RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**182-8160**
SRP Section:	**03.07.01 – Seismic Design Parameters**
Application Section:	**3.7.1**
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Question No. 03.07.01-4

10 CFR 50 Appendix S requires that the safety functions of structures, systems, and components (SSCs) must be assured during and after the vibratory ground motion associated with the safe shutdown earthquake (SSE) ground motion through design, testing, or qualification methods. DCD Section 3.7.1.3, Appendix 3.7A, and APR1400-E-S-NR-14001-P, Rev. 0, “Seismic Design Bases,” provides information related to the DCD generic soil profiles, which were used in the various soil structure interaction (SSI) analyses of the APR1400 Seismic Category I structures. In accordance with 10 CFR 50 Appendix S, the staff reviewed this information related to the supporting media and determined that the following additional information should be provided to assist the staff’s evaluation

a) Strain compatible (not low strain) soil profiles should be used for DC/COL soil profile comparison

   Since magnitude/distance properties are not appropriate to be specified in the DCD, the ranges of soil profiles in the standard design are typically considered as strain-iterated. In the end, the combined license application (COLA) will need to compare their appropriate strain compatible properties (based on site-specific data and ground motion parameters) when developing ground motion response spectra (GMRS) with the range of profiles considered in the DCD.

   Furthermore, COLA profiles cannot easily be defined as “bounded” by the profiles used for the DCD. Since both low strain soil profiles and strain iterated soil profiles are provided in DCD Section 3.7.1.3, DCD Appendix 3.7A, and APR1400-E-S-NR-14001-P, Rev. 0, the applicant is requested to clearly indicate in these documents that the COLA strain iterated soil profiles should be compared to the strain iterated generic soil profiles. It is understood that COLA comparison of soil profiles is addressed separately in Section 2.5. Therefore, any revision of SRP 3.7.1 related information should be performed in connection with any required revision of DCD Section 2.5 including COL information items.

b) Treatment of DCD soil degradation models

It is not clear what is the purpose of specifying the modulus reduction and damping curves in the DCD as described in Section 3.7.1.2 because the SSI analyses in the DC stage only requires a range of generic soil profiles typically considered as strain iterated. Three soil degradation models are used in Section 5.1 of APR1400-E-S-NR-14001-P, Rev. 0: (1) curves for sand from EPRI TR-102293, (2) soft rock from Silva's report, and (3) rock from SHAKE. These curves do not always exhibit a clear trend (as evidenced in Figures 5-11, 5-12, and 5-13) to be consistent with the expected behavior of sand, soft rock and rock. As discussed in the above RAI question, consideration of soil/rock degradation is not necessary in the DCD because the SSI analyses in the DCD start typically with postulated range of strain iterated soil profiles. As such, the three degradation models should be treated as part of a demonstration of the DCD method and how the DCD demands and ISRS were reached. Accordingly, the applicant is requested to include a COL information item for the COLA to use methods/models/data suitable for its site and any use of these three DCD soil degradation models must be justified to be appropriate for the site in COLA.

c) Strain compatible P-wave velocities

DCD Section 3.7A.2.2 indicates that separate horizontal and vertical site response analyses were performed to get the strain compatible properties for the nine low-strain soil profiles, which are then used as equivalent linear properties in the SSI analyses. The strain compatible properties for the two horizontal directions were averaged to obtain a single set of strain compatible properties for the two horizontal directions. Tables 3.7A-1 through 3.7A-9 show both the low strain and strain compatible soil profiles. On the other hand, Section 2.2 of the HRHF technical report, "Site Response Analysis," indicated that the horizontal site response analyses considered soil degradation but the vertical site response analyses uses the low-strain compression wave velocities. It appears that strain compatible P-wave velocities were used for the CSDRS related analyses but the low strain P-wave velocities were used for the HRHF site response analysis.

The applicant is requested to identify what P-wave velocities were used in the SSI analysis for the HRHF related evaluation, and provide the basis for the inconsistent application of the P- wave velocities in the site response analyses and/or SSI analyses for CSDRS and HRHF evaluations.

Previous recommendations for site-specific SSI analyses indicated use of strain compatible properties for S-wave velocities and corresponding low strain velocities for P-wave velocities. However, that approach has recently been modified (ASCE Standard 4 for example) since these differences can lead to stability problems in SSI analyses. For example, Section C5.2 of the draft ASCE 4 (July 3, 2013) states that "Poisson's ratios at low strain levels should be maintained for strain-compatible soil properties, except for saturated soils for which the minimum P-wave velocity of saturated soil should be maintained." The DCD and APR1400-E-S- NR-14001-P, Rev. 0 present different Poisson's ratios for the low strain soil profiles and the strain compatible soil profiles. Therefore, the applicant is requested to:

(1) Explain the method used to develop the strain compatible P-wave velocities

(2) Explain how that method used in the DCD compares to the currently recommended approach (i.e., maintaining the low strain Poisson's ratio as described in the draft ASCE 4).

Response

a) The COLA should compare their appropriate strain compatible soil properties to the strain compatible generic soil profiles of the APR1400. The use of strain compatible soil profiles for DC/COL soil profile comparison will be clearly specified in DCD Tier 2, Table 1.8-2, Subsection 3.7.1.3 and 3.7.5 as COL 3.7(12).

b) The three soil degradation models in the DCD are used in site response analyses of the APR1400 standard design. These soil degradation models are provided for a description of site response analysis procedure performed in APR1400 seismic analysis. The COLA can determine the soil degradation models from dynamic laboratory testing of the site materials, information obtained from published literature, or both as specified in SRP 3.7.2, Rev.4. The suitability of soil degradation models for a COL site should be reviewed in the COL stage. The application of site-specific soil degradation models will be clearly specified in DCD Tier 2, Table 1.8-2, Subsection 3.7.1.2 and 3.7.5 as COL 3.7(11).

c) The SSI analyses for CSDRS and HRHF response spectra do not use strain compatible P-wave velocities, but use low strain P-wave velocities of generic soil profiles.

The approach recommended in Section C5.2 of the draft ASCE 4 (July 3, 2013), which states that "Poisson's ratios at low strain levels should be maintained for strain-compatible soil properties except for saturated soils for which the minimum P-wave velocity of saturated soil should be maintained," implies that the strain-compatible P-wave velocity degrades with the ground-motion-induced compression strain level in the same way as the strain-compatible S-wave velocity degrades with the ground-motion-induced shear strain level.

In principle, the dynamic Poisson's ratios of soils at the low strain level are derived quantities based on measured P- and S-wave velocities at the low strain level. At the higher shear strain level, it is known that the shear-strain-compatible S-wave velocity degrades with the shear strain level induced by the ground motion. However, at the higher shear strain level, whether the compression-strain-compatible P-wave velocity will degrade with the compression strain level induced by the ground motion in the same manner as the S-wave velocity degrades with the shear strain level induced is yet to be validated.

For saturated soils, the P-wave velocity at all compression strain levels is maintained at a value not less than the P-wave velocity of water, which is approximately 4800 to 5000 ft/sec, depending on temperature. This, coupled with the shear-strain-compatible degraded S-wave velocity, will cause the dynamic Poisson's ratios of saturated soils to increase from the dynamic Poisson's ratios measured at the low strain level. Thus, maintaining the dynamic Poisson's ratios at the low-strain level for the higher strain levels is no longer valid.

Another approach for soil-structure interaction (SSI) analysis is to use the strain-compatible S-wave velocities coupled with the low-strain P-wave velocities measured at the low stain levels to perform the seismic SSI analysis. This approach results in increase of dynamic Poisson's ratios for soils at higher shear strain levels. As a result, the strain-compatible Poisson's ratios could approach a high value (close to the limiting value of 0.5 for an incompressible solid), which may cause numerical stability for the finite elements used to model the soils. To maintain numerical stability, the strain-compatible dynamic Poisson's ratios are usually limited to a value of 0.48. When the limiting value of 0.48 is reached for the dynamic Poisson's ratios, the P-wave velocities of soils that are computed from the strain-compatible S-wave velocities and the limiting Poisson's ratio value of 0.48 will decrease from their low-strain P-wave velocity values. This approach is the approach used for the seismic SSI analysis for CSDRS and HRHF DRS of the APR1400.

Impact on DCD

DCD Tier 2, Table 1.8-2, Subsection 3.7.1.2, 3.7.1.3 and 3.7.5 will be revised, as indicated in the attachment associated with this response.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Report.

Table 1.8-2 (4 of 29)

Item No.	Description
COL 3.7(3)	The COL applicant is to provide the seismic design of the seismic Category I SSCs that are not part of the APR1400 standard plant design. The seismic Category I structures are as follows: a. Seismic Category I essential service water building b. Seismic Category I component cooling water heat exchanger building
COL 3.7(4)	The COL applicant is to confirm that the any site-specific non-seismic Category I SSCs are designed not to degrade the function of a seismic Category I SSC to an unacceptable safety level due to their structural failure or interaction.
COL 3.7(5)	The COL applicant is to perform any site-specific seismic design for dams that is required.
COL 3.7(6)	The COL applicant is to perform seismic analysis of buried seismic Category I piping, conduits, and tunnels.
COL 3.7(7)	The COL applicant is to perform seismic analysis for the seismic Category I above-ground tanks.
COL 3.7(8)	The COL applicant that references the APR1400 design certification will determine whether essentially the same seismic response from a given earthquake is expected at each unit in a multi-unit site or each unit is to be provided with a separate set of seismic instruments.
COL 3.7(9)	The COL applicant is to confirm details of the locations of the triaxial time-history accelerograph.
COL 3.7(10)	The COL applicant is to identify the implementation milestones for the seismic instrumentation implementation program based on the discussion in Subsections 3.7.4.1 through 3.7.4.5.
	Insert "A" from page 4.
COL 3.7B(1)	The COL applicant is to evaluate the HRHF response spectra.
COL 3.7B(2)	The COL applicant is to evaluate the representative items listed in Table 3.7B-2.
COL 3.8(1)	The COL applicant is to provide the design of site-specific seismic Category I structures such as the essential service water supply structure and the component cooling water heat exchanger building.
COL 3.8(2)	The COL applicant is to identify any applicable site-specific loads such as site proximity explosions and missiles, potential aircraft crashes, and the effects of seiches, surges, waves, and tsunamis.
COL 3.8(3)	The COL applicant is to determine the environmental condition associated with the durability of concrete structures and provide the concrete mix design that prevents concrete degradation including the reactions of sulfate and other chemicals, corrosion of reinforcing bars, and influence of reactive aggregates.
COL 3.8(4)	The COL applicant is to determine construction techniques to minimize the effects of thermal expansion and contraction due to hydration heat, which could result in cracking.
COL 3.8(5)	The COL applicant is to monitor the safety and serviceability of seismic Category I structures during the operation of the plant and provide the appropriate maintenance.
COL 3.8(6)	The COL applicant is to provide reasonable assurance that the design criteria listed in Table 2.0-1 are met or exceeded.

analysis are obtained from generic modulus reduction and hysteretic damping curves recommended by EPRI TR-102293 (Reference 11) based on site response analysis of soil columns for the standard plant profiles considering shear strains compatibility.

Insert "B" from page 4.

3.7.1.3 Supporting Media for Seismic Category I Structures

Seismic Category I structures are founded directly on rock or competent soil. The nuclear island and emergency diesel generator building correspond to the seismic Category I structures of the APR1400 standard plant design. The nuclear island consists of the following seismic Category I structures, the reactor containment building and the auxiliary building, which are founded on a common basemat. The emergency diesel generator building and a diesel fuel oil storage tank room are also seismic Category I structures. The foundation embedment depth, foundation size, and total height of the seismic Category I structures are presented in Table 3.7-8.

For the design of seismic Category I structures, nine soil profiles and one fixed-base condition are established with various shear wave velocities compared with soil depth.

The supporting media for the generic site are described in Appendix 3.7A about soil properties, layering characteristics, shear wave velocity, shear modulus, and density. Basically, soil-structure interaction analyses on soil sites for the APR1400 use the soil degradation curves recommended by EPRI TR-102293. The curves are used to generate the strain-compatible soil properties.

Insert "C" from page 4.

These nine profiles are considered representative to envelop sites where competent soil is defined by the shear wave velocity of the supporting medium at the foundation level exceeding 304.8 m/sec (1,000 ft/sec). The shear wave velocity profiles of the nine sites considered are shown in Figure 3.7-23. The nine soil profiles, S1 through S9, are developed as combinations of six soil layering categories, which are designated as 55, 100, 200, 500, 1,000 ft, and half-space, and five average-shear-wave-velocity categories, namely, 1,200, 2,000, 4,000, 6,000, and 9,200 ft/sec. The generic site soil profiles are described further in Technical Report, APR1400-E-S-NR-14001-P (Reference 9).

COL 3.7(6) The COL applicant is to perform seismic analysis of buried seismic Category I piping, conduits, and tunnels.

COL 3.7(7) The COL applicant is to perform seismic analysis for the seismic Category I above-ground tanks.

COL 3.7(8) The COL applicant that references the APR1400 design certification will determine whether essentially the same seismic response from a given earthquake is expected at each unit in a multi-unit site or each unit is to be provided with a separate set of seismic instruments.

COL 3.7(9) The COL applicant is to confirm details of the locations of the triaxial time-history accelerographs.

COL 3.7(10) The COL applicant is to identify the implementation milestones for the seismic instrumentation implementation program based on the discussion in Subsections 3.7.4.1 through 3.7.4.5.

Insert "D" from page 4.

3.7.6 References

1. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena," U.S. Nuclear Regulatory Commission.

2. 10 CFR Part 50, Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," U.S. Nuclear Regulatory Commission.

3. Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants," Rev. 2, U.S. Nuclear Regulatory Commission, July 2014.

4. Regulatory Guide 1.208, "A Performance-based Approach to Define the Site-specific Earthquake Ground Motion," Rev. 4, U.S. Nuclear Regulatory Commission, March 2007.

5. NUREG-0800, Standard Review Plan, Section 3.7.1, "Seismic Design Parameters," Draft Rev. 4, U.S. Nuclear Regulatory Commission, December 2012.

"A"

COL 3.7(11)	The COL applicant is to demonstrate the applicability of soil degradation models used in site-specific site response analysis for the site conditions.
COL 3.7(12)	The COL applicant is to compare the site-specific strain-compatible soil properties with strain-compatible generic soil properties in order to confirm that the site meets the generic soil profile used in the standard design.

"B"

The site-specific soil degradation models can be determined from dynamic laboratory testing of the site materials or from the published literature. The COL applicant is to demonstrate the applicability of soil degradation models used in site-specific site response analysis for the site conditions (COL 3.7(11)).

"C"

The COL applicant is to compare the site-specific strain-compatible soil properties with strain-compatible generic soil properties in order to confirm that the site meets the generic soil profile used in the standard design (COL 3.7(12)).

"D"

COL 3.7(11) The COL applicant is to demonstrate the applicability of soil degradation models used in site-specific site response analysis for the site conditions.

COL 3.7(12) The COL applicant is to compare the site-specific strain-compatible soil properties with strain-compatible generic soil properties in order to confirm that the site meets the generic soil profile used in the standard design.