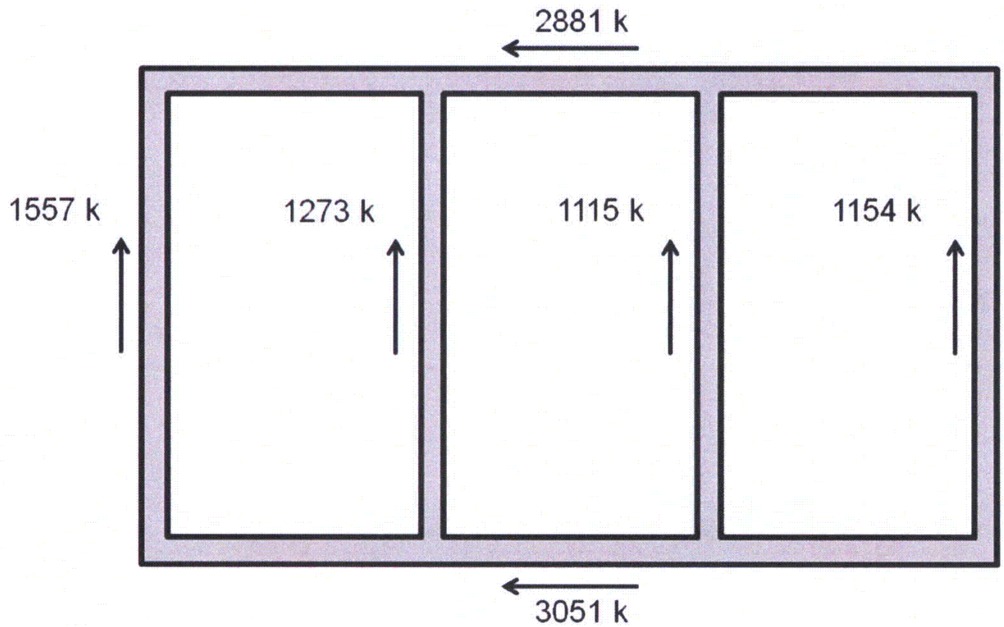
3MM.4 In-Structure Response Spectra (ISRS)

The enveloped broadened ISRS calculated in SASSI are presented in Figure 3MM-3 for the PSFSV base slab and roof for each of the three orthogonal directions (east-west, north-south, vertical) for 0.5 percent, 2 percent, 3 percent, 4 percent, 5 percent, 7 percent, 10 percent and 20 percent damping. The ISRS for each orthogonal direction are resultant spectra which have been combined using SRSS to account for cross-directional coupling effects in accordance with RG 1.122 (Reference 3MM-6). The ISRS include the envelope of the 11 site conditions (BE, LB, UB, and HB with and without backfill separation from the structure, and the no-fill surface foundation condition with BE, LB, and UB subgrade conditions). All results have been broadened by 15 percent and all valleys removed. The spectra ~~can be~~are used for the design of seismic category I and II subsystems and components housed within or mounted to the PSFSV. ~~It is permitted to perform 15 percent peak clipping of the spectra for damping values below 10 percent in accordance with ASCE 4 (Reference 3MM-3).~~ For the design of seismic category I and II subsystems and components mounted to the PSFSV walls and slabs, it is required to account for the effects of out-of-plane wall flexibility, including seismic anchor motions. RCOL2_03.07.02-11 RCOL2_03.08.04-50 RCOL2_03.07.02-15 RCOL2_03.08.04-33

3MM.5 References

3MM-1 *An Advanced Computational Software for 3D Dynamic Analysis Including Soil Structure Interaction,* ACS SASSI Version 2.2, Ghiocel Predictive Technologies, Inc., July 23, 2007.

3MM-2 ANSYS Release 11.0, SAS IP, Inc. 2007.



Notes:

1) The seismic shear forces shown above are computed for the west vault at the bottom of each wall at the interface with the foundation mat and account for accidental eccentricity and total seismic base shear to be resisted by in plane shear of walls. East vault shear forces are symmetrical about the north-south axis. RCOL2_03.08.04-49 RCOL2_03.08.04-49

Figure 3MM-2 Maximum Seismic Base Shear Forces in Wall

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-50

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsection 3.8.4.4.3.3, "PSFSVs", which references Appendix 3MM. In Appendix 3MM, "Model Properties and Seismic Analysis Results for PSFSVs," Section 3MM.4, "In-Structure Response Spectra (ISRS)," the paragraph (Page 3MM-4) states that "The spectra can be used for the design of seismic category I and II subsystems and components housed within or mounted to the PSFSV."

The applicant is requested to address the issue: Are the emergency power fuel oil tanks and their supports designed by making use of these ISRS? Where is this design presented?

ANSWER:

The fuel oil tanks and their supports are designed during the detailed design effort and will be available for NRC review when completed. The design will be based on the ISRS for the base slabs as shown in Figure 3MM-3, Sheets 1 through 3. FSAR Section 3MM.4 has been updated to clarify the basis of the seismic designs.

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

See attached marked-up FSAR Revision 1 page 3MM-6.

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

None.

<u>Impact on DCD</u>

None.

The seismic design forces and moments based on the ANSYS analysis are presented in Table 3MM-6. The force and moment values represent the enveloped seismic results for all site conditions considered in the analysis. These results are calculated from ANSYS design model subjected to the enveloped of accelerations and dynamic lateral soil pressure from all calculated SASSI analyses. Accidental torsion is accounted by increasing the wall shears given in Table 3MM-6. The walls seismic base shear was increased to account for accidental torsion and total seismic base shear to be resisted by in plane shear of walls. The total adjusted wall shear forces used for design are presented in Figure 3MM-2. The forces presented in the figure are not symmetrical due to model non-symmetry including the sizes of the exterior walls and openings in the north wall. For structural design of members and components, the design seismic forces due to three different components of the earthquake are combined using the Newmark 100% - 40% – 40% method. RCOL2_03.07.02-11 RCOL2_03.08.04-49

The PSFSV displacements due to seismic loading are less than 0.07 inch. Table 3MM-7 summarizes the resulting maximum displacements for enveloped seismic loading conditions.

3MM.4 In-Structure Response Spectra (ISRS)

The enveloped broadened ISRS calculated in SASSI are presented in Figure 3MM-3 for the PSFSV base slab and roof for each of the three orthogonal directions (east-west, north-south, vertical) for 0.5 percent, 2 percent, 3 percent, 4 percent, 5 percent, 7 percent, 10 percent and 20 percent damping. The ISRS for each orthogonal direction are resultant spectra which have been combined using SRSS to account for cross-directional coupling effects in accordance with RG 1.122 (Reference 3MM-6). The ISRS include the envelope of the 11 site conditions (BE, LB, UB, and HB with and without backfill separation from the structure, and the no-fill surface foundation condition with BE, LB, and UB subgrade conditions). All results have been broadened by 15 percent and all valleys removed. The spectra ~~can be~~are used for the design of seismic category I and II subsystems and components housed within or mounted to the PSFSV. ~~It is permitted to perform 15 percent peak clipping of the spectra for damping values below 10 percent in accordance with ASCE 4 (Reference 3MM 3).~~ For the design of seismic category I and II subsystems and components mounted to the PSFSV walls and slabs, it is required to account for the effects of out-of-plane wall flexibility, including seismic anchor motions. RCOL2_03.07.02-11 RCOL2_03.08.04-50 RCOL2_03.07.02-15 RCOL2_03.08.04-33

3MM.5 References

3MM-1 *An Advanced Computational Software for 3D Dynamic Analysis Including Soil Structure Interaction,* ACS SASSI Version 2.2, Ghiocel Predictive Technologies, Inc., July 23, 2007.

3MM-2 ANSYS Release 11.0, SAS IP, Inc. 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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-51

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsections 3.8.4.4.3.1, "ESWPT", 3.8.4.4.3.2, "UHSRS", and 3.8.4.4.3.3, "PSFSVs", which reference Appendices 3LL, 3KK, and 3MM, respectively. Each of these appendices reference Appendix 3NN, "Model Properties and Seismic Analysis Results R/B-PCCV-Containment Internal Structure".

In Appendix 3NN, Section 3NN.2 (Page 3NN-1), the 1st paragraph states "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 limestone to level the surface below the building basemat established at nominal elevation of 783 ft.-2 in. Fill concrete will be also placed below the surface mat located at the north-east corner of the FH/A [fuel handling area] under the central portion of the mat underneath the PCCV. The foundation will be backfilled with a 40 ft. thick layer of engineered fill material to establish the nominal elevation of the plant ground surface at 822 ft."

The applicant is requested to address the following issues:

(a) The 3rd sentence in the above quote is not clear. It is not clear where the fill concrete is placed. (Is there an "and" missing between "the FH/A" and "under the central portion of the mat under the PCCV"?) For example, information given in the US-APWR DCD shows that the bottom of the common basemat below the R/B PCCV and containment internal structure (CIS) is not at one elevation or level. Rather, it varies, as for example, below the FH/A. It also varies below the PCCV, wherein the bottom of the central circular portion of the basemat below the PCCV is at a much higher elevation than the bottom of the concrete slabs under the prestressing tendon gallery. Is fill concrete also placed under this central region of the basemat under the PCCV? The staff suggests that a figure be included in the CPNPP COL FSAR that clearly indicates the extent of the concrete fill, both in plan view and in cross section.

(b) The quoted paragraph suggests that the intent of the CPNPP design is to have a concrete fill below the central region of the basemat under the PCCV. Describe the design of this fill, including how and when it is placed between the tendon gallery foundation slab, and how it joins with the structural concrete of the tendon gallery. This description should also address any special precautions to be taken when placing thick sections of concrete.

(c) If there is fill concrete below the PCCV slab, describe how the design of the concrete common basemat under the R/B, PCCV, and containment internal structures is treated in the region where the ASME Code governs the design (i.e., under the PCCV). Describe the design of the basemat at the juncture between regions designed to the requirements of the ASME Code and regions governed by the ACI-349 code.

(d) Does this concrete fill have any steel reinforcement?

ANSWER:

(a) The thrid sentence in the above quote from FSAR Section 3NN.2 has been revised to place an "and" between "the FH/A" and "under the central portion of the mat under the PCCV". Fill concrete is placed under the elevated portion of the basemat in the fuel handling area, and fill concrete is also placed in the central circular portion of the basemat below the PCCV. With respect to the vertical extent of concrete fill, FSAR Subsection 3.7.1.3 states,

> For CPNPP Units 3 and 4, all seismic category I and II buildings and structures, including the R/B-PCCV-containment internal structure on a common mat, the PS/Bs, UHSRS, ESWPT, PSFSVs, A/B, and T/B, are founded directly on solid limestone or on fill concrete which extends from the foundation bottom to the top of solid limestone at nominal elevation 782'.

Fill concrete will also be used as "dental" fill in any areas where additional removal of materials below the nominal top of limestone is required in order to reach competent limestone. With respect to horizontal extent, concrete fill matches the footprint of the foundation, except that the fill may extend beyond the foundation edges to facilitate construction and placement of forms. FSAR Subsection 3.7.1.3 has been revised to add these clarifications. DCD Subsection 3.8.4.1, which is incorporated by reference in the FSAR, states that there shall be no isolation joint in the concrete fill at the interface with other buildings.

As part of the design certification process for the US-APWR standard plant, MHI intends to thicken the reinforced concrete of the PCCV basemat in this region such that the entire R/B-PCCV-containment internal structure basemat is at one elevation. After that change is implemented, the thickness of fill concrete underneath the FH/A and the central circular portion of the basemat will not vary due to changes in the foundation thickness.

(b) MHI intends to thicken PCCV basemat by replacing the fill concrete with the reinforced concrete as described in (a) above. Un-reinforced fill concrete will be used under the foundation mat where required as a thin leveling layer between top of competent limestone and bottom of foundation. Special precautions to be considered when placing thick sections of concrete are included in the construction specifications which will be available for NRC review when completed. These specifications are expected to include precautions as discussed below:

The thermal behavior of the basemat concrete pour is the most important characteristic that differentiates it from other concrete pours. Significant temperature differential between the interior and outside surface of the basemat could result due to heat of hydration caused by large concrete pours. When the temperature differential across the gradient is excessive, potential of cracking becomes a concern.

Standard provisions of ACI are anticipated to be applied where necessary to address issues related to the use of massive concrete pours. The following provisions will be needed for mass concrete pour of basemats to control heat generation, volume change effects and concrete cracking control:

(1) Use of low heat cement. For mass concrete, specify (a) ASTM C150 Type II cement with moderate heat of hydration and (b) Fly Ash (ASTM C618, Type F) up to 25% of cement content by weight. ASTM C150 Type II cement is specified in the DCD and incorporated by reference in the FSAR.

The temperature rise can be minimized by the use of minimal cement contents in the mixture, partial substitution of pozzolans for cement, and use of special type of cement with lower or delayed heat of hydration.

(2) Minimize change in the volume to the extent feasible. As reported in Section 1.3 of ACI 207.2R-07, the change in volume can be minimized by such measures as reducing cement content, replacing part of the cement with pozzolans, precooling, postcooling, insulating to control the rate of heat absorbed or lost, and by other temperature control measures outlined in ACI 207.4R-05. These measures will be considered in developing the site-specific concrete mix designs.

(3) Use approaches for crack control as prescribed in Section 1.3 of ACI 207.2R-07 and Section 7.2 of ACI 224R-01. Mitigate concrete cracking by effective placement of reinforcement per provisions of ACI 349-01. This method is included in the standard plant design of the common basemat.

This approach can eliminate large cracks and replaces with many smaller cracks of acceptably smaller widths. However, this is achieved in the normal design practice since crack control is important for other issues such as leakage and corrosion.

Appropriate construction procedures can be used to meet the above provisions. The following are construction techniques commonly employed, either singularly or in combination, to mitigate the problems associated with massive concrete pours for basemats:

1. Limiting the size of concrete pour.

2. Use a "checkerboard" pattern of concrete placement in a single lift. To avoid a weak horizontal shear plane, a double lift placement of concrete, in general, is avoided. However, when it is absolutely needed to have two lifts, there will be adequate design considerations and also, in general, shear stirrups will be provided.

3. Schedule pour for the most advantageous day and time to control temperature rise in the concrete.

4. Post-cooling can be performed by cooling the freshly placed concrete by running chilled water lines in the concrete.

(c) Fill concrete is below the PCCV slab as explained in the response in (a) above. For purposes of seismic soil-structure interaction analysis, the fill concrete is included in the foundation model. However, the fill concrete is not subject to the requirements of the ASME Code. The fill concrete will conform to pertinent requirements of ACI-349 such as durability.

(d) Fill concrete used at CPNPP Units 3 and 4 is generally designed as un-reinforced concrete, except at locations such as underneath the ESWPT, adjacent to the UHSRS, where the fill concrete extends into the limestone with a shear key and is locally reinforced (shown in FSAR Figure 3.8-202). There may also be miscellaneous reinforcing installed in the fill concrete during construction, particularly at construction joints within the fill, to aid in forming and placement.

References

Report on Thermal and Volume Change Effects on Cracking of Mass Concrete. ACI-207.2R, American Concrete Institute, 2007.

Cooling and Insulating Systems for Mass Concrete. ACI-207.4R, American Concrete Institute, 2005.

Control of Cracking in Concrete Structures. ACI-224R, American Concrete Institute, 2001.

Impact on R-COLA

See attached marked-up FSAR Revision 1 pages 3.7-6 and 3NN-2.

Impact on S-COLA

None.

Impact on DCD

None.

3.7.1.3 Supporting Media for Seismic Category I Structures

CP COL 3.7(28) Replace the second sentence of the first paragraph in DCD Subsection 3.7.1.3 with the following.

The overall basemat dimensions, basemat embedment depths, and maximum height of ~~major~~ seismic category I buildings and structures are given in Table 3.7.1-3R. CTS-00922

CP COL 3.7(7) Replace the last two sentences of the second paragraph in DCD Subsection 3.7.1.3 with the following.

For CPNPP Units 3 and 4, all ~~major~~ seismic category I and II buildings and structures, including the R/B-PCCV-containment internal structure on a common mat, the PS/Bs, UHSRS, ESWPT, PSFSVs, A/B, and T/B, are founded directly on solid limestone or on fill concrete which extends from the foundation bottom to the top of solid limestone at nominal elevation 782'. The fill concrete conforms to pertinent requirements of ACI-349 such as durability. Fill concrete is used as "dental" fill in any areas where additional removal of materials below the nominal top of limestone is required in order to reach competent limestone. With respect to horizontal extent, concrete fill matches the footprint of the foundation, except that the fill is permitted to extend beyond the foundation edges slightly to facilitate construction and placement of forms. The material properties of the limestone are presented in Table 3.7-203. The underlying stratigraphy is discussed further in ~~Chapter 2~~Subsection 2.5.4. CTS-00922 RCOL2_03.08.04-51 CTS-00922

The fill concrete has a design compressive strength of 3,000 psi that corresponds to a shear wave velocity of 6,400 ft/sec. To further assure that the site-specific effects of the fill concrete are captured, where applicable, the fill concrete is considered as part of the structure in the site-specific SASSI (Reference 3.7-17) models used to perform the site-specific SSI analyses of the R/B-PCCV-containment internal structure, UHSRS, ESWPT, and PSFSVs.

The maximum bearing loads and available factors of safety for all ~~major~~seismic category I and II buildings and structures are presented in Table 3.8-202. Table 3.8-202 demonstrates that the minimum factor of safety for ultimate bearing capacity versus maximum bearing load (static + dynamic/seismic) is at least 2 for the R/B-PCCV-containment internal structure, PS/Bs, UHSRS, ESWPT, PSFSVs, A/B, and T/B, based on site-specific subgrade conditions and the site-specific FIRS ground input motion with a PGA of 0.1 g. CTS-00922

3.7.2.1 Seismic Analysis Methods

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limestone to level the surface below the building basemat established at nominal elevation of 783 ft.-2 in. Fill concrete will be also placed below the surface mat located at the north-east corner of the FH/A and under the central portion of the mat underneath the PCCV. The foundation will be backfilled with a 40 ft. thick layer of engineered fill material to establish the nominal elevation of the plant ground surface at 822 ft. RCOL2_03.08.04-51

Besides the best estimate (BE) values, the site-specific analyses address the variation of the subgrade properties by considering lower bound (LB) and upper bound (UB) properties. The LB and UB properties represent a coefficient of variation (COV) on the subgrade shear modulus of ~~0.65~~0.69~~, the value of variation that was also used in Chapter 2 for development of ground motion response spectra (GMRS)~~. The typical properties for a granular engineered backfill are adopted as the BE values for the dynamic properties of the backfill. Four profiles, LB, BE, 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. The profiles address the possibility of stiffer backfill, and the project specifications limit the minimum shear wave velocity of the backfill material to 600 ft/s for 0 to 3 ft. depth, 720 ft/s for 3 to 20 ft. depth, and 900 ft/s for 20 to 40 ft. depth. Table 3NN-1 presents the COV on shear modulus used for development of different soil profiles. RCOL2_03.07.02-5

The engineered backfill is not placed underneath the R/B-PPCV-Containment Internal Structure common basemat (or underneath any other seismic Category I or II structure foundations), and therefore is not used as "dental" fill. Further, the engineered backfill is not relied upon for lateral support of the building structure. Therefore, it is anticipated that shear wave velocity testing for verification of the above-cited limits will not utilize a test fill prior to placement of the backfill. Resonant column torsional shear testing (RCTS) is not required, and shear wave velocity testing during construction is also not required. Instead, testing requirements for backfill include routine pre-construction (pre-installation) mechanical and index testing to perform traditional quality control testing on physical characteristics (such as grain size, compaction, moisture content, lift thickness, etc), and in-situ shear wave velocity testing performed post construction. Subsection 2.5.4.5.4 discusses further backfill material and applicable quality control measures. RCOL2_03.08.04-52

Due to the small intensity of the seismic motion and the high stiffness of the rock, the SSI analyses use rock subgrade input properties derived directly from the measured low-strain values, i.e., the dynamic properties of the rock subgrade are considered strain-independent (Refer to FSAR ~~Chapter 2~~Subsection 2.5.2.5.2.1 for further discussion). The SSI analyses use input stiffness and damping properties of the backfill that are compatible to the strains generated by the design input motion. The strain-compatible backfill properties are obtained from site response analyses of the four backfill profiles using two horizontal acceleration RCOL2_03.07.02-5

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-52

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsections 3.8.4.4.3.1, "ESWPT", 3.8.4.4.3.2, "UHSRS", and 3.8.4.4.3.3, "PSFSVs", which reference Appendices 3LL, 3KK, and 3MM, respectively. Each of these appendices reference Appendix 3NN, "Model Properties and Seismic Analysis Results R/B-PCCV-Containment Internal Structure".

In Appendix 3NN, Section 3NN.2, "Seismological and Geotechnical Considerations," the second paragraph (Page 3NN-2) states, in part, that "The profiles address the possibility of stiffer backfill, and the project specifications limit the minimum shear wave velocity of the backfill material to 600 ft/s for 0 to 3 ft. depth, 720 ft/s for 3 to 20 ft. depth, and 900 ft/s for 20 to 40 ft. depth. Table 3NN-1 presents the COV on shear modulus used for development of different soil profiles."

The applicant is requested to address the following issues:

(a) Explain how the project specification limit (i.e., the minimum shear wave velocity of the backfill material to be 600 ft/s for 0 to 3 ft. depth, 720 ft/s for 3 to 20 ft. depth, and 900 ft/s for 20 to 40 ft. depth) is enforced during the construction.

(b) Correct typo in the third column heading of Table 3NN-1. The abbreviation for Upper Bound should be UB not LB.

ANSWER:

(a) The project specification limits on shear wave velocity are enforced using project specification requirements for verification testing. The project specifications are not complete at this time. The specifications are developed and approved as needed to support construction and will be available on site for NRC review when complete. As discussed in FSAR Subsection 3.7.2.4.1, the engineered backfill at CPNPP is not placed underneath category I or II foundations. The engineered backfill is therefore not used as "dental" fill. Further, the engineered backfill at CPNPP is not relied upon for lateral support of the building structure. Therefore, it is anticipated that shear wave velocity testing of the backfill will not utilize a test fill prior to placement of the backfill. Also resonant column torsional shear testing (RCTS) is not required, and shear wave velocity testing during construction is not required. Instead, testing requirements for backfill will include routine pre-construction (pre-installation) mechanical and index testing to perform traditional quality control testing on physical characteristics (such as grain size, compaction, moisture content, lift thickness, etc), and in-situ shear wave velocity testing performed post-construction. Backfill material and applicable quality control measures are discussed further in FSAR Subsection 2.5.4.5.4. Testing methods considered will include but not be limited to those discussed in the NEI white paper "Verification of Category I Structural Backfill". Potential in-situ shear wave velocity test methods, include downhole geophysical surveys, seismic cone penetrometer soundings, and/or spectral analysis of surface waves.

FSAR Section 3NN.2 has been revised to reflect this response. Portions of the discussion on backfill testing above are incorporated into the FSAR in the response to RAI No. 2994 (CP RAI #108) Question 03.08.04-5 via Luminant Letter TXNB-09078 dated December 10, 2009.

(b) The typographical error in the third column of FSAR Table 3NN-1 has been revised to correct abbreviation of Upper Bound to UB.

Impact on R-COLA

See attached marked-up FSAR Revision 1 pages 3NN-2 and 3NN-10.

Impact on S-COLA

None.

Impact on DCD

None.

limestone to level the surface below the building basemat established at nominal elevation of 783 ft.-2 in. Fill concrete will be also placed below the surface mat located at the north-east corner of the FH/A and under the central portion of the mat underneath the PCCV. The foundation will be backfilled with a 40 ft. thick layer of engineered fill material to establish the nominal elevation of the plant ground surface at 822 ft. RCOL2_03.08.04-51

Besides the best estimate (BE) values, the site-specific analyses address the variation of the subgrade properties by considering lower bound (LB) and upper bound (UB) properties. The LB and UB properties represent a coefficient of variation (COV) on the subgrade shear modulus of ~~0.65~~0.69~~, the value of variation that was also used in Chapter 2 for development of ground motion response spectra (GMRS)~~. The typical properties for a granular engineered backfill are adopted as the BE values for the dynamic properties of the backfill. Four profiles, LB, BE, 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. The profiles address the possibility of stiffer backfill, and the project specifications limit the minimum shear wave velocity of the backfill material to 600 ft/s for 0 to 3 ft. depth, 720 ft/s for 3 to 20 ft. depth, and 900 ft/s for 20 to 40 ft. depth. Table 3NN-1 presents the COV on shear modulus used for development of different soil profiles. RCOL2_03.07.02-5

The engineered backfill is not placed underneath the R/B-PPCV-Containment Internal Structure common basemat (or underneath any other seismic Category I or II structure foundations), and therefore is not used as "dental" fill. Further, the engineered backfill is not relied upon for lateral support of the building structure. Therefore, it is anticipated that shear wave velocity testing for verification of the above-cited limits will not utilize a test fill prior to placement of the backfill. Resonant column torsional shear testing (RCTS) is not required, and shear wave velocity testing during construction is also not required. Instead, testing requirements for backfill include routine pre-construction (pre-installation) mechanical and index testing to perform traditional quality control testing on physical characteristics (such as grain size, compaction, moisture content, lift thickness, etc), and in-situ shear wave velocity testing performed post construction. Subsection 2.5.4.5.4 discusses further backfill material and applicable quality control measures. RCOL2_03.08.04-52

Due to the small intensity of the seismic motion and the high stiffness of the rock, the SSI analyses use rock subgrade input properties derived directly from the measured low-strain values, i.e., the dynamic properties of the rock subgrade are considered strain-independent (Refer to FSAR ~~Chapter 2~~Subsection 2.5.2.5.2.1 for further discussion). The SSI analyses use input stiffness and damping properties of the backfill that are compatible to the strains generated by the design input motion. The strain-compatible backfill properties are obtained from site response analyses of the four backfill profiles using two horizontal acceleration RCOL2_03.07.02-5

Table 3NN-1

Variation in Input Soil Properties

Stratum	Coefficient Of Variation on Shear Modulus		
	Lower Bound (LB)	Upper Bound (~~LB~~UB)	High Bound (HB)
Backfill	0.69	0.69	1.25
Rock Subgrade	0.65	0.65	0.65

RCOL2_03.08.04-52

Table 3NN-2

Basement Model Z-~~-~~Coordinates (Bottom to Top)

CTS-01090

Z (ft)	Elevation (ft)	Description
-37.420	782.00	Basemat Bottom
-24.083	795.34	Bottom of Basemat under Reactor
2.583	822.00	Ground Elevation

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-53

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsections 3.8.4.4.3.1, "ESWPT", 3.8.4.4.3.2, "UHSRS", and 3.8.4.4.3.3, "PSFSVs", which reference Appendices 3LL, 3KK, and 3MM, respectively. Each of these appendices reference Appendix 3NN, "Model Properties and Seismic Analysis Results R/B-PCCV-Containment Internal Structure".

In Appendix 3NN, Section 3NN.2, "Seismological and Geotechnical Considerations," the fourth paragraph (Page 3NN-2) states that "The compression or P-wave velocity is developed for the rock and the backfill from the strain-compatible shear or S-wave velocity (Vs) and the measured value of the Poisson's ratio. The SSI analyses use identical values for the shear S-wave and compression P-wave velocity damping. Figure 3NN-1, Figure 3NN-2 and Figure 3NN-3 present, respectively, the rock subgrade LB, BE and UB profiles for shear (S) wave velocity (Vs), compression (P) wave velocity (Vp) and material damping. Figure 3NN-4, Figure 3NN-5 and Figure 3NN-6 present in solid lines the results of the site response analyses for the profiles of strain-compatible backfill properties. The plots also show with dashed lines the backfill profiles that were modified to match the geometry of the mesh of the SASSI basement model. The presented input S and P wave profiles are modified using the equal arrival time averaging method."

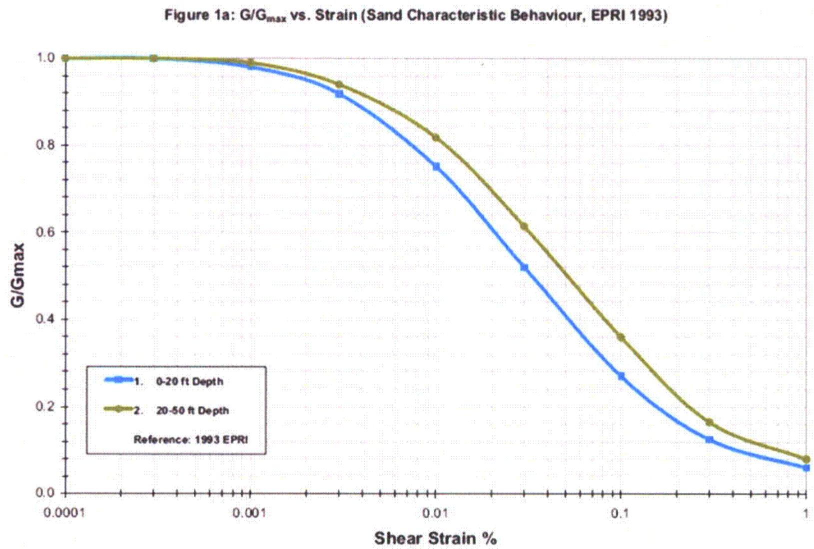
The applicant is requested to provide:

(a) Plots for soil shear modulus and damping as a function of soil strain used in the above analysis.

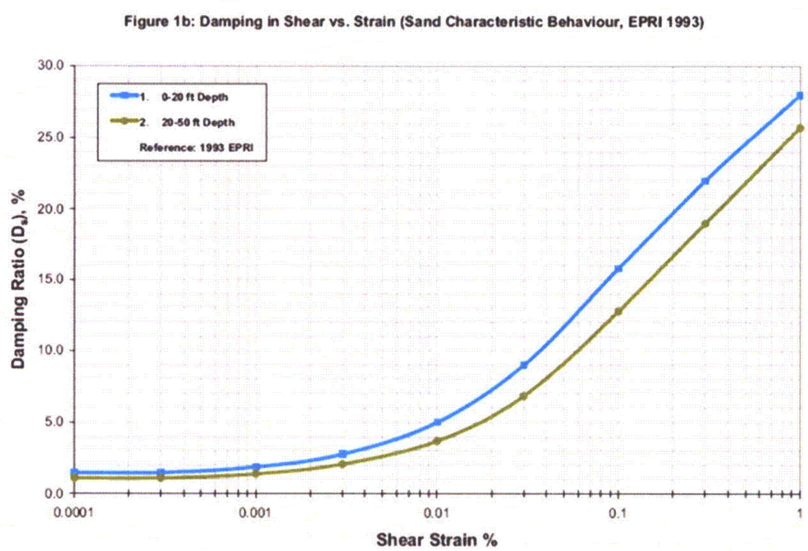
(b) Technical information for "the equal arrival time averaging method."

ANSWER:

(a) The degradation curves presented in FSAR Figure 2.5.2-232, which are derived based on standard EPRI shear modulus reduction and damping curves for granular fill, were used to model the properties of the embedment soil, which are non-linear. The plots presenting the soil shear modulus and the damping as a function of shear strain are presented below and in FSAR Figure 2.5.2-232.



Shear Modulus Degradation Curves



Damping Degradation Curves

ACS SASSI SOIL calculated strain-compatible fill properties using 65% of the peak strain value for selection of effective soil strain. The results for the strain compatible backfill properties obtained from the two horizontal site response analyses were averaged to obtain the backfill profiles used as input for the site-specific SSI analyses. The compression or P-wave velocity (Vp) is calculated from the strain compatible shear or S-wave velocity (Vs) and the Poisson's ratio (ν) of 0.35 by using the following equation:

$$Vp = Vs \cdot \sqrt{2 \cdot \frac{1-\nu}{1-2\nu}}$$

As stated in FSAR Section 3NN.2, shear modulus values are developed for four backfill conditions, lower bound (LB), best estimate (BE), upper bound (UB), and high bound (HB). The LB, UB, and HB shear modulus values are obtained using coefficients of variation from best estimate (BE) shear modulus values as presented in FSAR Table 3NN-1. The strain-compatible properties for the backfill used in the site-specific seismic analyses, correspond to those shear modulus values and FSAR Figures 3NN-4, 3NN-5, and 3NN-6. Those values are also presented in FSAR Table 3NN-16 for backfill strain compatible properties.

The Luminant response to RAI No. 2897 (CP RAI #60) Question 03.07.02-2 attached to Luminant letter TXNB-09073 dated November 24, 2009 (ML093340447) provides further discussion of how the strain compatible properties of the backfill were calculated.

(b) Technical information for "the equal arrival time averaging method."

The layering of the backfill profiles is modified in order to match the geometry of the mesh of the SASSI basement model. The S-wave and P-wave velocities of the backfill (Vs and Vp) are adjusted using an "equivalent arrival time" methodology. The "equivalent arrival time" methodology is based on the premise that the time required for the seismic wave to travel through the soil column remains unaffected by the changes made in the layer thicknesses to match the meshing of the structural model. In other words, the time needed for the vertically propagating S-waves and P-waves to propagate through the two profiles will be identical regardless of the adjustments made to the soil layering. Based on the "equivalent arrival time" principle, the S-wave and P-wave velocities of the adjusted soil layers are calculated as follows:

$$Vs = \frac{D}{\sum d_i / Vs_i} \quad \text{and} \quad Vp = \frac{D}{\sum d_i / Vp_i}$$

where: D is the thickness of the adjusted backfill layer in SASSI model, d_i is the thickness of each backfill layer in the site-response analysis soil column model, Vs_i and Vp_i are the strain compatible S-wave and P-wave velocities corresponding to the layering of the site response model. The P-wave damping (Dp) of the rock and backfill is set equal to the S-wave damping. The S-wave damping (Ds) of the rock and backfill layers is calculated as a weighted average using the following formula:

$$Ds = Dp = \frac{\sum d_i \cdot Ds_i}{D}$$

where Ds_i is the S-wave damping value of each backfill layer.

FSAR Sections 3NN.2 and 3NN.3 have been revised to incorporate this response.

Impact on R-COLA

See attached marked-up FSAR Revision 1 pages 3NN-3, 3NN-5, and 3NN-6.

Impact on S-COLA

None.

Impact on DCD

None.

surface of the rock subgrade at nominal elevation of 782 ft. The degradation curves presented in Figure 2.5.2-232, which are derived based on standard EPRI shear modulus reduction and damping curves for granular fill, were used to model the properties of the backfill, which are non-linear. The curves' values of the soil shear modulus and the damping as a function of shear strain are listed in Table 2.5.2-227. RCOL2_03.08.04-22 RCOL2_03.08.04-43 RCOL2_03.08.04-53

ACS SASSI SOIL calculated strain-compatible fill properties using 65% of the peak strain value for selection of effective soil strain. The results for the strain-compatible backfill properties obtained from the two horizontal site response analyses are averaged to obtain the backfill profiles used as the input for the site-specific SSI analyses.

The compression or P-wave velocity is developed for the rock and the backfill from the strain-compatible shear or S-wave velocity (Vs) and the measured value of the Poisson's ratio by using the following equation:~~.~~ RCOL2_03.07.02-2

$$Vp = Vs \cdot \sqrt{2 \cdot \frac{1-v}{1-2v}}$$

The SSI analyses use identical values for the shear S-wave and compression P-wave velocity damping. Figure 3NN-1, Figure 3NN-2 and Figure 3NN-3 present, respectively, the rock subgrade LB, BE and UB profiles for shear (S) wave velocity (Vs), compression (P) wave velocity (Vp) and material damping. Figure 3NN-4, Figure 3NN-5 and Figure 3NN-6 present in solid lines the results of the site response analyses for the profiles of strain-compatible backfill properties. The plots also show with dashed lines the backfill profiles that were modified to match the geometry of the mesh of the SASSI basement model. The presented input S and P wave profiles are modified using the equal arrival time averaging method. Table 3NN-16 provides the strain-compatible backfill properties, used for the SASSI analysis for LB, BE, UB, and HB embedment conditions. RCOL2_03.07.02-2

The minimum design spectra, tied to the shapes of the certified seismic design response spectra (CSDRS) and anchored at 0.1g, define the safe-shutdown earthquake (SSE) design motion for the seismic design of category I structures that is specified as outcrop motion at the top of the limestone at nominal elevation of 782 ft. Two statistically independent time histories H1 and H2 are developed compatible to the horizontal design spectrum, and a vertical acceleration time history V is developed compatible to the vertical design spectrum. The time step of the acceleration time histories used as input for the SASSI analysis is 0.005 seconds. The SASSI analysis requires the object motion to be defined as within-layer motion. ~~The site response analyses convert the design motion that is defined as outcrop motion (or motion at the free surface) to within-layer (or base motion) that depends on the properties of the backfill above the rock surface. The site response analyses provide for each considered backfill profile, two horizontal acceleration time histories of the design motion within the top limestone rock layer~~ RCOL2_03.08.04-54

reproduce the rigid link behavior present in the standard plant lumped mass stick models. RCOL2_03.08.04-57

The major coordinates that define the geometry of the FE basement model are listed in Table 3NN-2 to Table 3NN-5. 3NN-6 presents the types of SASSI finite elements used to model the different structural members in the basement model. The table also presents the ~~stiffness and mass inertia~~material properties (modulus of elasticity and weight density) assigned to each group of finite elements. The ~~stiffness and damping~~ properties assigned to each material of the SASSI model are listed in Table 3NN-7. The site-specific SASSI analysis uses the operating-basis earthquake (OBE) damping values of Chapter 3, Table 3.7.1-3(b), which is consistent with the requirements of Section 1.2 of RG 1.61 (Reference 3NN-4) for structures on sites with low seismic responses where the analyses consider a relatively narrow range of site-specific subgrade conditions. RCOL2_03.08.04-58

SASSI solid FE elements, shown in Figure 3NN-9, model the stiffness and mass inertia properties of the building basemat. The modeling of the thick central part of the basemat supporting the PCCV and containment internal structure is simplified to minimize the size of the SASSI model as shown in Figure 3NN-10. Rigid shell elements connect the thick portion of the basemat with the floor slabs at the ground elevation. Rigid 3D beam elements connect the PCCV and containment internal structure lumped-mass stick models to the rigid shell elements as shown in Figure 3NN-13 and Figure 3NN-14. Massless shell elements are added at the top of the basemat solid element to accurately model the bending stiffness of the central part of the mat. Figure 3NN-11 shows the solid FE elements representing the stiffness and mass inertia of the fill concrete placed under the central elevated part of the basemat and under the surface mat at the northeast corner of the building.

SASSI 3D shell elements model the basement shear walls, the surface mat under the northeast corner of the R/B, and the R/B slabs at ground floor elevation. The elastic modulus and unit weight assigned to the material of the shell elements modeling the R/B basement shear walls shown in Figure 3NN-12 are adjusted to account for the different height of walls and reductions of stiffness due to the openings. Table 3NN-8 lists the adjusted material properties assigned to the shell elements of the walls with openings.

Rigid 3D beam elements connect the top of the basement shear walls with lumped-mass stick model representing the above ground portion of the R/B and FH/A. This modeling approach enables the R/B-FH/A to be connected to the flexible part of the building basement and decoupled from the thick central part that serves as foundation to the PCCV and containment internal structure part of the building.

The layering of the backfill profiles is modified in order to match the geometry of the mesh of the SASSI basemat model described above. The S-wave and P-wave velocities of the backfill (Vs and Vp) are adjusted using an equivalent arrival time methodology as follows: RCOL2_03.08.04-43 RCOL2_03.08.04-53

$$Vs = \frac{D}{\sum d_i / Vs_i} \quad \text{and} \quad Vp = \frac{D}{\sum d_i / Vp_i}$$

RCOL2_03.08.04-43
RCOL2_03.08.04-53

where:

D is the thickness of the backfill layer in SASSI, d_i is the thickness of each backfill layer in the site-response analysis model, and Vs_i and Vp_i are the strain-compatible S-wave and P-wave velocities corresponding to the layering of the site response model.

The P-wave damping (Dp) of the rock and backfill is set equal to the S-wave damping. The S-wave damping (Ds) of the rock and backfill layers is calculated as a weighted average using the following formula:

$$Ds = Dp = \frac{\sum d_i \cdot Ds_i}{D}$$

where Ds_i is the S-wave damping value of each backfill layer.

In addition to the weights assigned to the lumped-mass-stick models of the US-APWR standard plant summarized in Table 3H.2-10 of Appendix 3H, the SASSI model used for site specific analyses includes the weight of 47,085 kips pertaining to the fill concrete placed beneath the building basemat. The combined total weight of the R/B, containment internal structure, and PCCV including the basemat and the fill concrete is 781,685 kips. The equivalent uniform pressure under the building foundation is 11.86 ksf. In the SASSI model of the basement, unit mass weight is assigned only to the 3D shell elements modeling the shear walls of R/B and to the portion of the basemat represented by 3D brick elements. Table 3NN-9 presents the weights assigned to the elements of the basement structural members. The remaining weight of the basement is lumped at a single node that, as shown in Figure 3NN-10, is connected to the central portion of the foundation by rigid beams. As shown in Table 3NN-10, the magnitude and the location of the lumped mass are calculated such that, when combined with the mass inertia properties of the mat and walls, the FE model duplicates the overall lumped mass inertia properties assigned to the standard plant lumped mass stick model at basement node BS01.

Four layers of SASSI solid elements, shown Figure 3NN-15, are used to represent the stiffness and the mass inertia of the excavated backfill soil. Figure 3NN-4, Figure 3NN-5, and Figure 3NN-6 show in dashed lines the input strain-compatible properties assigned to the different layers of excavated soil elements.

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-54

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsections 3.8.4.4.3.1, "ESWPT", 3.8.4.4.3.2, "UHSRS", and 3.8.4.4.3.3, "PSFSVs", which reference Appendices 3LL, 3KK, and 3MM, respectively. Each of these appendices reference Appendix 3NN, "Model Properties and Seismic Analysis Results R/B-PCCV-Containment Internal Structure".

In Appendix 3NN, Section 3NN.2, "Seismological and Geotechnical Considerations," the last paragraph (Page 3NN-3) states that "The site response analyses convert the design motion that is defined as outcrop motion (or motion at the free surface) to within-layer (or base motion) that depends on the properties of the backfill above the rock surface. The site response analyses provide for each considered backfill profile, two horizontal acceleration time histories of the design motion within the top limestone rock layer that are used as input in the SASSI analyses of embedded foundation. The outcrop horizontal time histories are used as input for the SASSI analyses of surface foundations."

The above quoted paragraph is confusing. The applicant is requested to explain and/or rewrite. Does the paragraph imply that the site response analysis is needed only for the embedded foundation?

ANSWER:

The site response analyses described in FSAR Section 3NN.2 provide input for SASSI analyses of the embedded foundations that use input time histories of the column within motion at foundation bottom elevation and dynamic properties of the embedment material that are compatible to the strains generated by the design ground motion. The design ground motion is represented by the minimum design earthquake spectra that define the outcrop motion at the surface of the subgrade. Since the outcrop and within-column motion at the top of the soil column are identical, the acceleration time histories that are compatible to the minimum design earthquake spectra can be directly used as input for SASSI analyses of surface foundations resting on the rock subgrade which dynamic properties remain independent of strain for the intensity level of the design ground motion. The paragraph quoted above has been revised to clarify the FSAR.

The response to RAI No. 2876 (CP RAI #55) Question 03.07.01-01 provided in Luminant letter TXNB-09058 dated October 26, 2009 (ML093010366) further explained "outcrop". For convenience, that response is repeated below:

> As used in FSAR Section 3.7 and FSAR Appendices 3KK, 3LL, 3MM, and 3NN, the term "outcrop" follows the formulation of the SHAKE family of programs for one-dimensional wave propagation analysis. The wave propagation in layered media results in motion in each layer that can be decomposed into incoming components and reflected components. In SHAKE, the term "outcrop" motion defines the motion of the layer equivalent to two times the incoming component of the motion of that layer. This definition of the term "outcrop" is used consistently throughout the FSAR Chapter 3 and FSAR Appendices 3KK, 3LL, 3MM, and 3NN.
>
> FSAR Subsection 2.5.2 identifies that the vertical strata of the site subsurface is divided into layers that are distinguished by different physical characteristics. Most prominent of these layers is an approximately 60-ft. thick limestone layer, which is referred to as engineering Layer C. This layer lies about 40 ft. below the finish grade elevation of 822 ft. at an approximate elevation of 782 ft. The foundation mats for all seismic Category I structures, except seismic Category I duct banks and chases embedded in compacted fill, are founded on this layer. Excavation to layer C will remove the shallower, noncompetent layers. As explained in FSAR Subsections 2.5.2.5 and 2.5.2.6, the site-specific ground motion response spectra (GMRS) are developed as free-field outcrop motions on the uppermost in-situ competent material. The uppermost in-situ competent layer is the Layer C discussed above.
>
> Theoretically, the "outcrop" motion as defined in FSAR Chapter 3 is equal to the hypothetical outcrop surface motion defining the GMRS and foundation input response spectra (FIRS) developed in FSAR Subsection 2.5.4 at the top of the in-situ limestone layer at elevation 782'-0" only after the excavation of the overlying non-competent soil and rock layers. Therefore, the "outcrop" motion will be equivalent to the motion defined by GMRS and FIRS only for the case of surface foundations where no soil exists above the top of the in-situ limestone layer at elevation 782'-0". The presence of in-situ or engineered fill materials above the elevation where GMRS and FIRS are defined will affect the incoming motion at the top of the in-situ competent material. In this case of an embedded foundation, the "outcrop" motion as defined in FSAR Chapter 3 will be different from the GMRS and FIRS defined motion that represents the motion at the top of the rock column with the top layers of incompetent in-situ materials removed. However, as discussed in FSAR Subsection 3.7.1.1, the nominal site-specific response spectra which are described in FSAR Subsection 2.5.4 are less than the minimum required response spectra, and are therefore not used for site specific design and analyses. Instead, the site-specific FIRS are defined as the shape of the certified seismic design response spectra (CSDRS) anchored at 0.1g, in order to comply with the intent of 10 CFR 50 Appendix S (IV)(a)(1)(i). This is discussed further in the response to Question 03.07.01-5.
>
> Time histories for the CSDRS anchored at 0.1g are developed as discussed in FSAR Subsection 3.7.1.1. The site-specific SSI analyses of the seismic Category I facilities - UHSRS (FSAR App. 3KK), ESWPT (FSAR App. 3LL), PSFSV (FSAR App. 3MM), R/B-PCCV-CONTAINMENT INTERNAL STRUCTURE (FSAR App. 3NN) – are based on this input motion. These structures are analyzed as both surface-mounted and embedded structures to capture a wide range of site-specific SSI seismic response effects. The analyses of the surface mounted foundation conditions utilize the outcrop input motion as defined by the CSDRS anchored at 0.1g. The SASSI analyses, which consider embedment effects, use "within-layer" motion as input for the horizontal component

of the design earthquake. As further explained in FSAR Section 3NN.2, for analysis of embedded foundations, the design input motion is converted to within-layer motion using SHAKE wave propagation analyses that take into account the properties of the backfill above the limestone outcrop surface at elevation 782'-0". These input horizontal acceleration time histories of the within layer limestone motion are developed in a manner that captures a wide variation of possible embedment stiffness and damping properties (lower bound, best estimate, upper bound, and high bound profiles as discussed in FSAR Appendix 3NN). The properties of the embedment material that are compatible to the strains generated by this input motion are used in conjunction with the input motion."

[[the above is the complete response to Question 3.7.1-1. I don't believe we should repeat the whole thing here. The reference is clear and the reviewer can easily find it if he wants. This is not a practice we have engaged in in the past. – JTC.]]

FSAR Section 3NN.2 has been revised to incorporate this response.

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

See attached marked-up FSAR Revision 1 pages 3NN-3 and 3NN-4.

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

None.

<u>Impact on DCD</u>

None.

surface of the rock subgrade at nominal elevation of 782 ft. The degradation curves presented in Figure 2.5.2-232, which are derived based on standard EPRI shear modulus reduction and damping curves for granular fill, were used to model the properties of the backfill, which are non-linear. The curves' values of the soil shear modulus and the damping as a function of shear strain are listed in Table 2.5.2-227. RCOL2_03.08.04-22 RCOL2_03.08.04-43 RCOL2_03.08.04-53

ACS SASSI SOIL calculated strain-compatible fill properties using 65% of the peak strain value for selection of effective soil strain. The results for the strain-compatible backfill properties obtained from the two horizontal site response analyses are averaged to obtain the backfill profiles used as the input for the site-specific SSI analyses.

The compression or P-wave velocity is developed for the rock and the backfill from the strain-compatible shear or S-wave velocity (Vs) and the measured value of the Poisson's ratio by using the following equation:~~.~~ RCOL2_03.07.02-2

$$Vp = Vs \cdot \sqrt{2 \cdot \frac{1-\nu}{1-2\nu}}$$

The SSI analyses use identical values for the shear S-wave and compression P-wave velocity damping. Figure 3NN-1, Figure 3NN-2 and Figure 3NN-3 present, respectively, the rock subgrade LB, BE and UB profiles for shear (S) wave velocity (Vs), compression (P) wave velocity (Vp) and material damping. Figure 3NN-4, Figure 3NN-5 and Figure 3NN-6 present in solid lines the results of the site response analyses for the profiles of strain-compatible backfill properties. The plots also show with dashed lines the backfill profiles that were modified to match the geometry of the mesh of the SASSI basement model. The presented input S and P wave profiles are modified using the equal arrival time averaging method. Table 3NN-16 provides the strain-compatible backfill properties, used for the SASSI analysis for LB, BE, UB, and HB embedment conditions. RCOL2_03.07.02-2

The minimum design spectra, tied to the shapes of the certified seismic design response spectra (CSDRS) and anchored at 0.1g, define the safe-shutdown earthquake (SSE) design motion for the seismic design of category I structures that is specified as outcrop motion at the top of the limestone at nominal elevation of 782 ft. Two statistically independent time histories H1 and H2 are developed compatible to the horizontal design spectrum, and a vertical acceleration time history V is developed compatible to the vertical design spectrum. The time step of the acceleration time histories used as input for the SASSI analysis is 0.005 seconds. The SASSI analysis requires the object motion to be defined as within-layer motion. ~~The site response analyses convert the design motion that is defined as outcrop motion (or motion at the free surface) to within-layer (or base motion) that depends on the properties of the backfill above the rock surface. The site response analyses provide for each considered backfill profile, two horizontal acceleration time histories of the design motion within the top limestone rock layer~~ RCOL2_03.08.04-54

~~that are used as input in the SASSI analyses of embedded foundation. The outcrop horizontal time histories are used as input for the SASSI analyses of surface foundations.~~The outcrop horizontal time histories are used directly as input for the SASSI analyses of surface foundations applied at the FIRS bottom of foundation elevation. The analyses of embedded foundation use "within" motion input time histories that are also applied at the FIRS input elevation. The "within" motions are obtained from a set of site response analyses, separate from these documented in Subsection 2.5.4, that are performed on a soil column consisting of the rock subgrade and the backfill, for purposes of embedded foundation SSI analysis. The design motion is applied to the soil column as layer outcrop motion at the FIRS elevation in order to calculate the within-layer motion. These site response analyses provides for each considered backfill profile, two horizontal acceleration time histories (East-West and North-South) of the design motion within the top limestone rock layer that are used as input in the SASSI analyses of embedded foundations. The time history of the vertical outcrop accelerations serves as input for both surface and embedded foundations. ~~The time step of the acceleration time histories used as input for the SASSI analysis is 0.005 sec.~~ RCOL2_03.08.04-54

3NN.3 SASSI Model Description and Analysis Approach

Figure 3NN-7 shows the three-dimensional SASSI FE model used for site-specific seismic analysis of the US-APWR R/B-PCCV-containment internal structure of Units 3 and 4. The SASSI structural model uses lumped-mass-stick models of the PCCV, containment internal structure, and R/B to represent the stiffness and mass inertia properties of the building above the ground elevation. A three-dimensional (3D) FE model, presented in Figure 3NN-8, represents the building basement and the floor slabs at ground elevation.

The model is established with reference to the Cartesian coordinate system with origin established 2 ft.-7 in. below the ground surface elevation at the center of the PCCV foundation. The origin location corresponds to the location of the coordinate system used as reference for the seismic analysis of the standard plant presented in Section 3.7. The orientation of the Z-axis is upward. The orientation of the standard plant model is modified such that the positive X-axis is oriented northward and the Y-axis is oriented westward.

The geometry and the properties of the lumped-mass-stick models 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. SASSI 3D beam and spring elements with cross sectional properties identical to those of the standard plant models represent stiffness properties. All of the modeling characteristics present in the standard plant lumped mass stick models for the R/B-PCCV-containment internal structure are the same as for the SASSI model, with the exception of minor adjustments for compatibility with SASSI, described as follows. Because SASSI does not have rigid link capability, ~~T~~the rigid links in the lumped mass stick models that connect different nodal points at the same floor elevation are replaced with SASSI 3D beam elements with high stiffness properties. The 3D beam elements RCOL2_03.08.04-57 RCOL2_03.08.04-57

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-55

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsections 3.8.4.4.3.1, "ESWPT", 3.8.4.4.3.2, "UHSRS", and 3.8.4.4.3.3, "PSFSVs", which reference Appendices 3LL, 3KK, and 3MM, respectively. Each of these appendices reference Appendix 3NN, “Model Properties and Seismic Analysis Results R/B-PCCV-Containment Internal Structure”.

In Appendix 3NN, Section 3NN.2, “Seismological and Geotechnical Considerations,” the last paragraph (Page 3NN-3) states that “The time history of the vertical outcrop accelerations serves as input for both surface and embedded foundations. The time step of the acceleration time histories used as input for the SASSI analysis is 0.005 sec.”

The applicant is requested to address the issue, “What is the cutoff frequency specified in the SASSI runs?”

ANSWER:

The cutoff frequency for the SASSI analyses is between 29 and 51 Hz for the UHSRS, ESWPT, and PSFSV seismic analyses documented in FSAR Appendices 3KK, 3LL, and 3MM, respectively. The cutoff frequency for the SASSI analyses is 50 Hz for the R/B-PCCV-Containment Internal Structure seismic analyses documented in FSAR Appendix 3NN. The total number of frequencies of analysis for each SASSI run for each structure is provided in Tables 1 through 6 below. Tables 1 through 5 also present the cutoff frequencies for the individual SASSI runs for the UHSRS, ESWPT, and PSFSV analyses. For the R/B-PCCV-Containment Internal Structure SASSI analyses, Table 5 of Calculation SSI-12-05-100-003 (see Reference below) lists the frequencies of analysis for each of the seven (7) site conditions considered, three (3) cases of surface foundation (SLB, SBE and SUB) and four (4) cases of embedded foundation (ELB, EBE, EUB and EHB). The nomenclature for the site profiles and SASSI runs is described in FSAR Appendices 3KK, 3LL, 3MM, and 3NN. The response to RAI

No. 2897 (CP RAI #60) Question 03.07.02-16 as attached to Luminant letter TXNB-09073 dated November 24, 2009 provides further discussion regarding the frequencies of analysis for the UHSRS, ESWPT and PSFSV SASSI runs.

FSAR Section 3NN.4 has been revised to incorporate this response.

Reference

Site Specific SSI Analysis of US-APWR Reactor Building (SSI-12-05-100-003 Rev. C), 4DS-CP34-20090015, Mitsubishi Heavy Industries, LTD, December 2, 2009, provided as Attachment 4 in the response to RAI No. 2879 (CP RAI #60) via Luminant letter TXNB-09073 dated November 24, 2009 (ML093340447).

Impact on R-COLA

See attached marked-up FSAR Revision 1 page 3NN-8.

Portions of this discussion related to the UHSRS, ESWPT, and PSFSV have been added to the FSAR as part of the response to RAI No. 2879 (CP RAI #60) as attached to Luminant letter TXNB-09073 dated November 24, 2009 (ML093340447).

Impact on S-COLA

None.

Impact on DCD

None.

Attachments

Table 1 - Frequencies Used in SSASI Analysis (Hz) for UHSRS

Table 2 - Tunnel Segment 1 - Frequencies Used in SSASI Analysis (Hz) for ESWPT

Table 3 - Tunnel Segment 2 - Frequencies Used in SSASI Analysis (Hz) for ESWPT

Table 4 - Tunnel Segment 3 - Frequencies Used in SSASI Analysis (Hz) for ESWPT

Table 5 - Frequencies Used in SSASI Analysis (Hz) for PSFSVs

Table 6 - Number of Frequencies of Analysis for R/B-PCCV-Containment Internal Structure for each set of SASSI Runs

Table 1 - Frequencies used in SASSI Analysis (Hz) for UHSRS						
	Non-Separated	Separated Fill				Lower Bound No Fill
	Best Estimate	Lower Bound	Best Estimate	Upper Bound	High Bound	
1	1.22	1.22	1.22	1.22	1.22	1.22
2	1.83	1.83	1.83	1.83	1.83	1.83
3	2.44	2.44	2.44	2.44	2.44	2.44
4	3.05	3.05	3.05	3.05	3.05	3.05
5	3.66	3.66	3.66	3.66	3.66	3.66
6	4.27	4.27	4.27	4.27	4.27	4.27
7	4.88	4.88	4.57	4.88	4.57	4.88
8	5.18	5.49	4.88	5.18	4.88	5.49
9	5.49	6.10	5.18	5.49	5.49	6.10
10	6.10	6.71	5.49	6.10	6.10	6.71
11	6.71	7.32	6.10	6.71	6.71	7.32
12	7.32	7.94	6.71	7.01	7.01	7.94
13	7.94	8.55	7.01	7.32	7.32	8.55
14	8.55	9.16	7.32	7.94	7.94	9.16
15	9.16	9.77	7.94	8.55	8.23	9.77
16	9.77	10.38	8.55	9.16	8.55	10.38
17	10.38	10.99	9.16	9.77	9.16	10.99
18	10.99	11.60	9.77	10.38	9.77	11.60
19	11.28	12.21	10.38	10.99	10.38	12.21
20	11.60	12.82	10.99	11.60	10.99	12.82
21	12.21	13.43	11.60	12.21	11.60	13.43
22	12.82	14.04	12.21	12.82	12.21	14.04
23	13.43	14.33	12.82	13.43	12.82	14.65
24	14.04	14.65	13.43	14.04	13.43	15.26
25	14.65	15.26	14.04	14.65	14.04	15.87
26	15.26	15.87	14.65	15.26	14.65	16.48
27	15.87	16.48	15.26	15.87	15.26	17.09
28	16.48	17.09	15.55	16.48	15.87	17.70
29	17.09	17.70	15.87	17.09	16.48	18.31
30	17.70	18.31	16.48	17.70	17.09	18.92
31	18.31	18.92	17.09	18.31	17.38	19.53
32	18.92	19.53	17.70	18.92	17.70	20.14
33	19.53	20.14	18.31	19.53	18.31	20.75
34	20.14	20.75	18.92	20.14	18.92	21.36

Table 1 - Frequencies used in SASSI Analysis (Hz) for UHSRS **(continued)**						
	Non-Separated	Separated Fill				Lower Bound No Fill
	Best Estimate	Lower Bound	Best Estimate	Upper Bound	High Bound	
35	20.75	21.36	19.53	20.75	19.21	21.97
36	21.36	21.97	20.14	21.36	19.53	22.58
37	21.97	22.58	20.75	21.97	20.14	23.19
38	22.58	23.19	21.36	22.27	20.43	23.80
39	23.19	23.80	21.97	22.58	20.75	24.41
40	23.80	24.41	22.58	23.19	21.36	25.02
41	24.41	25.02	23.19	23.80	21.97	25.63
42	25.02	25.63	23.80	24.41	22.58	26.25
43	25.63	26.25	24.41	25.02	23.19	26.86
44	26.25	26.86	25.02	25.63	23.80	27.47
45	26.86	27.47	25.63	26.25	24.41	28.08
46	27.47	28.08	26.25	26.86	25.02	28.69
47	28.08	28.69	26.86	27.47	25.63	29.30
48	28.69	29.30	27.47	28.08	25.93	29.91
49	29.30	29.91	28.08	28.69	26.25	30.52
50	29.91	30.52	28.69	29.30	26.86	31.13
51	30.52	31.13	29.30	29.91	27.47	31.74
52	31.13	31.74	29.91	30.52	28.08	32.35
53	31.74	32.96	30.52	31.13	28.69	32.96
54	32.35	34.18	31.13	31.74	29.30	33.57
55	32.96	35.40	31.74	32.35	29.91	34.18
56	33.57	36.62	32.35	32.96	30.52	34.79
57	34.18	37.84	32.96	34.18	31.13	35.40
58	34.79		33.57	35.40	31.74	36.01
59	35.40		34.18	36.62	32.96	36.62
60	36.01		35.40	37.84	34.18	37.23
61	36.62		36.62	39.06	35.40	37.84
62	37.23		37.84	40.28	36.62	38.45
63	37.84			41.50	37.84	39.06
64	38.45			42.72	39.06	39.67
65				43.95	40.28	40.28
66				45.17	41.50	40.89
67				46.39	42.72	41.50
68				47.61	43.95	42.11
69				48.83	45.17	42.72
70					46.39	43.33
71					47.61	43.95
72					48.83	44.56
73					50.05	45.17
74						45.78
75						46.39
76						47.00
77						47.61
78						48.22
79						49.44
80						50.05
81						50.66

Table 2. Tunnel Segment 1 - Frequencies used in SASSI Analysis (Hz) for ESWPT

	Tunnel Segment 1			
	Lower Bound	Best Estimate	Upper Bound	High Bound
1	1.22	1.22	1.22	1.22
2	1.83	1.83	1.83	1.83
3	2.44	2.44	2.44	2.44
4	3.05	3.05	3.05	3.05
5	3.66	3.66	3.66	3.66
6	4.27	4.27	4.27	4.27
7	4.88	4.88	4.88	4.88
8	5.49	5.49	5.49	5.49
9	6.10	6.10	6.10	6.10
10	6.71	6.71	6.71	6.71
11	7.32	7.32	7.32	7.32
12	7.94	7.94	7.94	7.94
13	8.55	8.55	8.55	8.55
14	9.16	9.16	9.16	9.16
15	9.77	9.77	9.77	9.77
16	10.38	10.38	10.38	10.38
17	10.99	10.99	10.99	10.99
18	11.60	11.60	11.60	11.60
19	12.21	12.21	12.21	12.21
20	12.82	12.82	12.82	12.82
21	13.43	13.43	13.43	13.43
22	14.04	14.04	14.04	14.04
23	14.65	14.65	14.65	14.65
24	15.26	15.26	15.26	15.26
25	15.87	15.87	15.87	15.87
26	16.48	16.48	16.48	16.48
27	17.09	17.09	17.09	17.09
28	17.70	17.70	17.70	17.70
29	18.31	18.31	18.31	18.31
30	18.92	18.92	18.92	18.92
31	19.53	19.53	19.53	19.53
32	20.14	20.14	20.14	20.14
33	20.75	20.75	20.75	20.75
34	21.36	21.36	21.36	21.36
35	21.97	21.97	21.97	21.97
36	22.58	22.58	22.58	22.58
37	23.19	23.19	23.19	23.19
38	23.80	23.80	23.80	23.80
39	24.41	24.41	24.41	24.41
40	25.02	25.02	25.02	25.02
41	25.63	25.63	25.63	25.63

Table 2. Tunnel Segment 1 - Frequencies used in SASSI Analysis (Hz) for ESWPT **(continued)**

	Tunnel Segment 1			
	Lower Bound	**Best Estimate**	**Upper Bound**	**High Bound**
42	26.25	26.25	26.25	26.25
43	26.86	26.86	26.86	26.86
44	27.47	27.47	27.47	27.47
45	28.08	28.08	28.08	28.08
46	28.69	29.30	28.69	28.69
47	29.30	29.91	29.30	29.30
48	29.91	30.52	29.91	29.91
49	30.52	31.13	30.52	30.52
50		31.74	31.13	31.13
51		32.35	31.74	31.74
52		32.96	32.35	32.35
53		33.57	32.96	32.96
54		34.18	33.57	33.57
55		34.79	34.18	34.18
56		35.40	34.79	34.79
57		36.01	35.40	35.40
58		36.62	36.01	36.01
59		37.23	36.62	36.62
60		37.84	37.23	37.23
61		38.45	37.84	37.84
62		39.06	38.45	38.45
63			39.06	39.06
64			39.67	39.67
65			40.28	40.28
66			40.89	40.89
67			41.50	41.50
68			42.11	42.11
69			42.72	42.72
70			43.33	43.33
71			43.95	43.95
72			44.56	44.56
73			45.17	45.17
74			45.78	45.78
75			46.39	46.39
76			47.00	47.00
77			47.61	47.61
78			48.22	48.22
79			48.83	48.83
80			49.44	49.44
81			50.05	50.05

Table 3. Tunnel Segment 2 - Frequencies used in SASSI Analysis (Hz) for ESWPT

	Tunnel Segment 2 Non-Separated Fill				**Tunnel Segment 2 Separated Fill**			
	Lower Bound	**Best Estimate**	**Upper Bound**	**High Bound**	**Lower Bound**	**Best Estimate**	**Upper Bound**	**High Bound**
1	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.46
2	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93
3	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66
4	4.39	4.39	4.39	4.39	4.39	4.39	4.39	4.39
5	5.13	5.13	5.13	5.13	5.13	5.13	5.13	5.13
6	5.86	5.86	5.86	5.86	5.86	5.86	5.86	5.86
7	6.59	6.59	6.59	6.59	6.59	6.59	6.59	6.59
8	7.32	7.32	7.32	7.32	7.32	7.32	7.32	7.32
9	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06
10	8.79	8.79	8.79	8.79	8.79	8.79	8.79	8.79
11	9.52	9.52	9.52	9.52	9.52	9.52	9.52	9.52
12	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25
13	10.99	10.99	10.99	10.99	10.99	10.99	10.99	10.99
14	11.72	11.72	11.72	11.72	11.72	11.72	11.72	11.72
15	12.45	12.45	12.45	12.45	12.45	12.45	12.45	12.45
16	13.18	13.18	13.18	13.18	13.18	13.18	13.18	13.18
17	13.92	13.92	13.92	13.92	13.92	13.92	13.92	13.92
18	14.65	14.65	14.65	14.65	14.65	14.65	14.65	14.65
19	15.38	15.38	15.38	15.38	15.38	15.38	15.38	15.38
20	16.11	16.11	16.11	16.11	16.11	16.11	16.11	16.11
21	16.85	16.85	16.85	16.85	16.85	16.85	16.85	16.85
22	17.58	17.58	17.58	17.58	17.58	17.58	17.58	17.58
23	18.31	18.31	18.31	18.31	18.31	18.31	18.31	18.31
24	19.04	19.04	19.04	19.04	19.04	19.04	19.04	19.04
25	19.78	19.78	19.78	19.78	19.78	19.78	19.78	19.78
26	20.51	20.51	20.51	20.51	20.51	20.51	20.51	20.51
27	21.24	21.24	21.24	21.24	21.24	21.24	21.24	21.24
28	21.97	21.97	21.97	21.97	21.97	21.97	21.97	21.97
29	22.71	22.71	22.71	22.71	22.71	22.71	22.71	22.71
30	23.44	23.44	23.44	23.44	23.44	23.44	23.44	23.44
31	24.17	24.17	24.17	24.17	24.17	24.17	24.17	24.17
32	24.90	24.90	24.90	24.90	24.90	24.90	24.90	24.90
33	25.63	25.63	25.63	25.63	25.63	25.63	25.63	25.63
34	26.37	26.37	26.37	26.37	26.37	26.37	26.37	26.37
35	27.10	27.10	27.10	27.10	27.10	27.10	27.10	27.10
36	27.83	27.83	27.83	27.83	27.83	27.83	27.83	27.83
37	28.56	28.56	28.56	28.56	28.56	28.56	28.56	28.56
38	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30
39	30.03	30.03	30.03	30.03	30.03	30.03	30.03	30.03

Table 3. Tunnel Segment 2 - Frequencies used in SASSI Analysis (Hz) for ESWPT **(continued)**								
	Tunnel Segment 2 Non-Separated Fill				**Tunnel Segment 2 Separated Fill**			
	Lower Bound	**Best Estimate**	**Upper Bound**	**High Bound**	**Lower Bound**	**Best Estimate**	**Upper Bound**	**High Bound**
40		30.76	30.76	30.76		30.76	30.76	30.76
41		32.23	32.23	32.25		32.23	32.23	32.25
42		33.69	33.69	33.69		33.69	33.69	33.69
43		35.16	35.16	35.16		35.16	35.16	35.16
44		36.62	36.62	36.62		36.62	36.62	36.62
45		38.09	38.09	38.09		38.09	38.09	38.09
46			39.55	39.55			39.55	39.55
47			41.02	41.02			41.02	41.02
48			42.48	42.48			42.48	42.48
49			43.95	43.95			43.95	43.95
50			45.41	45.41			45.41	45.41
51			46.88	46.88			46.88	46.88
52			48.34	48.34			48.34	48.34
53			49.80	49.80			49.80	49.80

Table 4. Tunnel Segment 3 - Frequencies used in SASSI Analysis (Hz) for ESWPT				
	Tunnel Segment 3			
	Lower Bound	Best Estimate	Upper Bound	High Bound
1	1.22	1.22	1.22	1.22
2	1.83	1.83	1.83	1.83
3	2.44	2.44	2.44	2.44
4	3.05	3.05	3.05	3.05
5	3.66	3.66	3.66	3.66
6	4.27	4.27	4.27	4.27
7	4.88	4.88	4.88	4.88
8	5.49	5.49	5.49	5.49
9	6.10	6.10	6.10	6.10
10	6.71	6.71	6.71	6.71
11	7.32	7.32	7.32	7.32
12	7.94	7.94	7.94	7.94
13	8.55	8.55	8.55	8.55
14	9.16	9.16	9.16	9.16
15	9.77	9.77	9.77	9.77
16	10.38	10.38	10.38	10.38
17	10.99	10.99	10.99	10.99
18	11.60	11.60	11.60	11.60
19	12.21	12.21	12.21	12.21
20	12.82	12.82	12.82	12.82
21	13.43	13.43	13.43	13.43
22	14.04	14.04	14.04	14.04
23	14.65	14.65	14.65	14.65
24	15.26	15.26	15.26	15.26
25	15.87	15.87	15.87	15.87
26	16.48	16.48	16.48	16.48
27	17.09	17.09	17.09	17.09
28	17.70	17.70	17.70	17.70
29	18.31	18.31	18.31	18.31
30	18.92	18.92	18.92	18.92
31	19.53	19.53	19.53	19.53
32	20.14	20.14	20.14	20.14
33	20.75	20.75	20.75	20.75
34	21.36	21.36	21.36	21.36
35	21.97	21.97	21.97	21.97
36	22.58	22.58	22.58	22.58
37	23.19	23.19	23.19	23.19
38	23.80	23.80	23.80	23.80
39	24.41	24.41	24.41	24.41
40	25.02	25.02	25.02	25.02
41	25.63	25.63	25.63	25.63
42	26.25	26.25	26.25	26.25
43	26.86	26.86	26.86	26.86
44	27.47	27.47	27.47	27.47
45	28.08	28.08	28.08	28.08

Table 4. Tunnel Segment 3 - Frequencies used in SASSI Analysis (Hz) for ESWPT **(continued)**

	Tunnel Segment 3			
	Lower Bound	**Best Estimate**	**Upper Bound**	**High Bound**
46	28.69	28.69	28.69	28.69
47	29.30	29.30	29.30	29.30
48		29.91	29.91	29.91
49		30.52	30.52	30.52
50		31.13	31.13	31.13
51		31.74	31.74	31.74
52		32.35	32.35	32.35
53		32.96	32.96	32.96
54		33.57	33.57	33.57
55		34.18	34.18	34.18
56		34.79	34.79	34.79
57		35.40	35.40	35.40
58		36.01	36.01	36.01
59		36.62	36.62	36.62
60		37.23	37.23	37.23
61		37.84	37.84	37.84
62		38.45	38.45	38.45
63			39.06	39.06
64			39.67	39.67
65			40.28	40.28
66			40.89	40.89
67			41.50	41.50
68			42.11	42.11
69			42.72	42.72
70			43.33	43.33
71			43.95	43.95
72			44.56	44.56
73			45.17	45.17
74			45.78	45.78
75			46.39	46.39
76			47.00	47.00
77			47.61	47.61
78			48.22	48.22
79			48.83	48.83
80				49.44
81				50.05

Table 5 Frequencies used in SASSI Analysis (Hz) for PSFSVs

	Non-Separated Fill				Separated Fill					
	Lower Bound	Best Estimate	Upper Bound	High Bound	Lower Bound	Best Estimate	Upper Bound	High Bound	Fixed Base	Lower Bound No Fill
1	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22
2	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83
3	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44	2.44
4	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05
5	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66	3.66
6	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27
7	4.88	4.88	4.88	4.88	4.88	4.88	4.88	4.88	4.88	4.88
8	5.49	5.49	5.49	5.49	5.49	5.49	5.49	5.49	5.49	5.49
9	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10
10	6.71	6.71	6.71	6.71	6.71	6.71	6.71	6.71	6.71	6.71
11	7.32	7.32	7.32	7.32	7.32	7.32	7.32	7.32	7.32	7.32
12	7.94	7.94	7.94	7.94	7.94	7.94	7.94	7.94	7.94	7.94
13	8.55	8.55	8.55	8.55	8.55	8.55	8.55	8.55	8.55	8.55
14	9.16	9.16	9.16	9.16	9.16	9.16	9.16	9.16	9.16	9.16
15	9.77	9.77	9.77	9.77	9.77	9.77	9.77	9.77	9.77	9.77
16	10.38	10.38	10.38	10.38	10.38	10.38	10.38	10.38	10.38	10.38
17	10.99	10.99	10.99	10.99	10.99	10.99	10.99	10.99	10.99	10.99
18	11.60	11.60	11.60	11.60	11.60	11.60	11.60	11.60	11.60	11.60
19	12.21	12.21	12.21	12.21	12.21	12.21	12.21	12.21	12.21	12.21
20	12.82	12.82	12.82	12.82	12.82	12.82	12.82	12.82	12.82	12.82
21	13.43	13.43	13.43	13.43	13.43	13.43	13.43	13.43	13.43	13.43
22	14.04	14.04	14.04	14.04	14.04	14.04	14.04	14.04	14.04	14.04
23	14.65	14.65	14.65	14.65	14.65	14.65	14.65	14.65	14.65	14.65
24	15.26	15.26	15.26	15.26	15.26	15.26	15.26	15.26	15.26	15.26
25	15.87	15.87	15.87	15.87	15.87	15.87	15.87	15.87	15.87	15.87
26	16.48	16.48	16.48	16.48	16.48	16.48	16.48	16.48	16.48	16.48
27	17.09	17.09	17.09	17.09	17.09	17.09	17.09	17.09	17.09	17.09
28	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70
29	18.31	18.31	18.31	18.31	18.31	18.31	18.31	18.31	18.31	18.31
30	18.92	18.92	18.92	18.92	18.92	18.92	18.92	18.92	18.92	18.92
31	19.53	19.53	19.53	19.53	19.53	19.53	19.53	19.53	19.53	19.53
32	20.14	20.14	20.14	20.14	20.14	20.14	20.14	20.14	20.14	20.14
33	20.75	20.75	20.75	20.75	20.75	20.75	20.75	20.75	20.75	20.75
34	21.36	21.36	21.36	21.36	21.36	21.36	21.36	21.36	21.36	21.36
35	21.97	21.97	21.97	21.97	21.97	21.97	21.97	21.97	21.97	21.97
36	22.58	22.58	22.58	22.58	22.58	22.58	22.58	22.58	22.58	22.58
37	23.19	23.19	23.19	23.19	23.19	23.19	23.19	23.19	23.19	23.19
38	23.80	23.80	23.80	23.80	23.80	23.80	23.80	23.80	23.80	23.80
39	24.41	24.41	24.41	24.41	24.41	24.41	24.41	24.41	24.41	24.41
40	25.02	25.02	25.02	25.02	25.02	25.02	25.02	25.02	25.02	25.02

Table 5 Frequencies used in SASSI Analysis (Hz) for PSFSVs **(continued)**

	Non-Separated Fill				Separated Fill				Fixed Base	Lower Bound No Fill
	Lower Bound	Best Estimate	Upper Bound	High Bound	Lower Bound	Best Estimate	Upper Bound	High Bound		
41	25.63	25.63	25.63	25.63	25.63	25.63	25.63	25.63	25.63	25.63
42	26.25	26.25	26.25	26.25	26.25	26.25	26.25	26.25	26.25	26.25
43	26.86	26.86	26.86	26.86	26.86	26.86	26.86	26.86	26.86	26.86
44	27.47	27.47	27.47	27.47	27.47	27.47	27.47	27.47	27.47	27.47
45	28.08	28.08	28.08	28.08	28.08	28.08	28.08	28.08	28.08	28.08
46	28.69	28.69	28.69	28.69	28.69	28.69	28.69	28.69	28.69	28.69
47	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30	29.30
48	29.91	29.91	29.91	29.91	29.91	29.91	29.91	29.91	29.91	29.91
49		30.52	30.52	30.52		30.52	30.52	30.52	30.52	30.52
50		31.13	31.13	31.13		31.13	31.13	31.13	31.13	31.13
51		31.74	31.74	31.74		31.74	31.74	31.74	31.74	31.74
52		32.35	32.35	32.35		32.35	32.35	32.35	32.35	32.35
53		32.96	32.96	32.96		32.96	32.96	32.96	32.96	32.96
54		33.57	33.57	33.57		33.57	33.57	33.57	33.57	33.57
55		34.18	34.18	34.18		34.18	34.18	34.18	34.18	34.18
56		34.79	34.79	34.79		34.79	34.79	34.79	34.79	34.79
57		35.40	35.40	35.40		35.40	35.40	35.40	35.40	35.40
58		36.01	36.01	36.01		36.01	36.01	36.01	36.01	36.01
59		36.62	36.62	36.62		36.62	36.62	36.62	36.62	36.62
60		37.23	37.23	37.23		37.23	37.23	37.23	37.23	37.23
61		37.84	37.84	37.84		37.84	37.84	37.84	37.84	37.84
62		38.45	38.45	38.45		38.45	38.45	38.45	38.45	38.45
63			39.06	39.06			39.06	39.06	39.06	39.06
64			39.67	39.67			39.67	39.67	39.67	39.67
65			40.28	40.28			40.28	40.28	40.28	40.28
66			40.89	40.89			40.89	40.89	40.89	40.89
67			41.50	41.50			41.50	41.50	41.50	41.50
68			42.11	42.11			42.11	42.11	42.11	42.11
69			42.72	42.72			42.72	42.72	42.72	42.72
70			43.33	43.33			43.33	43.33	43.33	43.33
71			43.95	43.95			43.95	43.95	43.95	43.95
72			44.56	44.56			44.56	44.56	44.56	44.56
73			45.17	45.17			45.17	45.17	45.17	45.17
74			45.78	45.78			45.78	45.78	45.78	45.78
75			46.39	46.39			46.39	46.39	46.39	46.39
76			47.00	47.00			47.00	47.00	47.00	47.00
77			47.61	47.61			47.61	47.61	47.61	47.61
78			48.22	48.22			48.22	48.22	48.22	48.22
79			48.83	48.83			48.83	48.83	48.83	48.83
80			49.44	49.44			49.44	49.44	49.44	49.44
81				50.05				50.05	50.05	50.05

Table 6 – Number of Frequencies of Analysis for R/B-PCCV-Containment Internal Structure for each set of SASSI Runs

Set of SASSI Runs	Site Profile	No. Freq. of Analysis
1	SLB	48
2	SBE	48
3	SUB	48
4	ELB	51
5	EBE	51
6	EUB	55
7	EHB	52

Each set of SASSI runs includes three runs where the input motion is applied to the models at top of the rock subgrade in North-South (NS), East-West (EW) and vertical direction. The responses obtained for the earthquake components in the three global orthogonal directions are combined in accordance with RG 1.92 (Reference 3NN-3) using the square root sum of the squares (SRSS) method.

Each set of SASSI runs has a minimum cut-off frequency of 50 Hz. For each set of SASSI runs, the minimum of frequencies of analysis for the surface foundation conditions is 48, and the minimum number of frequencies of analysis for the embedded foundation is 51. RCOL2_03.08.04-55

Table 3NN-12, Table 3NN-13, and Table 3NN-14 present maximum absolute accelerations (zero period acceleration values) at lumped-mass locations of the R/B-PCCV-containment internal structure in NS, EW, and vertical direction, respectively. The results obtained from each set of SASSI analysis are listed together with the enveloped values for the surface and embedded foundation ~~from all of the considered~~ site conditions. The last column in the tables presents the ratio between the envelopes of the embedded foundation results with the envelopes of the surface foundation results that serves as an indicator of the embedment effects. The comparisons indicate that the embedment in general lowers the maximum horizontal accelerations. Exceptions are some portions of the building, in particular the Fuel Handling Area (FH/A), where the embedment resulted in magnified maximum horizontal accelerations due to local resonance effects. The comparison of the maximum acceleration results indicates that the reflection of the P-waves in the embedment soil resulting from the stiffness mismatch between the backfill and subgrade magnifies the vertical accelerations of R/B complex structures. RCOL2_03.07.02-8

Table 3NN-15 presents the influence of different SSI effects on the response of the PCCV, R/B, and containment internal structures.

3NN.5 In-Structure Response Spectra (ISRS)

The site-specific SASSI analysis provides results for the 5 percent damping acceleration response spectra (ARS) at all lumped mass locations for the three orthogonal directions. The ARS results for the three components of the input earthquake are combined using the SRSS method and compared with the US-APWR standard plant ISRS. Figure 3NN-16, Figure 3NN-20 and Figure 3NN-24 compare of the ARS results for seismic response in three directions at ground elevation at the nominal center of the basement (mass location CV00) with the corresponding CSDRS. The comparison of the ARS results for the response at the top of PCCV (mass node CV11) with the corresponding ISRS are shown in Figure 3NN-17, Figure 3NN-21, and Figure 3NN-25. Figure 3NN-18, Figure 3NN-22, and Figure 3NN-26 present the comparison of ISRS and ARS results for the containment internal structure response at lumped mass location IC18. The ARS results for the response of R/B structure at lumped mass location RE05 are presented in Figure 3NN-19, TFigure 3NN-23 and Figure 3NN-27. The ISRS envelope by a high margin all of the ARS results at all lumped mass locations,

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-56

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsections 3.8.4.4.3.1, "ESWPT", 3.8.4.4.3.2, "UHSRS", and 3.8.4.4.3.3, "PSFSVs", which reference Appendices 3LL, 3KK, and 3MM, respectively. Each of these appendices reference Appendix 3NN, "Model Properties and Seismic Analysis Results R/B-PCCV-Containment Internal Structure".

In Appendix 3NN, Section 3NN.3, "SASSI Model Description and Analysis Approach," the first paragraph (Page 3NN-3) states that "The SASSI structural model uses lumped-mass-stick models of the PCCV, containment internal structure, and R/B to represent the stiffness and mass inertia properties of the building above the ground elevation."

The applicant is requested to provide data to show that the lumped-mass-stick models adequately match the dominant frequencies, related mode shapes, and participation factors of the 3D ANSYS model used in the detailed design.

ANSWER:

The ESWPT, UHSRS and PSFSV dynamic models do not utilize lumped mass stick models. The dynamic SASSI finite element models are validated using comparisons made against the finer mesh fixed-base ANSYS models used for detailed design as described in FSAR Appendices 3LL, 3KK, and 3MM, and as further clarified in the response to RAI No. 2879 (CP RAI #60) Question 03.07.02-16 attached to Luminant letter TXNB-09073 dated November 24, 2009 (ML093340447).

The above-ground portion of the R/B complex is modeled in SASSI with stick models having same stiffness and mass inertia properties as the lumped mass dynamic stick models used in the DCD. Validation of these stick models is performed as part of the US-APWR standard plant and is addressed in DCD Subsection 3.7.2.3.10. NRC staff questions on validation of these stick models were received in

DCD RAI 212-1950 Question RAI 3.7.2-3, were responded to by MHI letter UAP-HF-09113 dated April 24, 2009 (ML091180437), and are being addressed by MHI as part of the DCD certification process.

Calculation 4DS-CP34-20080048 Rev.1 documents the development and validation of the SASSI model used for site-specific SSI analyses of the R/B complex. As discussed in FSAR Section 3NN.3, the structural model used for the SASSI analyses consists of three lumped-mass-stick models of the PCCV, CIS and R/B representing the stiffness and mass inertia properties of the building above the ground elevation and a 3-D Finite Element (FE) model represents the building basement and the floor slabs at ground elevation. The lumped mass stick models used for the SSI analyses for the standard design SSI analyses described in DCD Subsection 3.7.2 are translated into SASSI and combined together with the FE model of the basement. As explained in FSAR Section 3NN.3, a set of SASSI analyses was performed on the R/B complex structural model resting on the surface of a "hard rock" half space with high stiffness with the intent of simulating fixed base conditions. The acceleration time histories documented in DCD Subsection 3.7.1 were input to the model at the foundation-subgrade interface. The results of these SASSI analyses were compared with the results of the ANSYS fixed base modal and direct integration time history analyses to validate the SASSI model. In Figures 45 through 56 of Calculation 4DS-CP34-20080048 Rev.1, the transfer function results of the "hard rock" SASSI analyses are compared to the results of the ANSYS modal analysis. The figures show that the peaks of the transfer functions occur at frequencies that are very close to the frequencies of the predominant modes calculated by the modal analysis. The comparison of the results for 5% damping ARS at selected locations that are presented in Figures 21 through 28 in Calculation 4DS-CP34-20080048 Rev.1, demonstrates that the response obtained from the SASSI model match well the response calculated from the ANSYS direct integration time history analyses. Section 7.5 of Calculation 4DS-CP34-20080048 Rev.1 provides a detailed description of the validation of the SASSI model for the R/B complex structures.

FSAR Section 3NN.3 has been revised to incorporate this response.

<u>Reference</u>

SASSI Model of US-APWR Reactor Building, 4DS-CP34-20080048 Rev.1, Mitsubishi Heavy Industries, LTD, September 17, 2008 (This document was provided to NRC as Attachment 3 in the response to RAI No. 2879 (CP RAI #60) via Luminant letter TXNB-09073 dated November 24, 2009 (ML093340447).

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

See attached marked-up FSAR Revision 1 page 3NN-7.

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

None.

<u>Impact on DCD</u>

None.

The results of a SASSI analysis in which fixed-base conditions are simulated by attaching the lumped-mass-stick models to a rigid foundation resting on a rigid rock subgrade, verify the accuracy of the conversion of the standard plant lumped-mass-stick models into SASSI. An additional verification analysis is performed on the combined SASSI model resting on the surface of rigid half-space to identify the dynamic properties of the SASSI model. Transfer functions obtained from the "hard rock" SASSI analyses, which are compared to the results of the ANSYS model analysis, show that the peaks of the transfer functions occur at frequencies that are very close to the frequencies of the predominant modes calculated by the modal analysis. Table 3NN-11 presents the frequencies that characterize the different modes of response of the structural models. In the table, the results of the two verification SASSI analyses are compared with the results of the fixed base modal analysis of the model presented in Appendix 3H. RCOL2_03.08.04-56

3NN.4 Seismic Analysis Results

The buildings surrounding the R/B (including FH/A), PCCV, and containment internal structures are separated by expansion joints to prevent their interaction during an earthquake. A part of the building foundation is embedded in backfill of engineered granular material. The site-specific SSI analyses address the effects of these site-specific conditions by considering both surface foundation and foundation basement embedded in backfill that is modeled as infinite in the horizontal direction. Seven sets of SASSI analyses are performed that consider the following site conditions:

1. SLB - Foundation without backfill resting on the surface of the rock subgrade profile with LB properties.
2. SBE - Foundation without backfill resting on the surface of the rock subgrade profile with BE properties.
3. SUB - Foundation without backfill resting on the surface the rock subgrade profile with UB properties.
4. ELB - Foundation embedded in backfill with LB properties resting on the surface of the rock subgrade profile with LB properties.
5. EBE - Foundation embedded in backfill with BE properties resting on the surface of the rock subgrade profile with BE properties.
6. EUB - Foundation embedded in backfill with UB properties resting on the surface of the rock subgrade profile with UB properties.
7. EHB - Foundation embedded in backfill with high bound HB properties resting on the surface of the rock subgrade profile with UB properties.

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-57

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsections 3.8.4.4.3.1, "ESWPT", 3.8.4.4.3.2, "UHSRS", and 3.8.4.4.3.3, "PSFSVs", which reference Appendices 3LL, 3KK, and 3MM, respectively. Each of these appendices reference Appendix 3NN, "Model Properties and Seismic Analysis Results R/B-PCCV-Containment Internal Structure".

In Appendix 3NN, Section 3NN.3, "SASSI Model Description and Analysis Approach," the third paragraph (Page 3NN-3) states that "All of the modeling characteristics present in the standard plant lumped mass stick models for the R/B-PCCV-containment internal structure are the same as for the SASSI model, with the exception of minor adjustments for compatibility with SASSI, described as follows. The rigid links in the lumped mass stick models that connect different nodal points at the same floor elevation are replaced with SASSI 3D beam elements with high stiffness properties."

The applicant is requested to provide the rationale for replacing the rigid links with the 3D beam elements with high stiffness properties. Isn't that like using the 3D beam elements with high stiffness in trying to simulate the rigid link behavior?

ANSWER:

ACS SASSI does not have rigid link capability. Instead, 3D beam elements with a high stiffness are used to simulate rigid link behavior for the R/B-PCCV-containment internal structure SASSI model. This is a typical modeling practice for modeling rigid links in SASSI applications. The stiffness properties of the rigid beams are adjusted to ensure accuracy of the results. The validation of the SASSI model, where the results of SASSI analyses of the building resting on the surface of a hard half-space are compared with the results of ANSYS fixed base analyses of lumped mass stick models, demonstrates the accuracy of the rigid link modeling. The wording of the paragraph quoted above from FSAR Section 3NN.3 has been revised to reflect this response.

With respect to the ESWPT, UHSRS, and PSFSV models, lumped mass stick models are not used in the SASSI analyses. FSAR Appendices 3LL, 3KK, and 3MM refer to FSAR Appendix 3NN for descriptions of the backfill and subgrade properties, and for descriptions of how those properties are developed from site response analyses.

Impact on R-COLA

See attached marked-up FSAR Revision 1 pages 3NN-4 and 3NN-5.

Impact on S-COLA

None.

Impact on DCD

None.

~~that are used as input in the SASSI analyses of embedded foundation. The outcrop horizontal time histories are used as input for the SASSI analyses of surface foundations.~~The outcrop horizontal time histories are used directly as input for the SASSI analyses of surface foundations applied at the FIRS bottom of foundation elevation. The analyses of embedded foundation use "within" motion input time histories that are also applied at the FIRS input elevation. The "within" motions are obtained from a set of site response analyses, separate from these documented in Subsection 2.5.4, that are performed on a soil column consisting of the rock subgrade and the backfill, for purposes of embedded foundation SSI analysis. The design motion is applied to the soil column as layer outcrop motion at the FIRS elevation in order to calculate the within-layer motion. These site response analyses provides for each considered backfill profile, two horizontal acceleration time histories (East-West and North-South) of the design motion within the top limestone rock layer that are used as input in the SASSI analyses of embedded foundations. The time history of the vertical outcrop accelerations serves as input for both surface and embedded foundations. ~~The time step of the acceleration time histories used as input for the SASSI analysis is 0.005 sec.~~ RCOL2_03.08.04-54

3NN.3 SASSI Model Description and Analysis Approach

Figure 3NN-7 shows the three-dimensional SASSI FE model used for site-specific seismic analysis of the US-APWR R/B-PCCV-containment internal structure of Units 3 and 4. The SASSI structural model uses lumped-mass-stick models of the PCCV, containment internal structure, and R/B to represent the stiffness and mass inertia properties of the building above the ground elevation. A three-dimensional (3D) FE model, presented in Figure 3NN-8, represents the building basement and the floor slabs at ground elevation.

The model is established with reference to the Cartesian coordinate system with origin established 2 ft.-7 in. below the ground surface elevation at the center of the PCCV foundation. The origin location corresponds to the location of the coordinate system used as reference for the seismic analysis of the standard plant presented in Section 3.7. The orientation of the Z-axis is upward. The orientation of the standard plant model is modified such that the positive X-axis is oriented northward and the Y-axis is oriented westward.

The geometry and the properties of the lumped-mass-stick models 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. SASSI 3D beam and spring elements with cross sectional properties identical to those of the standard plant models represent stiffness properties. All of the modeling characteristics present in the standard plant lumped mass stick models for the R/B-PCCV-containment internal structure are the same as for the SASSI model, with the exception of minor adjustments for compatibility with SASSI, described as follows. Because SASSI does not have rigid link capability, ~~T~~the rigid links in the lumped mass stick models that connect different nodal points at the same floor elevation are replaced with SASSI 3D beam elements with high stiffness properties. The 3D beam elements RCOL2_03.08.04-57 RCOL2_03.08.04-57

reproduce the rigid link behavior present in the standard plant lumped mass stick models. RCOL2_03.08.04-57

The major coordinates that define the geometry of the FE basement model are listed in Table 3NN-2 to Table 3NN-5. 3NN-6 presents the types of SASSI finite elements used to model the different structural members in the basement model. The table also presents the ~~stiffness and mass inertia~~material properties (modulus of elasticity and weight density) assigned to each group of finite elements. The ~~stiffness and damping~~ properties assigned to each material of the SASSI model are listed in Table 3NN-7. The site-specific SASSI analysis uses the operating-basis earthquake (OBE) damping values of Chapter 3, Table 3.7.1-3(b), which is consistent with the requirements of Section 1.2 of RG 1.61 (Reference 3NN-4) for structures on sites with low seismic responses where the analyses consider a relatively narrow range of site-specific subgrade conditions. RCOL2_03.08.04-58

SASSI solid FE elements, shown in Figure 3NN-9, model the stiffness and mass inertia properties of the building basemat. The modeling of the thick central part of the basemat supporting the PCCV and containment internal structure is simplified to minimize the size of the SASSI model as shown in Figure 3NN-10. Rigid shell elements connect the thick portion of the basemat with the floor slabs at the ground elevation. Rigid 3D beam elements connect the PCCV and containment internal structure lumped-mass stick models to the rigid shell elements as shown in Figure 3NN-13 and Figure 3NN-14. Massless shell elements are added at the top of the basemat solid element to accurately model the bending stiffness of the central part of the mat. Figure 3NN-11 shows the solid FE elements representing the stiffness and mass inertia of the fill concrete placed under the central elevated part of the basemat and under the surface mat at the northeast corner of the building.

SASSI 3D shell elements model the basement shear walls, the surface mat under the northeast corner of the R/B, and the R/B slabs at ground floor elevation. The elastic modulus and unit weight assigned to the material of the shell elements modeling the R/B basement shear walls shown in Figure 3NN-12 are adjusted to account for the different height of walls and reductions of stiffness due to the openings. Table 3NN-8 lists the adjusted material properties assigned to the shell elements of the walls with openings.

Rigid 3D beam elements connect the top of the basement shear walls with lumped-mass stick model representing the above ground portion of the R/B and FH/A. This modeling approach enables the R/B-FH/A to be connected to the flexible part of the building basement and decoupled from the thick central part that serves as foundation to the PCCV and containment internal structure part of the building.

The layering of the backfill profiles is modified in order to match the geometry of the mesh of the SASSI basemat model described above. The S-wave and P-wave velocities of the backfill (Vs and Vp) are adjusted using an equivalent arrival time methodology as follows: RCOL2_03.08.04-43 RCOL2_03.08.04-53

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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-58

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsections 3.8.4.4.3.1, "ESWPT", 3.8.4.4.3.2, "UHSRS", and 3.8.4.4.3.3, "PSFSVs", which reference Appendices 3LL, 3KK, and 3MM, respectively. Each of these appendices reference Appendix 3NN, "Model Properties and Seismic Analysis Results R/B-PCCV-Containment Internal Structure".

In Appendix 3NN, Section 3NN.3, "SASSI Model Description and Analysis Approach," the fourth paragraph (Page 3NN-3) states that "Table 3NN-6 presents the types of SASSI finite elements used to model the different structural members in the basement model. The table also presents the stiffness and mass inertia properties assigned to each group of finite elements."

The applicant is requested to provide the following information:

(a) The data in Table 3NN-6 indicate that shell elements are used for walls and solid elements are used for basemat and fill concrete. Explain how the shell elements are connected to the solid elements. The shell element has six degrees of freedom per node; whereas, the solid element has three degrees of-freedom per node.

(b) The second sentence of the above quoted paragraph states that Table 3NN-6 also presents the stiffness and mass inertia properties assigned to each group of finite elements. One example in the table is the data presented under NS Exterior Walls. The entries for "Mass" and "Stiffness" in the table are "Concrete (adjusted)" and "Concrete fc=4000 psi (adjusted)," respectively. This information is confusing. Concrete fc=4000 psi is the 28-day concrete compression strength, not the stiffness. Provide the actual data used in the model for "Mass" and "Stiffness."

ANSWER:

(a) The shell element used has five degrees of freedom per node (three translational degrees, two bending degrees and no drilling degree of freedom). Shell elements are connected to the brick elements at shared nodes.

The ESWPT, UHSRS, and PSFSV structures are primarily composed of plate elements representing slabs and walls. Brick elements are used only to represent the soil or structural fill. The slabs and walls are designed to carry moments and the plate elements are used for calculating the design moments. The elastic soil or fill is modeled by brick elements and intended to resist only forces. In no instance in these models is a plate element connected to a structural member represented by brick element for the purpose of transferring moment.

(b) FSAR Section 3NN.3 and Table 3NN-6 have been revised to show the values of the modulus of elasticity and weight densities for the different members of the basement model.

The geometry of some structural members in the FE model of the R/B complex basement differs from actual dimensions to help simplify the model and reduce the size of the FE model. The material properties assigned to these structural members are adjusted to accurately model the overall dynamic properties of the basement.

The layer of solid elements modeling the R/B basemat is thicker (h_{fe} = 13.333 ft) than the actual combined thickness of the basemat and the concrete fill (h_{mat} =11.083 ft). The concrete material properties shown in Table 3NN-8 were developed as follows to account for this geometrical difference:

$$E_{fe} = E_c \times (h_{mat}/h_{fe})^3 = 5.191 \times 10^5 \times (11.083/13.333)^3 = 2.982 \times 10^5 \text{ ksf}$$

$$w_{fe} = w_c \times (h_{mat}/h_{fe}) = 0.150 \times (11.083/13.333) = 0.125 \text{ kcf}$$

The elements modeling the floor under the tendon gallery are corrected as follows to account for the actual floor thickness (h_{tg} =11.5 ft):

$$E_{fe} = E_c \times (h_{tg}/h_{fe})^3 = 5.191 \times 10^5 \times (11.50/13.333)^3 = 4.209 \times 10^5 \text{ ksf}$$

$$w_{fe} = w_c \times (h_{tg}/h_{fe}) = 0.150 \times (11.50/13.333) = 0.140 \text{ kcf}$$

The following formulas are used to adjust the material properties assigned to the finite elements of the shear walls in order to account for the difference between the actual height of the walls (h_w) and the height of the FE model walls (h_{fe} = 26.67 ft):

$$E_{fe} = E_c \times (h_{fe}/h_w) \qquad w_{fe} = w_c \times (h_{mat}/h_{fe})$$

The coarse FE mesh of the basement model does not permit the accurate modeling of the openings of the walls. A set of FE analyses is performed using ANSYS to obtain the stiffness reduction factors needed to adjust the material properties to account for the reduced stiffness of the shear walls with openings. The correction factors are obtained by comparing the results obtained from the static analysis of two detailed solid FE models shown in the figure below: Figure 1 (Model A) represents the actual geometry of the wall with openings, and Figure 2 (Model B) representing the wall without openings. Unit displacements are applied at the top of each model in both the in-plane and the out of plane directions, to calculate corresponding reactions that indicate the in-plane and out-of-plane wall stiffness. The ratio between the reaction obtained from Figure 1 and Figure 2 is used to determine stiffness reduction factors to adjust the elastic modulus of the wall material.

FE Models to Calculate Wall Stiffness Reduction Factors

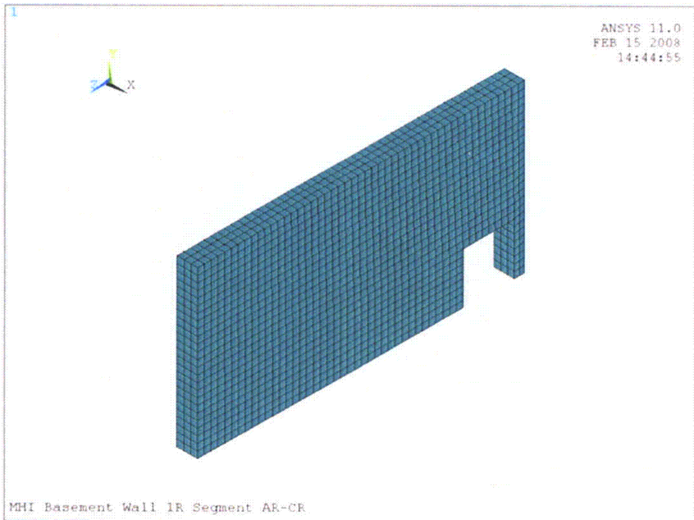


Figure 1 Model A of Actual Wall

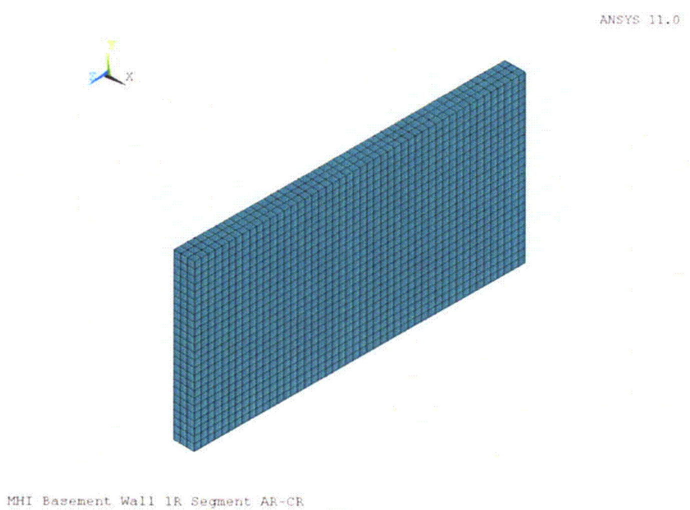


Figure 2 Model B of Wall in SASSI Model

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

See attached marked-up FSAR Revision 1 pages 3NN-5 and 3NN-14.

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

None.

<u>Impact on DCD</u>

None.

reproduce the rigid link behavior present in the standard plant lumped mass stick models. RCOL2_03.08.04-57

The major coordinates that define the geometry of the FE basement model are listed in Table 3NN-2 to Table 3NN-5. 3NN-6 presents the types of SASSI finite elements used to model the different structural members in the basement model. The table also presents the ~~stiffness and mass inertia~~material properties (modulus of elasticity and weight density) assigned to each group of finite elements. The ~~stiffness and damping~~ properties assigned to each material of the SASSI model are listed in Table 3NN-7. The site-specific SASSI analysis uses the operating-basis earthquake (OBE) damping values of Chapter 3, Table 3.7.1-3(b), which is consistent with the requirements of Section 1.2 of RG 1.61 (Reference 3NN-4) for structures on sites with low seismic responses where the analyses consider a relatively narrow range of site-specific subgrade conditions. RCOL2_03.08.04-58

SASSI solid FE elements, shown in Figure 3NN-9, model the stiffness and mass inertia properties of the building basemat. The modeling of the thick central part of the basemat supporting the PCCV and containment internal structure is simplified to minimize the size of the SASSI model as shown in Figure 3NN-10. Rigid shell elements connect the thick portion of the basemat with the floor slabs at the ground elevation. Rigid 3D beam elements connect the PCCV and containment internal structure lumped-mass stick models to the rigid shell elements as shown in Figure 3NN-13 and Figure 3NN-14. Massless shell elements are added at the top of the basemat solid element to accurately model the bending stiffness of the central part of the mat. Figure 3NN-11 shows the solid FE elements representing the stiffness and mass inertia of the fill concrete placed under the central elevated part of the basemat and under the surface mat at the northeast corner of the building.

SASSI 3D shell elements model the basement shear walls, the surface mat under the northeast corner of the R/B, and the R/B slabs at ground floor elevation. The elastic modulus and unit weight assigned to the material of the shell elements modeling the R/B basement shear walls shown in Figure 3NN-12 are adjusted to account for the different height of walls and reductions of stiffness due to the openings. Table 3NN-8 lists the adjusted material properties assigned to the shell elements of the walls with openings.

Rigid 3D beam elements connect the top of the basement shear walls with lumped-mass stick model representing the above ground portion of the R/B and FH/A. This modeling approach enables the R/B-FH/A to be connected to the flexible part of the building basement and decoupled from the thick central part that serves as foundation to the PCCV and containment internal structure part of the building.

The layering of the backfill profiles is modified in order to match the geometry of the mesh of the SASSI basemat model described above. The S-wave and P-wave velocities of the backfill (Vs and Vp) are adjusted using an equivalent arrival time methodology as follows: RCOL2_03.08.04-43 RCOL2_03.08.04-53

Table 3NN-6

Finite Elements Assigned to Basement Model

RCOL2_03.08.04-58

Structural Member	Element	Mass	~~Stiffness~~ Material	Young's Modulus, E ($x10^{-5}$ ksf)	Weight Density (kcf)
Upper Portion of Reactor Mat	Shell	Weightless	Concrete f_c=4000psi	5.191	N/A
Fuel Handling Area Surface Basemat	Shell	Weightless	Concrete f_c =4000psi	5.191	N/A
NS Exterior Walls	Shell	Concrete (adjusted)	Concrete f_c =4000psi (adjusted)	Varies with Location of Wall	Varies with Location of Wall
EW Exterior Walls	Shell	Concrete (adjusted)	Concrete f_c =4000psi (adjusted)	Varies with Location of Wall	Varies with Location of Wall
NS Basement Inner Shear Walls	Shell	Concrete (adjusted)	Concrete f_c =4000psi (adjusted)	Varies with Location of Wall	Varies with Location of Wall
EW Basement Inner Shear Walls	Shell	Concrete (adjusted)	Concrete f_c =4000psi (adjusted)	Varies with Location of Wall	Varies with Location of Wall
Connecting Shells	Shell	Weightless	Rigid	N/A	N/A
Ground Floor Slabs	Shell	~~Weightless~~ Concrete	Concrete f_c =4000psi	5.191	0.15
Tendon Gallery Floor	Shell	Concrete (adjusted)	Concrete f_c =4000psi (adjusted)	4.209	0.14
Basemat	Solid	Concrete (adjusted)	Concrete f_c =4000psi (adjusted)	2.982	0.125
Fill Concrete	Solid	Concrete	Concrete f_c =3000psi	4.496	0.15
Rigid Rim at top of Reactor Mat	Beam	Weightless	Rigid	N/A	N/A
PCCV stick Rigid Connection	Beam	Weightless	Rigid	N/A	N/A
Containment Internal Structure Stick Rigid Connection	Beam	Weightless	Rigid	N/A	N/A
R/B-Fuel Handling Area Stick Rigid Connection	Beam	Weightless	Rigid	N/A	N/A
BS01 Lumped Mass Rigid Connection	Beam	Weightless	Rigid	N/A	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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-59

This Request for Additional Information (RAI) is necessary for the staff to determine if the application meets the requirements of General Design Criteria (GDC) 2.

CP COL 3.8(29) in CPNPP COL FSAR inserts subsections 3.8.4.4.3.1, "ESWPT", 3.8.4.4.3.2, "UHSRS", and 3.8.4.4.3.3, "PSFSVs", which reference Appendices 3LL, 3KK, and 3MM, respectively. Each of these appendices reference Appendix 3NN, "Model Properties and Seismic Analysis Results R/B-PCCV-Containment Internal Structure".

In Appendix 3NN, Section 3NN.4, "Seismic Analysis Results," the third paragraph (Page 3NN-6) states that "Table 3NN-12, Table 3NN-13, and Table 3NN-14 present maximum absolute accelerations (zero period acceleration values) at lumped-mass locations of the R/B-PCCV-containment internal structure in NS, EW, and vertical direction,
respectively. The results obtained from each set of SASSI analysis are listed together with the enveloped value from all of the considered site conditions."

The applicant is requested to provide, in these tables, the corresponding values of the maximum absolute accelerations of the analysis in the US-APWR DCD.

ANSWER:

DCD Appendix 3H, Tables 3H.3-5 through 3H.3-8 provide the maximum accelerations for the R/B-PCCV-Containment Internal Structure Lumped Mass Stick Model for soil subgrades with V_s = 1,000 ft/s, 3,500 ft/s, 6,500 ft/s, and 8,000 ft/s, respectively. These tables are shown below for comparison with CPNPP FSAR Tables 3NN-12 through 3NN-14. FSAR Tables 3NN-12 through 3NN-14 have been revised to incorporate this response.

Impact on R-COLA

See attached marked-up FSAR Revision 1 pages 3NN-19, 3NN-20, 3NN-21, 3NN-22, 3NN-23, and 3NN-24.

Impact on S-COLA

None.

Impact on DCD

None.

Attachments

Table 3H.3-5	R/B-PCCV-Containment Internal Structure Lumped Mass Stick Model, Maximum Accelerations – Soil Subgrade (V_s = 1,000 ft/s)
Table 3H.3-6	R/B-PCCV-Containment Internal Structure Lumped Mass Stick Model, Maximum Accelerations – Rock Subgrade (Vs = 3,500 ft/s)
Table 3H.3-7	R/B-PCCV-Containment Internal Structure Lumped Mass Stick Model, Maximum Accelerations – Rock Subgrade (V_s = 6,500 ft/s)
Table 3H.3-8	R/B-PCCV-Containment Internal Structure Lumped Mass Stick Model, Maximum Accelerations – Hard Rock Subgrade (Vs = 8,000 ft/s)

Table 3H.3-5 R/B-PCCV-Containment Internal Structure Lumped Mass Stick Model, Maximum Accelerations – Soil Subgrade (V_s = 1,000 ft/s)

Model	Mass Node	Max. N-S Acc. (g)				Max. E-W Acc. (g)				Max. Vert. Acc. (g)			
		Earthquake				Earthquake				Earthquake			
		H1	H2	V	3-C*	H1	H2	V	3-C*	H1	H2	V	3-C*
R/B	FH08	0.48	0.01	0.09	0.49	0.01	0.49	0.02	0.49	0.17	0.05	0.32	0.36
	FH07	0.43	0.01	0.07	0.43	0.01	0.44	0.02	0.44	0.17	0.05	0.31	0.36
	FH06	0.39	0.01	0.04	0.39	0.01	0.39	0.01	0.39	0.17	0.05	0.30	0.35
	RE41	0.39	0.02	0.04	0.39	0.04	0.40	0.06	0.41	0.06	0.21	0.32	0.39
	RE42	0.39	0.03	0.03	0.39	0.03	0.40	0.03	0.40	0.02	0.21	0.30	0.37
	RE05	0.40	0.01	0.04	0.40	0.01	0.44	0.02	0.44	0.17	0.02	0.31	0.35
	RE04	0.38	0.01	0.02	0.38	0.01	0.41	0.01	0.41	0.17	0.01	0.30	0.35
	RE03	0.36	0.00	0.02	0.36	0.00	0.36	0.01	0.36	0.03	0.01	0.29	0.29
	RE02	0.34	0.00	0.02	0.34	0.00	0.33	0.01	0.33	0.02	0.00	0.28	0.28
	RE01	0.32	0.00	0.01	0.32	0.00	0.32	0.01	0.32	0.01	0.00	0.27	0.27
PCCV	CV11	0.57	0.01	0.07	0.57	0.00	0.77	0.02	0.77	0.03	0.01	0.36	0.37
	CV10	0.56	0.01	0.07	0.56	0.00	0.76	0.02	0.76	0.02	0.01	0.35	0.35
	CV09	0.52	0.00	0.06	0.52	0.00	0.68	0.01	0.68	0.02	0.01	0.33	0.33
	CV08	0.48	0.00	0.05	0.48	0.00	0.59	0.01	0.59	0.02	0.01	0.31	0.31
	CV07	0.45	0.00	0.05	0.45	0.00	0.54	0.01	0.54	0.01	0.01	0.31	0.31
	CV06	0.42	0.01	0.04	0.42	0.00	0.48	0.01	0.48	0.01	0.01	0.30	0.30
	CV05	0.39	0.01	0.04	0.39	0.00	0.43	0.01	0.43	0.01	0.00	0.29	0.29
	CV04	0.38	0.01	0.03	0.38	0.00	0.39	0.01	0.39	0.01	0.00	0.28	0.28
	CV03	0.37	0.01	0.03	0.37	0.00	0.37	0.01	0.37	0.01	0.00	0.28	0.28
	CV02	0.35	0.01	0.02	0.35	0.00	0.34	0.01	0.34	0.01	0.00	0.27	0.27
	CV01	0.32	0.00	0.02	0.32	0.00	0.31	0.01	0.31	0.01	0.00	0.27	0.27
Containment Internal Structure	IC09	0.51	0.01	0.07	0.52	0.01	0.58	0.05	0.58	0.07	0.01	0.31	0.32
	IC08	0.44	0.00	0.04	0.44	0.00	0.49	0.03	0.49	0.07	0.01	0.31	0.31
	IC18	0.44	0.00	0.04	0.44	0.00	0.48	0.03	0.48	0.07	0.01	0.31	0.31
	IC61	0.38	0.01	0.05	0.38	0.01	0.40	0.02	0.40	0.02	0.11	0.28	0.30
	IC62	0.38	0.02	0.04	0.38	0.01	0.40	0.02	0.40	0.02	0.11	0.28	0.30
	IC05	0.36	0.00	0.03	0.36	0.00	0.37	0.01	0.37	0.02	0.00	0.28	0.28
	IC15	0.35	0.00	0.03	0.35	0.00	0.34	0.01	0.34	0.01	0.00	0.27	0.27
	IC04	0.34	0.00	0.03	0.34	0.00	0.33	0.01	0.33	0.01	0.01	0.27	0.27
	IC14	0.34	0.00	0.03	0.34	0.00	0.33	0.01	0.33	0.01	0.01	0.27	0.27
	IC03	0.33	0.00	0.02	0.33	0.00	0.32	0.01	0.32	0.01	0.00	0.26	0.26
	IC02	0.32	0.00	0.02	0.32	0.00	0.32	0.01	0.32	0.01	0.00	0.26	0.26
	IC01	0.31	0.00	0.01	0.31	0.00	0.31	0.00	0.31	0.01	0.00	0.26	0.26

*: combined by SRSS method

Table 3H.3-6 R/B-PCCV-Containment Internal Structure Lumped Mass Stick Model, Maximum Accelerations – Rock Subgrade (Vs = 3,500 ft/s)

Model	Mass Node	Max. N-S Acc. (g)				Max. E-W Acc. (g)				Max. Vert. Acc. (g)			
		Earthquake				Earthquake				Earthquake			
		H1	H2	V	3-C*	H1	H2	V	3-C*	H1	H2	V	3-C*
R/B	FH08	1.68	0.03	0.24	1.70	0.06	0.99	0.09	1.00	0.41	0.11	0.56	0.70
	FH07	1.00	0.03	0.18	1.02	0.04	0.83	0.07	0.83	0.40	0.12	0.53	0.67
	FH06	0.70	0.03	0.11	0.71	0.03	0.72	0.06	0.72	0.39	0.11	0.50	0.64
	RE41	0.62	0.11	0.19	0.65	0.18	0.81	0.22	0.86	0.18	0.42	0.53	0.70
	RE42	0.63	0.08	0.13	0.65	0.15	0.74	0.12	0.76	0.08	0.43	0.49	0.65
	RE05	0.71	0.07	0.18	0.73	0.04	0.83	0.07	0.83	0.43	0.07	0.48	0.65
	RE04	0.64	0.04	0.11	0.65	0.03	0.77	0.04	0.77	0.43	0.03	0.45	0.62
	RE03	0.56	0.02	0.10	0.57	0.01	0.65	0.05	0.65	0.09	0.03	0.39	0.40
	RE02	0.49	0.01	0.08	0.50	0.01	0.54	0.04	0.55	0.04	0.01	0.37	0.38
	RE01	0.46	0.01	0.06	0.47	0.01	0.48	0.03	0.48	0.03	0.01	0.35	0.35
PCCV	CV11	1.96	0.03	0.13	1.96	0.03	1.82	0.06	1.82	0.08	0.04	0.89	0.89
	CV10	1.93	0.03	0.13	1.93	0.02	1.79	0.06	1.79	0.07	0.04	0.77	0.78
	CV09	1.76	0.02	0.10	1.76	0.02	1.65	0.04	1.65	0.05	0.03	0.67	0.68
	CV08	1.52	0.01	0.08	1.52	0.01	1.45	0.02	1.45	0.04	0.02	0.61	0.61
	CV07	1.28	0.01	0.07	1.28	0.01	1.25	0.03	1.25	0.04	0.02	0.59	0.59
	CV06	1.03	0.02	0.06	1.04	0.02	1.04	0.03	1.04	0.04	0.02	0.54	0.54
	CV05	0.85	0.02	0.08	0.85	0.02	0.87	0.03	0.87	0.04	0.02	0.50	0.50
	CV04	0.74	0.02	0.08	0.74	0.01	0.76	0.03	0.76	0.03	0.01	0.47	0.47
	CV03	0.68	0.02	0.08	0.68	0.01	0.71	0.03	0.71	0.03	0.01	0.45	0.45
	CV02	0.56	0.02	0.08	0.57	0.01	0.60	0.03	0.60	0.03	0.01	0.42	0.42
	CV01	0.46	0.01	0.07	0.47	0.01	0.47	0.02	0.47	0.02	0.01	0.37	0.37
Containment Internal Structure	IC09	2.21	0.04	0.30	2.23	0.08	2.07	0.19	2.08	0.28	0.03	0.47	0.54
	IC08	1.28	0.02	0.13	1.29	0.05	1.21	0.11	1.22	0.27	0.02	0.45	0.53
	IC18	1.22	0.01	0.12	1.23	0.04	1.16	0.11	1.17	0.26	0.02	0.45	0.52
	IC61	0.70	0.08	0.20	0.73	0.03	0.88	0.11	0.89	0.06	0.22	0.40	0.45
	IC62	0.69	0.08	0.21	0.72	0.03	0.88	0.07	0.89	0.06	0.21	0.40	0.46
	IC05	0.61	0.02	0.15	0.63	0.01	0.65	0.04	0.65	0.05	0.01	0.38	0.38
	IC15	0.55	0.01	0.13	0.57	0.01	0.56	0.03	0.56	0.04	0.01	0.37	0.37
	IC04	0.52	0.01	0.12	0.53	0.01	0.51	0.03	0.51	0.04	0.01	0.37	0.37
	IC14	0.50	0.01	0.10	0.51	0.01	0.50	0.03	0.50	0.03	0.01	0.37	0.37
	IC03	0.47	0.01	0.08	0.48	0.01	0.47	0.03	0.47	0.03	0.01	0.36	0.36
	IC02	0.45	0.01	0.06	0.45	0.01	0.46	0.02	0.46	0.02	0.01	0.35	0.35
	IC01	0.44	0.01	0.05	0.44	0.01	0.45	0.02	0.45	0.02	0.01	0.34	0.34

*: combined by SRSS method

Table 3H.3-7 R/B-PCCV-Containment Internal Structure Lumped Mass Stick Model, Maximum Accelerations – Rock Subgrade (V_s = 6,500 ft/s)

Model	Mass Node	Max. N-S Acc. (g) Earthquake				Max. E-W Acc. (g) Earthquake				Max. Vert. Acc. (g) Earthquake			
		H1	H2	V	3-C*	H1	H2	V	3-C*	H1	H2	V	3-C*
R/B	FH08	2.19	0.04	0.35	2.21	0.08	1.17	0.13	1.18	0.55	0.18	0.79	0.98
	FH07	1.20	0.05	0.25	1.23	0.05	0.91	0.10	0.91	0.53	0.18	0.73	0.92
	FH06	0.61	0.04	0.16	0.63	0.04	0.79	0.08	0.80	0.51	0.16	0.69	0.87
	RE41	0.54	0.23	0.31	0.66	0.27	0.94	0.39	1.05	0.23	0.60	0.74	0.97
	RE42	0.60	0.20	0.23	0.67	0.28	0.86	0.22	0.93	0.16	0.64	0.65	0.92
	RE05	0.67	0.14	0.32	0.76	0.09	0.95	0.11	0.96	0.60	0.11	0.65	0.89
	RE04	0.61	0.09	0.19	0.64	0.06	0.86	0.06	0.86	0.60	0.05	0.60	0.84
	RE03	0.51	0.04	0.15	0.53	0.03	0.65	0.06	0.66	0.14	0.05	0.51	0.53
	RE02	0.46	0.04	0.15	0.48	0.03	0.58	0.07	0.58	0.07	0.03	0.45	0.46
	RE01	0.41	0.03	0.12	0.42	0.03	0.47	0.05	0.47	0.04	0.02	0.39	0.39
PCCV	CV11	2.02	0.05	0.18	2.03	0.04	2.15	0.08	2.15	0.16	0.07	1.42	1.43
	CV10	1.99	0.05	0.17	1.99	0.04	2.11	0.08	2.11	0.13	0.06	1.28	1.29
	CV09	1.80	0.03	0.13	1.81	0.02	1.90	0.05	1.90	0.08	0.04	0.97	0.98
	CV08	1.55	0.01	0.08	1.55	0.01	1.60	0.03	1.60	0.07	0.03	0.85	0.85
	CV07	1.30	0.02	0.11	1.30	0.02	1.41	0.05	1.41	0.06	0.03	0.80	0.81
	CV06	1.09	0.03	0.10	1.09	0.03	1.21	0.06	1.21	0.06	0.03	0.72	0.72
	CV05	0.90	0.03	0.12	0.91	0.03	1.03	0.06	1.03	0.05	0.02	0.64	0.65
	CV04	0.77	0.03	0.13	0.78	0.03	0.90	0.06	0.90	0.04	0.02	0.59	0.59
	CV03	0.69	0.03	0.13	0.71	0.03	0.82	0.05	0.82	0.04	0.02	0.56	0.56
	CV02	0.56	0.03	0.11	0.57	0.03	0.66	0.04	0.66	0.04	0.01	0.49	0.49
	CV01	0.43	0.02	0.08	0.44	0.02	0.46	0.04	0.46	0.03	0.01	0.39	0.39
Containment Internal Structure	IC09	2.73	0.07	0.44	2.77	0.10	2.85	0.24	2.86	0.54	0.05	0.53	0.76
	IC08	1.50	0.02	0.18	1.51	0.04	1.61	0.11	1.61	0.52	0.05	0.50	0.72
	IC18	1.43	0.02	0.17	1.44	0.04	1.53	0.10	1.54	0.52	0.05	0.49	0.71
	IC61	1.09	0.11	0.34	1.15	0.07	1.21	0.14	1.22	0.13	0.31	0.45	0.56
	IC62	1.09	0.12	0.31	1.14	0.06	1.21	0.12	1.22	0.13	0.32	0.45	0.57
	IC05	0.88	0.04	0.22	0.91	0.03	0.84	0.06	0.84	0.11	0.03	0.42	0.44
	IC15	0.70	0.03	0.16	0.72	0.02	0.64	0.05	0.64	0.08	0.02	0.40	0.41
	IC04	0.62	0.02	0.16	0.64	0.02	0.57	0.05	0.57	0.07	0.02	0.39	0.40
	IC14	0.57	0.02	0.15	0.59	0.02	0.52	0.05	0.53	0.06	0.02	0.38	0.39
	IC03	0.47	0.01	0.12	0.48	0.02	0.44	0.05	0.45	0.04	0.01	0.37	0.37
	IC02	0.41	0.02	0.10	0.42	0.02	0.40	0.05	0.41	0.03	0.01	0.35	0.35
	IC01	0.39	0.02	0.09	0.40	0.02	0.39	0.05	0.39	0.03	0.01	0.34	0.34

*: combined by SRSS method

Table 3H.3-8 R/B-PCCV-Containment Internal Structure Lumped Mass Stick Model, Maximum Accelerations – Hard Rock Subgrade (Vs = 8,000 ft/s)

Model	Mass Node	Max. N-S Acc. (g)				Max. E-W Acc. (g)				Max. Vert. Acc. (g)			
		Earthquake				Earthquake				Earthquake			
		H1	H2	V	3-C*	H1	H2	V	3-C*	H1	H2	V	3-C*
R/B	FH08	1.59	0.03	0.36	1.63	0.08	1.14	0.12	1.14	0.49	0.21	1.11	1.23
	FH07	0.92	0.05	0.29	0.97	0.06	0.96	0.11	0.96	0.44	0.20	0.91	1.03
	FH06	0.54	0.06	0.24	0.59	0.06	0.78	0.10	0.78	0.41	0.18	0.74	0.86
	RE41	0.59	0.19	0.31	0.69	0.33	0.90	0.47	1.06	0.32	0.53	0.71	0.95
	RE42	0.62	0.17	0.22	0.68	0.23	0.86	0.26	0.93	0.11	0.51	0.63	0.82
	RE05	0.83	0.12	0.37	0.92	0.08	0.93	0.17	0.95	0.50	0.10	0.53	0.74
	RE04	0.70	0.09	0.20	0.74	0.06	0.84	0.09	0.84	0.48	0.06	0.48	0.68
	RE03	0.51	0.04	0.18	0.54	0.04	0.63	0.09	0.63	0.12	0.05	0.46	0.48
	RE02	0.41	0.04	0.16	0.44	0.04	0.49	0.11	0.51	0.05	0.03	0.40	0.41
	RE01	0.34	0.02	0.10	0.36	0.02	0.40	0.06	0.40	0.02	0.01	0.34	0.34
PCCV	CV11	1.35	0.00	0.00	1.35	0.00	1.32	0.00	1.32	0.00	0.00	1.39	1.39
	CV10	1.32	0.00	0.00	1.32	0.00	1.29	0.00	1.29	0.00	0.00	1.21	1.21
	CV09	1.17	0.00	0.00	1.17	0.00	1.18	0.00	1.18	0.00	0.00	0.92	0.92
	CV08	1.01	0.00	0.00	1.01	0.00	1.02	0.00	1.02	0.00	0.00	0.82	0.82
	CV07	0.96	0.00	0.00	0.96	0.00	0.84	0.00	0.84	0.00	0.00	0.77	0.77
	CV06	0.88	0.00	0.00	0.88	0.00	0.78	0.00	0.78	0.00	0.00	0.70	0.70
	CV05	0.80	0.00	0.00	0.80	0.00	0.73	0.00	0.73	0.00	0.00	0.63	0.63
	CV04	0.72	0.00	0.00	0.72	0.00	0.68	0.00	0.68	0.00	0.00	0.57	0.57
	CV03	0.67	0.00	0.00	0.67	0.00	0.64	0.00	0.64	0.00	0.00	0.54	0.54
	CV02	0.57	0.00	0.00	0.57	0.00	0.55	0.00	0.55	0.00	0.00	0.47	0.47
	CV01	0.41	0.00	0.00	0.41	0.00	0.41	0.00	0.41	0.00	0.00	0.37	0.37
Containment Internal Structure	IC09	2.43	0.01	0.23	2.44	0.02	2.71	0.01	2.71	0.62	0.02	0.82	1.03
	IC08	1.38	0.00	0.18	1.39	0.01	1.73	0.01	1.73	0.59	0.02	0.77	0.97
	IC18	1.31	0.00	0.17	1.32	0.01	1.67	0.01	1.67	0.59	0.02	0.76	0.96
	IC61	1.05	0.07	0.31	1.10	0.04	0.96	0.07	0.97	0.18	0.36	0.55	0.68
	IC62	1.05	0.08	0.30	1.09	0.04	1.00	0.08	1.00	0.17	0.36	0.55	0.68
	IC05	0.79	0.00	0.10	0.80	0.00	0.72	0.00	0.72	0.14	0.01	0.52	0.54
	IC15	0.65	0.00	0.15	0.66	0.00	0.57	0.01	0.57	0.11	0.01	0.47	0.49
	IC04	0.58	0.01	0.19	0.61	0.01	0.53	0.01	0.53	0.09	0.01	0.45	0.46
	IC14	0.54	0.01	0.18	0.56	0.00	0.49	0.01	0.49	0.08	0.01	0.43	0.43
	IC03	0.45	0.00	0.15	0.47	0.00	0.41	0.00	0.41	0.05	0.00	0.38	0.39
	IC02	0.37	0.00	0.08	0.38	0.00	0.35	0.00	0.35	0.03	0.00	0.34	0.34
	IC01	0.34	0.00	0.04	0.34	0.00	0.33	0.00	0.33	0.02	0.00	0.32	0.32

*: combined by SRSS method

Table 3NN-12 (Sheet 1 of 2)

Maximum Accelerations in NS Direction

RCOL2_03.07.02-8

RCOL2_03.08.04-59

Structure	Lumped Mass	El. (ft)	~~Site Profile~~Surface Foundation (g)				Embedded Foundation (g)					~~Env.~~	Embed. /Surf	Enveloped Accelerations (g)	Standard Plant Eneveloped Accelerations (g)
			SLB	SBE	SUB	Env.	ELB	EBE	EUB	EHB	Env.				
PCCV	CV11	230.2	0.496	0.595	0.722	0.72	0.495	0.493	0.661	0.653	0.66	~~0.722~~	92%	0.72	2.03
	CV10	225.0	0.481	0.586	0.707	0.71	0.481	0.485	0.648	0.639	0.65	~~0.707~~	92%	0.71	1.99
	CV09	201.7	0.434	0.540	0.629	0.63	0.409	0.446	0.582	0.569	0.58	~~0.629~~	93%	0.63	1.81
	CV08	173.1	0.384	0.476	0.559	0.56	0.346	0.395	0.508	0.505	0.51	~~0.559~~	91%	0.56	1.55
	CV07	145.6	0.374	0.407	0.494	0.49	0.335	0.341	0.448	0.446	0.45	~~0.494~~	91%	0.49	1.30
	CV06	115.5	0.356	0.375	0.417	0.42	0.321	0.305	0.374	0.380	0.38	~~0.417~~	91%	0.42	1.09
	CV05	92.2	0.324	0.342	0.346	0.35	0.295	0.284	0.311	0.321	0.32	~~0.346~~	93%	0.35	0.91
	CV04	76.4	0.292	0.306	0.313	0.31	0.268	0.260	0.281	0.293	0.29	~~0.313~~	94%	0.31	0.78
	CV03	68.3	0.272	0.286	0.293	0.29	0.251	0.244	0.264	0.275	0.28	~~0.293~~	94%	0.29	0.71
	CV02	50.2	0.223	0.235	0.239	0.24	0.207	0.204	0.217	0.227	0.23	~~0.239~~	95%	0.24	0.57
	CV01	25.3	0.163	0.159	0.164	0.16	0.154	0.147	0.139	0.158	0.16	~~0.164~~	96%	0.16	0.47
	CV00	1.9	0.129	0.124	0.128	0.13	0.114	0.126	0.123	0.118	0.13	~~0.129~~	98%	0.13	N/A
Containment Internal Structure	IC09	139.5	0.913	1.054	1.156	1.16	0.819	0.869	0.976	0.911	0.98	~~1.156~~	84%	1.16	2.77
	IC08	112.3	0.507	0.574	0.627	0.63	0.497	0.494	0.520	0.523	0.52	~~0.627~~	83%	0.63	1.51
	IC18	110.8	0.482	0.546	0.595	0.60	0.477	0.470	0.493	0.499	0.50	~~0.595~~	84%	0.60	1.44
	IC61	96.6	0.266	0.305	0.349	0.35	0.233	0.301	0.287	0.266	0.30	~~0.349~~	86%	0.35	1.15
	IC62	96.6	0.272	0.301	0.347	0.35	0.238	0.300	0.294	0.267	0.30	~~0.347~~	86%	0.35	1.14
	IC05	76.4	0.224	0.252	0.278	0.28	0.189	0.237	0.219	0.209	0.24	~~0.278~~	85%	0.28	0.91
	IC07	76.4	0.224	0.252	0.278	0.28	0.189	0.237	0.219	0.209	0.24	~~0.278~~	85%	0.28	N/A
	IC15	59.2	0.199	0.207	0.221	0.22	0.164	0.195	0.193	0.187	0.20	~~0.221~~	88%	0.22	0.72
	IC04	50.2	0.186	0.189	0.201	0.20	0.155	0.178	0.177	0.176	0.18	~~0.201~~	89%	0.20	0.64
	IC14	45.7	0.177	0.179	0.189	0.19	0.148	0.169	0.169	0.162	0.17	~~0.189~~	89%	0.19	0.59
	IC03	35.6	0.156	0.159	0.163	0.16	0.135	0.151	0.151	0.150	0.15	~~0.163~~	93%	0.16	0.48
	IC02	25.3	0.139	0.139	0.142	0.14	0.127	0.135	0.133	0.132	0.14	~~0.142~~	95%	0.14	0.45
	IC01	16.0	0.132	0.132	0.132	0.13	0.120	0.131	0.128	0.124	0.13	~~0.132~~	99%	0.13	0.44
	IC00	1.9	0.129	0.124	0.128	0.13	0.114	0.127	0.124	0.119	0.13	~~0.129~~	98%	0.13	N/A

Table 3NN-12 (Sheet 2 of 2)

Maximum Accelerations in NS Direction

RCOL2_03.07.02-8

RCOL2_03.08.04-59

Structure	Lumped Mass	El. (ft)	~~Site Profile~~Surface Foundation (g)				Embedded Foundation (g)								Standard Plant Eneveloped Accelerations (g)
			SLB	SBE	SUB	Env.	ELB	EBE	EUB	EHB	Env.	~~Env.~~	Embed. /Surf	Enveloped Accelerations (g)	
R/B-FH/A	FH08	154.5	0.606	0.701	0.780	0.78	0.586	0.892	0.742	0.723	0.89	~~0.892~~	114%	0.89	2.21
	FH07	125.7	0.384	0.444	0.506	0.51	0.396	0.557	0.450	0.472	0.56	~~0.557~~	110%	0.56	1.23
	RE05	115.5	0.218	0.250	0.277	0.28	0.210	0.252	0.325	0.260	0.33	~~0.325~~	117%	0.33	0.71
	RE04	101.0	0.192	0.213	0.254	0.25	0.175	0.209	0.307	0.228	0.31	~~0.307~~	121%	0.31	0.69
	RE41	101.0	0.205	0.229	0.263	0.26	0.189	0.217	0.303	0.238	0.30	~~0.303~~	115%	0.30	0.68
	RE42	101.0	0.209	0.232	0.283	0.28	0.190	0.225	0.298	0.236	0.30	~~0.298~~	105%	0.30	0.92
	FH06	101.0	0.247	0.289	0.322	0.32	0.239	0.331	0.284	0.295	0.33	~~0.331~~	103%	0.33	0.74
	RE03	76.4	0.178	0.191	0.222	0.22	0.162	0.189	0.233	0.195	0.23	~~0.233~~	105%	0.23	0.57
	RE02	50.2	0.163	0.173	0.183	0.18	0.144	0.174	0.190	0.163	0.19	~~0.190~~	104%	0.19	0.50
	RE01	25.3	0.144	0.154	0.159	0.16	0.136	0.155	0.157	0.136	0.16	~~0.159~~	99%	0.16	0.47
	RE00	3.6	0.127	0.125	0.127	0.13	0.115	0.118	0.126	0.121	0.13	~~0.127~~	99%	0.13	N/A

RCOL2_03.07.02-8
RCOL2_03.08.04-59

Table 3NN-13 (Sheet 1 of 2)
Maximum Accelerations in EW Direction

Structure	Lumped Mass	El. (ft)	~~Site Profile~~Surface Foundation (g)				Embedded Foundation (g)					~~Env.~~	Embed. /Surf	Enveloped Accelerations (g)	Standard Plant Eneveloped Accelerations (g)
			SLB	SBE	SUB	Env.	ELB	EBE	EUB	EHB	Env.				
PCCV	CV11	230.2	0.565	0.713	0.854	0.85	0.538	0.552	0.704	0.691	0.70	~~0.854~~	82%	0.85	2.15
	CV10	225.0	0.555	0.699	0.837	0.84	0.532	0.541	0.689	0.678	0.69	~~0.837~~	82%	0.84	2.11
	CV09	201.7	0.510	0.635	0.757	0.76	0.506	0.491	0.620	0.616	0.62	~~0.757~~	82%	0.76	1.90
	CV08	173.1	0.445	0.544	0.644	0.64	0.427	0.420	0.526	0.528	0.53	~~0.644~~	82%	0.64	1.60
	CV07	145.6	0.389	0.448	0.526	0.53	0.366	0.349	0.427	0.439	0.44	~~0.526~~	83%	0.53	1.41
	CV06	115.5	0.321	0.347	0.405	0.41	0.298	0.276	0.327	0.341	0.34	~~0.405~~	84%	0.41	1.21
	CV05	92.2	0.283	0.306	0.319	0.32	0.253	0.237	0.269	0.280	0.28	~~0.319~~	88%	0.32	1.03
	CV04	76.4	0.249	0.276	0.280	0.28	0.220	0.212	0.237	0.243	0.24	~~0.280~~	87%	0.28	0.90
	CV03	68.3	0.230	0.259	0.261	0.26	0.202	0.199	0.221	0.223	0.22	~~0.261~~	85%	0.26	0.82
	CV02	50.2	0.185	0.214	0.213	0.21	0.163	0.169	0.188	0.181	0.19	~~0.214~~	88%	0.21	0.66
	CV01	25.3	0.133	0.151	0.153	0.15	0.120	0.136	0.139	0.128	0.14	~~0.153~~	91%	0.15	0.47
	CV00	1.9	0.119	0.118	0.117	0.12	0.102	0.111	0.120	0.111	0.12	~~0.120~~	101%	0.12	N/A
Containment Internal Structure	IC09	139.5	0.920	1.034	1.108	1.11	0.790	0.965	1.054	0.937	1.05	~~1.108~~	95%	1.11	2.86
	IC08	112.3	0.511	0.561	0.622	0.62	0.480	0.540	0.569	0.552	0.57	~~0.622~~	91%	0.62	1.73
	IC18	110.8	0.484	0.532	0.593	0.59	0.461	0.514	0.541	0.527	0.54	~~0.593~~	91%	0.59	1.67
	IC61	96.6	0.333	0.353	0.373	0.37	0.241	0.279	0.294	0.287	0.29	~~0.373~~	79%	0.37	1.22
	IC62	96.6	0.333	0.353	0.373	0.37	0.241	0.279	0.294	0.287	0.29	~~0.373~~	79%	0.37	1.22
	IC05	76.4	0.254	0.260	0.262	0.26	0.189	0.218	0.223	0.232	0.23	~~0.262~~	89%	0.26	0.84
	IC07	76.4	0.256	0.264	0.266	0.27	0.198	0.212	0.216	0.226	0.23	~~0.266~~	85%	0.27	N/A
	IC15	59.2	0.192	0.197	0.204	0.20	0.167	0.182	0.184	0.200	0.20	~~0.204~~	98%	0.20	0.64
	IC04	50.2	0.175	0.180	0.182	0.18	0.159	0.173	0.170	0.183	0.18	~~0.183~~	101%	0.18	0.57
	IC14	45.7	0.164	0.168	0.168	0.17	0.150	0.164	0.159	0.171	0.17	~~0.171~~	102%	0.17	0.53
	IC03	35.6	0.144	0.146	0.146	0.15	0.130	0.146	0.134	0.143	0.15	~~0.146~~	100%	0.15	0.47
	IC02	25.3	0.126	0.131	0.128	0.13	0.112	0.129	0.127	0.124	0.13	~~0.131~~	98%	0.13	0.46
	IC01	16.0	0.123	0.124	0.123	0.12	0.107	0.119	0.123	0.118	0.12	~~0.124~~	99%	0.12	0.45
	IC00	1.9	0.119	0.118	0.117	0.12	0.102	0.111	0.120	0.112	0.12	~~0.120~~	101%	0.12	N/A

RCOL2_03.07.02-8

RCOL2_03.08.04-59

Table 3NN-13 (Sheet 2 of 2)

Maximum Accelerations in EW Direction

Structure	Lumped Mass	El. (ft)	~~Site Profile~~Surface Foundation (g)				Embedded Foundation (g)								
			SLB	SBE	SUB	Env.	ELB	EBE	EUB	EHB	Env.	~~Env.~~	Embed./Surf	Enveloped Accelerations (g)	Standard Plant Eneveloped Accelerations (g)
R/B-FH/A	FH08	154.5	0.350	0.413	0.455	0.46	0.320	0.425	0.482	0.462	0.48	~~0.482~~	106%	0.48	1.18
	FH07	125.7	0.292	0.304	0.343	0.34	0.264	0.327	0.442	0.350	0.44	~~0.442~~	129%	0.44	0.96
	RE05	115.5	0.271	0.317	0.383	0.38	0.247	0.308	0.337	0.333	0.34	~~0.383~~	88%	0.38	0.80
	RE04	101.0	0.230	0.267	0.337	0.34	0.234	0.267	0.285	0.284	0.29	~~0.337~~	85%	0.34	1.06
	RE41	101.0	0.246	0.306	0.382	0.38	0.247	0.285	0.326	0.319	0.33	~~0.382~~	85%	0.38	0.93
	RE42	101.0	0.241	0.288	0.364	0.36	0.242	0.272	0.310	0.306	0.31	~~0.364~~	85%	0.36	0.96
	FH06	101.0	0.245	0.247	0.282	0.28	0.223	0.267	0.287	0.266	0.29	~~0.287~~	102%	0.29	0.86
	RE03	76.4	0.198	0.206	0.229	0.23	0.194	0.217	0.221	0.207	0.22	~~0.229~~	97%	0.23	0.66
	RE02	50.2	0.174	0.179	0.185	0.19	0.161	0.180	0.195	0.168	0.20	~~0.196~~	105%	0.20	0.58
	RE01	25.3	0.149	0.151	0.146	0.15	0.137	0.144	0.167	0.139	0.17	~~0.167~~	111%	0.17	0.48
	RE00	3.6	0.126	0.125	0.125	0.13	0.114	0.115	0.136	0.113	0.14	~~0.136~~	108%	0.14	N/A

Table 3NN-14 (Sheet 1 of 2)

Maximum Accelerations in Vertical Direction

RCOL2_03.07.02-8

RCOL2_03.08.04-59

Structure	Lumped Mass	El. (ft)	~~Site Profile~~Surface Foundation (g)				Embedded Foundation (g)					~~Env.~~	Embed. /Surf	Enveloped Accelerations (g)	Standard Plant Eneveloped Accelerations (g)
			SLB	SBE	SUB	Env.	ELB	EBE	EUB	EHB	Env.				
PCCV	CV11	230.2	0.437	0.482	0.515	0.52	0.362	0.394	0.626	0.430	0.63	~~0.626~~	122%	0.63	1.43
	CV10	225.0	0.388	0.420	0.448	0.45	0.323	0.341	0.543	0.334	0.54	~~0.543~~	121%	0.54	1.29
	CV09	201.7	0.313	0.327	0.349	0.35	0.230	0.240	0.398	0.249	0.40	~~0.398~~	114%	0.40	0.98
	CV08	173.1	0.271	0.283	0.302	0.30	0.185	0.220	0.327	0.212	0.33	~~0.327~~	108%	0.33	0.85
	CV07	145.6	0.255	0.266	0.284	0.28	0.174	0.212	0.303	0.203	0.30	~~0.303~~	107%	0.30	0.81
	CV06	115.5	0.227	0.237	0.253	0.25	0.163	0.196	0.263	0.187	0.26	~~0.263~~	104%	0.26	0.72
	CV05	92.2	0.201	0.209	0.223	0.22	0.152	0.179	0.232	0.170	0.23	~~0.232~~	104%	0.23	0.65
	CV04	76.4	0.180	0.188	0.201	0.20	0.144	0.166	0.209	0.158	0.21	~~0.209~~	104%	0.21	0.59
	CV03	68.3	0.169	0.177	0.188	0.19	0.138	0.159	0.196	0.149	0.20	~~0.196~~	104%	0.20	0.56
	CV02	50.2	0.148	0.154	0.159	0.16	0.127	0.141	0.166	0.132	0.17	~~0.166~~	104%	0.17	0.49
	CV01	25.3	0.128	0.132	0.133	0.13	0.117	0.122	0.130	0.120	0.13	~~0.133~~	98%	0.13	0.39
	CV00	1.9	0.110	0.112	0.113	0.11	0.111	0.110	0.108	0.122	0.12	~~0.122~~	108%	0.12	N/A
Containment Internal Structure	IC09	139.5	0.199	0.220	0.264	0.26	0.242	0.232	0.275	0.249	0.28	~~0.275~~	104%	0.28	1.03
	IC08	112.3	0.192	0.214	0.253	0.25	0.231	0.222	0.263	0.235	0.26	~~0.263~~	104%	0.26	0.97
	IC18	110.8	0.190	0.213	0.252	0.25	0.229	0.220	0.261	0.233	0.26	~~0.261~~	104%	0.26	0.96
	IC61	96.6	0.160	0.181	0.205	0.21	0.176	0.180	0.203	0.198	0.20	~~0.205~~	99%	0.21	0.68
	IC62	96.6	0.160	0.182	0.209	0.21	0.173	0.178	0.208	0.195	0.21	~~0.209~~	100%	0.21	0.68
	IC05	76.4	0.121	0.133	0.146	0.15	0.144	0.143	0.163	0.134	0.16	~~0.163~~	112%	0.16	0.54
	IC07	76.4	0.157	0.178	0.208	0.21	0.181	0.184	0.204	0.178	0.20	~~0.208~~	98%	0.21	N/A
	IC15	59.2	0.112	0.122	0.132	0.13	0.131	0.129	0.146	0.123	0.15	~~0.146~~	111%	0.15	0.49
	IC04	50.2	0.108	0.117	0.126	0.13	0.123	0.122	0.136	0.117	0.14	~~0.136~~	108%	0.14	0.46
	IC14	45.7	0.106	0.113	0.122	0.12	0.119	0.117	0.131	0.117	0.13	~~0.131~~	107%	0.13	0.43
	IC03	35.6	0.106	0.107	0.112	0.11	0.116	0.112	0.118	0.119	0.12	~~0.119~~	106%	0.12	0.39
	IC02	25.3	0.107	0.109	0.109	0.11	0.114	0.108	0.107	0.119	0.12	~~0.119~~	109%	0.12	0.35
	IC01	16.0	0.109	0.111	0.111	0.11	0.112	0.108	0.105	0.121	0.12	~~0.121~~	109%	0.12	0.34
	IC00	1.9	0.110	0.112	0.113	0.11	0.111	0.110	0.107	0.122	0.12	~~0.122~~	108%	0.12	N/A

Table 3NN-14 (Sheet 2 of 2)

Maximum Accelerations in Vertical Direction

RCOL2_03.07.02-8
RCOL2_03.08.04-59

Structure	Lumped Mass	El. (ft)	~~Site Profile~~Surface Foundation (g)				Embedded Foundation (g)					~~Env.~~	Embed. /Surf	Enveloped Accelerations (g)	Standard Plant Eneveloped Accelerations (g)
			SLB	SBE	SUB	Env.	ELB	EBE	EUB	EHB	Env.				
R/B-FH/A	FH08	154.5	0.318	0.361	0.392	0.39	0.363	0.401	0.501	0.408	0.50	~~0.501~~	128%	0.50	1.23
	FH07	125.7	0.290	0.330	0.358	0.36	0.331	0.373	0.473	0.374	0.47	~~0.473~~	132%	0.47	1.03
	RE05	115.5	0.264	0.294	0.312	0.31	0.262	0.306	0.325	0.322	0.33	~~0.325~~	104%	0.33	0.87
	RE04	101.0	0.245	0.273	0.286	0.29	0.241	0.291	0.308	0.309	0.31	~~0.309~~	108%	0.31	0.97
	RE41	101.0	0.314	0.354	0.371	0.37	0.348	0.420	0.512	0.400	0.51	~~0.512~~	138%	0.51	0.92
	RE42	101.0	0.259	0.292	0.325	0.33	0.274	0.309	0.354	0.305	0.35	~~0.354~~	109%	0.35	0.89
	FH06	101.0	0.265	0.300	0.332	0.33	0.302	0.342	0.438	0.345	0.44	~~0.438~~	132%	0.44	0.84
	RE03	76.4	0.131	0.140	0.148	0.15	0.164	0.182	0.228	0.174	0.23	~~0.228~~	154%	0.23	0.53
	RE02	50.2	0.124	0.127	0.127	0.13	0.153	0.164	0.205	0.154	0.21	~~0.205~~	161%	0.21	0.46
	RE01	25.3	0.117	0.119	0.119	0.12	0.143	0.147	0.172	0.141	0.17	~~0.172~~	145%	0.17	0.39
	RE00	3.6	0.111	0.114	0.115	0.12	0.135	0.134	0.139	0.126	0.14	~~0.139~~	121%	0.14	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.: 3006 (CP RAI #122)

SRP SECTION: 03.08.04 - Other Seismic Category I Structures

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

DATE OF RAI ISSUE: 10/9/2009

QUESTION NO.: 03.08.04-60

Appendix 3NN lists CP COL 3.7(3), CP COL 3.7(26), and CP COL 3.8(29) on its title page. However, the appendix is referenced by only CP COL 3.7(20), CP COL 3.7(23), and CP COL 3.7(25). This appears to be a carryover from the title pages of the three previous appendices.

Additionally, CP COL 3.8(29) lists Appendix 3NN, when it should list Appendix 3MM.

The Chapter 3 Table of Contents and the title page of Appendix 3NN lists the title as "Model Properties and Seismic Analysis Results for R/B-PCCV-Containment Internal Structure." The Table of Contents for the Appendix adds "SASSI" to this title.

Please confirm that these are typographical errors and correct them as appropriate.

ANSWER:

The references to CP COL 3.7(3), CP COL 3.7(26), and CP COL 3.8(29) on the title page of FSAR Appendix 3NN is a typographical error and was replaced with the correct references to CP COL 3.7(20), CP COL 3.7(23), and CP COL 3.7(25) in FSAR Revision 1.

In CP COL 3.8(29), the listing of Appendix 3NN is a typographical error and was corrected to be Appendix 3MM in FSAR Revision 1.

The Table of Contents for FSAR Appendix 3NN contained a typographical error in the title of the appendix. The title has been corrected to remove the word SASSI.

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

See attached marked-up FSAR Revision 1 pages 3NN-i and 3NN-1.

Impact on S-COLA

None.

Impact on DCD

None.

TABLE OF CONTENTS

RCOL2_03.08.04-60

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

RCOL2_03.08.04-60

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, <u>the spatial variation of the input ground motion is deemed not significant. Therefore,</u> the SASSI analyses do not consider incoherence of the input control motion. RCOL2_03.08.04-20

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.

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