3.0 DESIGN OF STRUCTURES, COMPONENTS, EQUIPMENT AND SYSTEMS

3.7 Seismic Design

Safety-related systems, structures, and components (SSCs) are designed to withstand safe-shutdown earthquake (SSE) loads and other dynamic loads, including those due to reactor building vibration (RBV) caused by suppression pool dynamics. This section addresses seismic aspects of the design and analysis in accordance with RG 1.70, Revision 3, “Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (LWR Edition).”

3.7.1 Seismic Design Parameters

Seismic Category I SSCs are designed to withstand the effects of the SSE event and to maintain the specified design functions. Seismic Category II and nonseismic (NS) structures are designed or physically arranged (or both) so that the SSE could not cause unacceptable structural interactions with or the failure of Seismic Category I SSCs. The ESBWR standard plant SSE design ground motion is addressed in Section 3.7 of ESBWR DCD Tier 2, Revision 9. The horizontal and vertical SSE design ground response spectra (for 5 percent damping), also termed certified seismic design response spectra (CSDRS) for the ESBWR design were developed based on enveloping RG 1.60 Revision 1, “Design Response Spectra for Seismic Design of Nuclear Power Plants,” response spectra anchored to 0.3 g peak ground acceleration (PGA) and the high-frequency hard rock spectra anchored to 0.5g PGA. These spectra are shown in ESBWR DCD Tier 2, Revision 9, Chapter 2.0, Figures 2.0-1 and 2.0-2 for horizontal and vertical directions, respectively. The CSDRS have been applied as the input ground motion at the building foundation level for the seismic design of the Category I structures included in the design document. For the reactor and fuel building (RB/FB) and the control building (CB), the input motion is the same as that shown in Figures 2.0-1 and 2.0-2. The input motion for the firewater service complex (FWSC) is 1.35 times the values shown in DCD Tier 2, Figures 2.0-1 and 2.0-2. The applicant has provided the seismic design parameters for the Fermi 3 site in this FSAR section, as documented below.

3.7.1.1 *Introduction*

This FSAR section addresses the design earthquake ground motion used for the seismic analysis and design of the Category I structures. The design earthquake ground motion is based on the seismic and geologic characteristics at the site and is established in terms of a set of idealized and smooth curves called the design response spectra. At the Fermi 3 site, the specific seismic design parameters include the design ground motion in terms of the foundation input response spectra (FIRS), design ground motion time histories, percentage of critical damping values, and the characteristics of the supporting media for Category I structures.

3.7.1.2 *Summary of Application*

Section 3.7.1 of the Fermi 3 COL FSAR Revision 6 incorporates by reference Section 3.7.1 of the ESBWR DCD, Revision 9. In addition, in FSAR Section 3.7.1, the applicant provides the following:

Supplemental Information

- EF3 SUP 3.7-1

In FSAR Section 3.7.1, the applicant provides the following:

1) The development of a comprehensive set of site-specific seismic inputs for the Fermi 3 site-specific soil-structure interaction (SSI) analyses of the RB/FB and the CB structures. Site-specific seismic inputs consist of performance-based surface response spectra (PBSRS), FIRS, site-specific ground motion time histories, and subsurface material profiles with corresponding dynamic properties used in the site-specific SSI analyses. The analyses also include the development of the FIRS for the FWSC structure.

2) The development of the damping ratios for the subsurface material profiles used in the site-specific SSI analyses of the RB/FB and the CB in FSAR Subsection 3.7.1.1.4.

3) The development of the dynamic properties of the subsurface material profiles used in the site-specific SSI analyses of the RB/FB and the CB in FSAR Subsection 3.7.1.1.4.

3.7.1.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is in NUREG–1966. In addition, the relevant requirements of the Commission regulations for the seismic design, and the associated acceptance criteria, are in Section 3.7.1 of NUREG–0800. The specific requirements include the following:

- 10 CFR Part 50, Appendix A, GDC 2, “Design bases for protection against natural phenomena,” as it relates to the seismic design basis to reflect the appropriate consideration of the most severe earthquakes historically reported for the site and surrounding area with a sufficient margin for the limited accuracy, quantity, and period of time in which historical data have been accumulated; and SSCs important to safety be designed to withstand the effects of earthquakes without a loss of capability to perform their intended safety functions.

- 10 CFR Part 50, Appendix S, “Earthquake Engineering Criteria for Nuclear Power Plants,” as it relates to the SSE ground motion in the free-field at the foundation level of the structures to be an appropriate response spectrum with a peak ground acceleration of at least 0.1 g; and if the operating-basis earthquake (OBE) is chosen to be less than or equal to one-third of the SSE ground motion, it will not be necessary to conduct explicit response or design analyses in accordance with Section IV.(2)(i)(A) of 10 CFR Part 50, Appendix S.

In addition, the acceptance criteria and regulatory guidance associated with the review of FSAR Section 3.7.1 include the following:

- SRP Section 3.7.1 for reviewing seismic design parameters to ensure that they are appropriate and contain a sufficient margin so that seismic analyses (reviewed under other SRP sections) accurately and/or conservatively represent the behavior of SSCs during postulated seismic events.

- RG 1.60, Revision 1, "Design Response Spectra for Seismic Design of Nuclear Power Plants," to determine the acceptability of design response spectra for input into the seismic analysis of nuclear power plants.

- RG 1.61, Revision 1, "Damping Values for Seismic Design of Nuclear Power Plants," to determine the acceptability of damping values used in the dynamic seismic analyses of seismic Category I SSCs.

- Design Certification/COL–Interim Staff Guidance (DC/COL-ISG)-017, "Interim Staff Guidance on Ensuring Hazard-Consistent Seismic Input for Site Response and Soil Structure Interaction Analysis."

- NUREG/CR–6728, "Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk-Consistent Ground Motion Spectra Guidelines," to determine the acceptability of the site-specific FIRS used in the site-specific seismic analysis.

3.7.1.4 *Technical Evaluation*

As documented in NUREG–1966, NRC staff reviewed and approved Section 3.7.1 of the ESBWR DCD. The staff reviewed Section 3.7.1 of the Fermi 3 COL FSAR and checked the referenced ESBWR DCD to ensure that the combination of the information in the COL FSAR and the information in the ESBWR DCD appropriately represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and the information incorporated by reference address the required information relating to this section.

The staff reviewed the following information in the Fermi 3 COL FSAR, Revision 6:

Supplemental Information

- EF3 SUP 3.7-1

Design Ground Motion

FSAR Figures 3.7.1-228, 3.7.1-229, and 3.7.1-238 show that the FIRS developed in FSAR Subsection 3.7.1.1.4 are enveloped by the ESBWR CSDRS in both horizontal and vertical directions for the RB/FB, CB, and FWSC. In addition, the Fermi 3 site-specific

[1] See *"Finality of Referenced NRC Approvals"* in SER Section 1.2.2, for a discussion on the staff's review related to verification of the scope of information to be included in a COL application that references a design certification.

SSI analyses for the RB/FB and the CB were performed to address the following two Fermi 3 site-specific conditions:

- To confirm that the DCD standard plant design is applicable to the Fermi 3 site-specific conditions, where the RB/FB and the CB structures are partially embedded in the Bass Islands Group rock, with the engineered granular backfill surrounding the structures from the top of the rock to the grade level of the plant.

- To demonstrate that the standard plant design is applicable to the Fermi 3 site-specific conditions, even though the DCD requirements for the engineered granular backfill that surrounds the seismic Category I structures are not being met for the RB/FB and the CB structures. Specifically, the requirements in DCD Tier 2 ,Table 2.0-1 state that the minimum shear wave velocity of the material surrounding the embedded walls of these structures should be greater than 300 meters per second (m/s) (1000 feet [ft]/s).

FSAR Subsection 3.7.1.1 indicates that the FWSC is a surface-founded structure according to DCD Tier 2, Subsection 3.7.1.1, and there are no embedded walls for the FWSC. Therefore, the DCD requirements for the backfill surrounding seismic Category I structures are not applicable to the FWSC. As discussed in FSAR Section 2.5.4, the FWSC is founded on fill concrete that meets the DCD Tier 2, Table 2.0-1 requirements underneath Seismic Category I structures. Therefore, no site-specific SSI analysis is performed for the FWSC. The staff's review of this issue is in Subsection 3.7.2.4 of this SER, where the staff concludes that no site-specific SSI analysis is needed for the FWSC.

The applicant developed seismic inputs for the site-specific SSI analysis to be consistent with the procedure described in DC/COL-ISG-017. The RB/FB and the CB design ground motions for the site-specific SSI analyses were based on the outcrop FIRS developed in FSAR Subsection 3.7.1.1.4 as the soil column outcrop response (SCOR). The SCOR was further enhanced to ensure that the PBSRS is enveloped at the ground surface. The SSE for Fermi 3 was then designated as the lower of the two enhanced SCOR FIRS for the RB/FB and the CB. The SSE is defined at the foundation level to be consistent with the definition used in the DCD. The applicant also stated that the OBE is one-third of the SSE.

The staff found the applicant's specification of the SSE acceptable because it is defined as the lower of the two enhanced SCOR FIRS at the foundation level, which is consistent with the definition in the DCD. The staff's evaluation of the SCOR FIRS and the enhanced SCOR FIRS for the RB/FB and the CB, as well as the FIRS for the FWSC, is provided below under "Fermi 3 Site-Specific Ground Motions." The staff's evaluation of the site-specific RB/FB and CB SSI analysis is in Subsection 3.7.2.4 of this SER.

Fermi 3 Site-Specific Ground Motions

Development of Horizontal RB/FB SCOR FIRS, CB SCOR FIRS, and PBSRS

In the Fermi 3 site-specific SSI analyses in FSAR Section 3.7.2, the RB/FB and the CB are modeled as partially embedded structures within the Bass Islands Group rock. The site-specific SSI analyses did not consider the effect of the engineered granular backfill on the RB/FB and the CB. To confirm that the engineered granular backfill does not adversely impact seismic Category I structures, the applicant performed additional site-specific SSI analyses that included the engineered granular backfill above the top of the Bass Islands Group bedrock.

The applicant used the Nuclear Energy Institute (NEI) method described in Section 5.2.1 of DC/COL-ISG-017 to develop SCOR FIRS at the RB/FB and the CB foundation levels, as well as the PBSRS at the finished grade level. The SCOR FIRS were enhanced using the procedure described in Section 5.2.1 of DC/COL-ISG-017 to ensure hazard-consistent seismic inputs for the site-specific SSI analyses when compared to the PBSRS at the finished grade level. The staff found the applicant's process of developing the SCOR FIRS and enhanced SCOR FIRS acceptable, because the method and procedure used are consistent with the guidance in DC/COL-ISG-017.

The applicant developed three base case site response profiles to reflect the range in granular backfill material properties that may be used. These base case profiles are referred to as the lower-range (LR), intermediate range (IR), and upper-range (UR) profiles, and their properties are defined in FSAR Tables 3.7.1-201, 3.7.1-202, and 3.7.1-203, respectively (the staff notes that the LR, IR, and UR profiles are identical below the backfill in the rock portion, which is assumed to be linear). In addition, the applicant randomized the dynamic properties of the three base case profiles (i.e., shear-wave velocity and shear modulus reduction and damping) using the method described in FSAR Subsection 2.5.2.5.1.3. To develop the SCOR FIRS and PBSRS, the applicant used the same process that was used to develop its ground motion response spectrum (GMRS) in FSAR Subsections 2.5.2.5.3 and 2.5.2.6. According to the logic tree shown in FSAR Figure 3.7.1-210, the applicant assigned relative weights of 0.35, 0.50, and 0.15 to the respective UR, IR, and LR base case profiles in the development of the final amplification functions.

In RAI 02.05.02-20 and RAI 02.05.02-21, the staff requested the applicant to provide information related to the properties of the proposed engineered granular backfill—including a justification for the weighting factors developed for the LR, IR, and UR base case profiles. Based on the information in the response to both RAIs (ML13043A012 and ML13226A030, respectively), the staff performed a confirmatory site response analysis for the three individual base case profiles (LR, IR, and UR) without assigning any weighting factors.

The staff's analysis indicates that the envelope of the FIRS developed with the staff's confirmatory analysis and obtained from the three base cases without consideration of any weighting factors, is bounded by the enhanced SCOR FIRS used by the applicant in the site-specific SSI analysis. Furthermore, a comparison with the DCD CSDRS shows that significant margin exists between the CSDRS and the site-specific enhanced SCOR FIRS for both the RB/FB and the CB, as shown in the FSAR Figures 3.7.1-228 and 3.7.1-229. In addition, the envelope of the PBSRS obtained from the staff's site response analysis using the three backfill base cases, without consideration of any weighting factors, is bounded by the surface envelope of the response spectra computed from the SSI deterministic input and based on the three deterministic profiles used in the site-specific SSI analysis.

Based on the confirmatory analysis, the staff concludes that the PBSRS and the enhanced SCOR FIRS used by the applicant to develop the seismic input for the site-specific SSI analysis of the RB/FB and the CB are adequate for the Fermi 3 site.

Basis of the Assumption of One-Dimensional Versus Two-Dimensional Backfill Material Surrounding the Power Block

FSAR Figure 2.5.4-201 shows that the backfill material surrounding the power block structures extends to a perimeter diaphragm wall that is used to support the excavation of in situ material. Beyond the diaphragm wall, it appears that in situ soils will remain in place. Because the use of backfill material is limited in the lateral extent, the staff requested the applicant in RAI 03.07.01-5 to explain why it is appropriate to establish the PBSRS and FIRS for the RB/FB and the CB on the basis of a one-dimensional (1-D) site response analysis using a column of backfill/rock material.

In the response to RAI 03.07.01-5 (ML12086A091), the applicant demonstrated the appropriateness of defining the PBSRS and FIRS for the RB/FB and the CB on the basis of the 1-D column of backfill/rock material, by comparing the amplification functions obtained from the soil profiles inside and outside of the diaphragm wall support. Figures 5 through 7 of the response to RAI 03.07.01-5 provide the comparisons of the amplification functions for inside and outside of the diaphragm wall. The staff's review of these comparisons concludes that a 1-D representation of the backfill material is acceptable for establishing the PBSRS and FIRS for the RB/FB and the CB, because the shear wave velocity profiles for the conditions inside and outside of the perimeter diaphragm wall produce comparable SCOR amplification functions at the RB/FB and the CB foundation levels.

Meeting the Minimum Requirement of 10 CFR Part 50, Appendix S

10 CFR Part 50, Appendix S, requires that the horizontal component of the SSE ground motion in the free-field at the foundation levels of structures must be an appropriate response spectrum with a PGA of at least 0.1g. Therefore, in RAI 03.07.01-8, the staff requested the applicant to provide in the FSAR comparison plots of the RB/FB and the CB horizontal FIRS with the RG 1.60 horizontal spectrum anchored at 0.1g, which demonstrate that the RB/FB and the CB horizontal FIRS envelop the RG 1.60 spectrum anchored at 0.1 g at all frequencies of interest.

FSAR Figures 3.7.1-226 and 3.7.1-227 provide the requested comparison plots of the RB/FB and the CB horizontal SCOR FIRS with the RG 1.60 horizontal spectrum anchored at 0.1g, respectively. The plots show that, the SCOR FIRS obtained from the site-response analysis for the RB/FB and the CB do not envelop the RG 1.60 shape scaled to a PGA of 0.1g in the frequency range of about 0.2 to 3 Hertz (Hz). To meet the requirements of the minimum horizontal ground motions specified in 10 CFR Part 50, Appendix S, the applicant modified the SCOR FIRS to ensure that these envelop the RG 1.60 spectrum scaled to a PGA of 0.1g. In addition, the applicant used the guidance specified in DC/COL-ISG-017 for ensuring performance-based seismic inputs for the site-specific SSI analysis. The staff notes that the initially enhanced FIRS as discussed above were further enhanced using the procedure described in Section 5.2.1 of DC/COL-ISG-017, thus ensuring performance-based seismic inputs for the site-specific SSI analyses when compared to the PBSRS at the finished grade level, as discussed above under "*Development of Horizontal RB/FB SCOR FIRS, CB SCOR FIRS, and PBSRS*."

The staff verified that the modified SCOR FIRS designated as “initially enhanced” FIRS in the FSAR enveloped the RG 1.60 spectrum scaled to a PGA of 0.1g as shown in FSAR Figures 3.7.1-226 and 3.7.1-227. The staff also verified that the final enhancements to the SCOR FIRS designated as the “enhanced SCOR FIRS” in the FSAR as shown in FSAR Figures 3.7.1-228 and 3.7.1-229 are developed using the guidance in DC/COL-ISG-017 and are bounded by the ESBWR CSDRS. On the above basis, the staff concludes that the site-specific enhanced SCOR FIRS meet the minimum requirement of 10 CFR Part 50, Appendix S and represent a performance-based seismic input acceptable for the site-specific SSI analysis.

Development of Horizontal FWSC FIRS

According to FSAR Subsection 3.7.1.1.4.1, the FWSC is founded on 9.15 meters (m) (30 feet [ft]) of fill concrete, which overlies the Bass Islands Group rock. The FSAR states that because the FWSC is essentially a surface-founded structure, the FIRS for the FWSC was developed as a truncated soil column response (TSCR) in accordance with the NEI method described in DC/COL-ISG-017. FSAR Table 3.7.1-204 provides the site response analysis profile for both the fill concrete and the rock beneath the fill concrete used in the development of the FWSC FIRS. In addition, the applicant randomized the dynamic properties of the FWSC profile (i.e., shear-wave velocity and shear modulus reduction and damping) using the method described in FSAR Subsection 2.5.2.5.1.3. The applicant used a process similar to the process for developing the GMRS in FSAR Subsections 2.5.2.5.3 and 2.5.2.6 to compute the FWSC amplification functions and the FIRS.

The staff found the applicant’s method for developing the FWSC FIRS acceptable, because the method is in accordance with the NEI method described in DC/COL-ISG017. In addition, the staff also performed a confirmatory analysis using the static and dynamic material properties in FSAR Subsection 3.7.1.1.4.1.1. To represent the input rock motions, the staff used the high- and low-frequency rock spectra associated with 10^{-4} exceedance probability, as well as the high- and low-frequency rock spectra associated with 10^{-5} exceedance probability. The staff’s analysis confirmed acceptability of the FIRS computed by the applicant because the results of the staff’s analysis are comparable with that of the applicant’s analysis used to establish the FIRS.

The FWSC FIRS is shown in FSAR Figure 3.7.1-238 and tabulated in FSAR Table 3.7.1-216. FSAR Figure 3.7.1-238 also shows the curve for FWSC CSDRS which is 1.35 times the ESBWR CSDRS as described in DCD Tier 2, Subsection 3.7.1.1. As shown in this Figure, the FWSC FIRS is enveloped by 1.35 times the ESBWR CSDRS by a significant margin. As such, the staff concludes that FWSC site-specific FIRS are bounded by the FWSC CSDRS and a site-specific SSI analysis for the FWSC is not needed.

Basis of the Assumption of One-Dimensional Versus Two-Dimensional Concrete Fill Material Underneath the FWSC

FSAR Figure 2.5.4-202 indicates that the lateral extent of the concrete fill material beneath the FWSC is limited to the footprint of the basemat. Because the concrete fill is limited in a lateral extent, the staff in RAI 03.07.01-3 requested the applicant to explain why it is appropriate to establish the FIRS for the FWSC on the basis of a 1-D site response analysis using a column of concrete fill/rock material, which presumes the concrete fill has infinite lateral extent.

In the response to RAI 03.07.01-3, dated March 13, 2012 (ML120730531), the applicant presented a methodology for developing the FIRS for the FWSC that takes into account 2-D site response analyses performed using the QUAD4MU program. In the 2-D analyses, the finite lateral extent of the concrete fill is explicitly taken into account; as well as the properties of the backfill from the LR, IR, and UR profiles. Following this methodology, the applicant established the 2-D versus the 1-D response spectral ratio envelopes at the FWSC foundation level. The 2-D versus the 1-D envelopes are shown in FSAR Figure 3.7.1-215 for the 10^{-4} and 10^{-5} exceedance probability levels of input ground motions. The plots indicate that the 2-D effect produces an increase in the mean site amplification functions above 5 Hz compared to the 1-D site response. The increase is generally greater for the 10^{-5} exceedance probability level than for the10^{-4} exceedance level. FSAR Figure 3.7.1-216 shows the smoothed mean site amplification functions for 10^{-4} and 10^{-5} exceedance probability levels at the FWSC foundation level for the 1-D site response compared with those incorporating the 2-D effects.

The FWSC FIRS shown in FSAR Figure 3.7.1-238 and tabulated in FSAR Table 3.7.1-216 are based on the mean site amplification functions that were modified by the 2-D versus the 1-D response spectral ratio envelopes shown in FSAR Figure 3.7.1-215 and illustrated in FSAR Figure 3.7.1-216.

Based on the above review, the staff concludes that the applicant's methodology for developing the FWSC FIRS adequately captures the 2-D effects resulting from the limited extent of the concrete fill beneath the FWSC basemat. The applicant's methodology is therefore acceptable.

Development of Vertical RB/FB SCOR FIRS, CB SCOR FIRS, FWSC FIRS, and PBSRS

The discussions above refer to the horizontal components of the SCOR FIRS for the RB/FB and CB, and the horizontal components of the FWSC FIRS and the PBSRS. To obtain the vertical component of the SCOR FIRS for the RB/FB and CB and the FWSC FIRS, FSAR Subsections 3.7.1.1.4.4 and 3.7.1.1.4.5 indicate that the applicant utilized the frequency-dependent vertical-to-horizontal (V/H) response spectral ratios for hard rock recommended by NUREG/CR–6728 for central and eastern United States (CEUS) bedrock sites (for 0.2 g ≤ PGA ≤ 0.5 g), which the staff finds acceptable because the RB/FB and the CB foundation levels are located within the bedrock. The staff noted that, unlike the RB/FB and the CB, the FWSC foundation level is located on concrete fill instead of the rock. The staff, however, finds the use of V/H response spectral ratios for hard rock recommended by NUREG/CR–6728 to be acceptable for the FWSC since the shear wave velocity for the concrete fill is comparable to that of the bedrock.

To obtain the vertical component of the PBSRS, the above approach is not entirely applicable because the full soil column for the PBSRS consists of a layer of backfill above the bedrock. Based on recent findings in the technical literature (FSAR References 3.7.1-213 and 3.7.1-215), FSAR Subsection 3.7.1.1.4.3.2 indicates that the applicant has modified the V/H ratios for hard rock by shifting the peak V/H ratio toward lower frequencies and slightly reducing the V/H ratios for frequencies below 9 Hz (a maximum reduction of approximately 15 percent).

The staff finds the above approach acceptable for the following reasons. First, the data in the references support the trend that (a) the peak V/H ratio is shifted to the lower frequencies, and (b) there is a slight reduction in the V/H ratios for low frequencies and for cases that compare soft rock relative to firm rock responses. Second, the full soil column for the PBSRS (which is closer to a shallow stiff soil site) is softer than the rock columns considered in the derivation of the V/H ratios recommended in NUREG/CR–6728 for CEUS bedrock sites; the staff thus expects a similar trend to apply. Third, a review of FSAR Figure 3.7.1-234 indicates that there is a sufficient margin between the vertical component of the PBSRS and the surface envelope of the vertical response spectra computed from the SSI deterministic inputs, based on the three deterministic profiles used in the site-specific SSI analysis. As a result of the above discussion, the staff concludes that the applicant has adequately addressed the effects of the variability in the modified V/H ratios on the SSI analysis.

FSAR Figure 3.7.1-220 shows the frequency-dependent V/H ratios for hard rock recommended by NUREG/CR–6728 for CEUS bedrock sites (for 0.2 g ≤ PGA ≤ 0.5 g) and the V/H ratios used to obtain the vertical component of the PBSRS.

The staff notes that the vertical components of the SCOR FIRS for the RB/FB and the CB were then enhanced following the procedure described in Section 5.2.1 of DC/COL-ISG-017. This procedure ensures hazard-consistent seismic inputs for the site-specific SSI analyses when compared to the PBSRS at the finished grade level, in the same manner as the horizontal components of the SCOR FIRS for the RB/FB and CB that the staff reviewed and accepted (see the discussion above under "*Development of Horizontal RB/FB SCOR FIRS, CB SCOR FIRS, and PBSRS*"). On the basis of this review, the staff concludes that the vertical components of the enhanced SCOR FIRS are acceptable for the RB/FB, the CB, the FWSC FIRS, and the PBSRS.

Deterministic Profiles for Site-Specific SSI Analyses

FSAR Subsection 3.7.1.1.4.3.3 describes the methodology used by the applicant to develop the following three deterministic profiles of subsurface material properties for site-specific SSI analyses: Best Estimate (BE), Lower Bound (LB), and Upper Bound (UB). The methodology follows the guidance in SRP Acceptance Criterion 3.7.2.II.4 and DC/COL-ISG-17. The methodology is based on the statistics of the strain-iterated soil properties obtained from the probabilistic site response analyses using the randomized full soil column profiles described in FSAR Subsection 3.7.1.1.4.1.1.3, which include the engineered granular backfill above the top of the Bass Islands Group bedrock. In the implementation of this methodology, the applicant addressed the following:

- The probabilistic site-response analyses took into consideration (a) the three base case profiles (LR, IR, and UR) to reflect the range of granular backfill material properties that may be used; (b) three alternate damping ratios for the bedrock (which was assumed to remain linear); and (c) 10^{-4} and 10^{-5} exceedance probability levels of high-frequency (HF) and low-frequency (LF) deaggregated earthquake (DE) of low, medium, and high seismic events. The logic tree is shown in FSAR Figure 3.7.1-210. As discussed in FSAR

Subsection 3.7.1.1.4.1.1.3, randomized full soil column profiles and randomized modulus reduction and damping curves were utilized in the process.

- The BE profile was determined from the 50th percentile results of the strain-iterated soil properties. The LB and UB profiles were determined from the 16th and 84th percentile results, respectively.

- The UB and LB shear wave velocity profiles were adjusted where necessary to satisfy SRP Acceptance Criterion 3.7.2.II.4, which indicates that G_{UB} should be greater than or equal to G_{BE} x (1 + COV) and G_{LB} should be less than or equal to G_{BE} / (1 + COV), where G_{UB}, GL_B, and G_{BE} are the shear moduli for the UB, LB, and BE profiles; and COV represents the coefficient of variation. Since the in situ subsurface materials have been well investigated at the Fermi 3 site, a COV of 0.5 was used for the bedrock. However, for the backfill, a COV of 1.0 was used to be consistent with SRP Acceptance Criterion 3.7.2.II.4 and to correspond with sites that are not well investigated.

- Damping ratios for the BE profile were determined from the 50th percentile results of the strain-iterated results. Damping ratios for the LB and UB profiles were determined from the 84th and 16th percentile results, respectively. Maximum damping ratios were below 15 percent in all cases and are thus consistent with SRP Acceptance Criterion 3.7.2.II.4.

- The compression wave velocity profiles were based on the corresponding shear wave velocity profiles and the site-specific Poisson's ratios identified in FSAR Table 2.5.4-202. In the layers of saturated backfill, the compression wave velocities were increased to the lower value of either 1,460 m/s (4,790 ft/s) or the compression wave velocity that resulted in a maximum Poisson's ratio of 0.48 for the corresponding LB, BE, and UB shear wave velocity. In the layers of bedrock below the groundwater table, the compression wave velocities exceeded 1,460 m/s (4,790 ft/s) in all cases and no adjustment was necessary.

FSAR Tables 3.7.1-206 through 3.7.1-211 and FSAR Figures 3.7.1-222 and 3.7.1-223 document the deterministic profiles of subsurface material properties used for site-specific SSI analyses, with and without engineered granular backfill above the top of the Bass Islands Group bedrock. The deterministic profiles without the backfill are the same as the deterministic profiles for the full soil column below the top of the Bass Islands Group bedrock.

The staff finds the above information acceptable because it was developed to adhere to the guidance in SRP Acceptance Criterion 3.7.2.II.4 and DC/COL-ISG-17.

Site-Specific Design Ground Motion Time Histories

FSAR Subsection 3.7.1.1.5 indicates that two sets of three orthogonal time histories (two horizontal and one vertical component) were generated to match the horizontal and vertical enhanced SCOR FIRS for the RB/FB and the CB, respectively, in accordance with SRP Acceptance Criterion 3.7.1.II.1.B, Option 1, Approach 2. The seed time histories used are those of the 1999 Chi-Chi Taiwan Earthquake, TAP078 recording, which was chosen from the CEUS record library in NUREG/CR–6728. Details of this record are in FSAR Table 3.7.1-217. Spectral matching was performed using the time-domain spectral matching technique described in FSAR References 3.7.1-219 and 3.7.1-220.

The staff verified the following aspects of the spectrally matched time histories:

- The correlation coefficients between the three components are less than 0.16, as listed in FSAR Table 3.7.1-218, which indicates statistical independence.

- The strong motion durations as defined in SRP Acceptance Criterion 3.7.1.II.1.B are listed in FSAR Table 3.7.1-219 and are in the order of 25 to 31 seconds, thus exceeding the minimum requirement of 6 seconds.

- The 5-percent damped response spectra of the time histories were compared with the enhanced SCOR FIRS at 301 spectral frequency points (or 100 frequencies per spectral frequency decade) in FSAR Figures 3.7.1-239 through 3.7.1-244. The comparison indicates that the response spectra are within 90 percent to 130 percent of the enhanced SCOR FIRS for the frequency range between 0.1 and 50 Hz.
- The time step and duration of the time histories are 0.005 seconds and 80 seconds, respectively, which correspond to an acceptable Nyquist frequency of 100 Hz.

On the basis of the above verifications, the staff finds the spectrally matched time histories to be acceptable per SRP Acceptance Criterion 3.7.1.II.1.B, Option 1, Approach 2. FSAR Figures 3.7.1-245 through 3.7.1-250 show that the spectrally matched time histories are compatible with the enhanced SCOR FIRS for the RB/FB and CB at the foundation levels.

The values of the parameter peak ground velocity (PGV)/PGA shown in FSAR Table 3.7.1-219 are consistent with the characteristic values reported in NUREG/CR–6728; however, the values of PGA x peak ground displacement (PGD)/PGV^2 are larger. This difference is acceptable because the time histories are spectrally matched to the enhanced SCOR FIRS, which represent a combination of hazards from both large, distant earthquakes and smaller, closer earthquakes. In this situation, a parameter such as PGA x PGD/PGV^2 may not necessarily match the characteristic values reported in NUREG/CR–6728 because the latter correspond to individual events and not combinations of events.

The applicant performed an additional verification to demonstrate that there are no significant gaps in power for the spectrally matched time histories. To do this, power spectral densities (PSDs) were calculated for the frequency range of 0.3 to 50 Hz per the guidance in Appendices A and B of SRP Section 3.7.1.

The staff notes that the spectrally matched time histories have a very long total duration (approximately 80 seconds) and clearly show non-stationary characteristics, with the high-frequency content decreasing significantly after about 45 to 50 seconds. These characteristics were inherited from the seed records corresponding to the 1999 Chi-Chi Taiwan event that were used to generate the time histories. As a consequence of the non-stationary characteristics, the PSD computations are sensitive to the definition and duration of the strong motion window used to define the PSD per the SRP guidance. To account for this sensitivity, the applicant considered several strong motion windows as shown in FSAR Figure 3.7.1-251.

The PSD plots are shown in FSAR Figures 3.7.1-252 through 3.7.1-255. The staff noted that the only appreciable dips in energy content are observed to occur below 1 Hz and above 25 Hz, for the shorter strong motion windows (the staff notes that the dips become attenuated as the durations of the windows increase). The reason for the dips is the energy content at these frequencies that occurs outside of the corresponding window used to define the PSD and thus cannot be represented in the plots. This is a limitation of the methodology for computing the PSD, which presumes stationary characteristics and does not necessarily reflect a deficiency in the energy content of the time histories. The staff concludes that the spectrally matched time histories are acceptable because the calculated PSD does not show significant gaps in power for the frequency range of 0.3 to 50 Hz, which is the frequency range of interest for the SSI analysis and is consistent with SRP Acceptance Criterion 3.7.1.II.1.B.ii.

Based on the NEI method described in DC/COL-ISG-017, the applicant developed in-column motions at the foundation levels of the RB/FB and the CB using the spectrally matched time histories defined as outcrop motions at the foundation levels and the deterministic subsurface profiles (BE, LB, and UB with and without backfill). These in-column motions are used as inputs into the Fermi 3 site-specific SSI analyses described in FSAR Section 3.7.2. This approach is acceptable to the staff because it is consistent with the NEI method described in DC/COL-ISG-17.

Percentage of Critical Damping Values

In FSAR Subsection 3.7.1.2, the applicant summarizes the damping ratios for the subsurface material profiles used in the site-specific SSI analyses of the RB/FB and CB, which were described in detail in FSAR Subsection 3.7.1.1.4. The staff's review of this information is discussed above in this SER under "*Deterministic Profiles for Site-Specific SSI Analyses.*" Maximum damping ratios were below 15 percent in all cases and are therefore acceptable per the guidance in SRP Acceptance Criterion 3.7.2.II.4.

Supporting Media for Category I Structures

In FSAR Subsection 3.7.1.3, the applicant summarizes the dynamic properties of the subsurface material profiles used in the site-specific SSI analyses of the RB/FB and CB, which were described in FSAR Subsection 3.7.1.1.4. The staff's review of this information is discussed above in this SER under "*Deterministic Profiles for Site-Specific SSI Analyses.*"

The applicant provides the site plans and profiles of the supporting media for the Category I and Category II structures in FSAR Figures 2.5.4-201 through 2.5.4-204. The staff determined that this information together with the standard plant structural data in the ESBWR DCD, Revision 9, is sufficient per SRP Acceptance Criterion 3.7.1.II.3. The staff's evaluation of the site-specific seismic analysis of the RB/FB using the site characteristics described in FSAR Subsection 3.7.1.3 is discussed in Section 3.7.2 of this SER.

3.7.1.5 *Post Combined License Activities*

There are no post COL activities related to this section.

3.7.1.6 *Conclusion*

The NRC staff's finding related to information incorporated by reference is in NUREG–1966. NRC staff reviewed the application and checked the referenced DCD. The staff's review confirmed that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the Fermi 3 FSAR related to this section. All nuclear safety issues relating to the seismic design parameters that were incorporated by reference have been resolved.

The staff compared the supplemental information in the COL application to the relevant NRC regulations, the guidance in Section 3.7.1 of NUREG–0800, other NRC regulatory guides, and the Interim Staff Guidance. The staff finds that the applicant has addressed seismic design parameters in accordance with the acceptance criteria delineated in these guidance documents. On this basis, the staff concludes that the applicant has satisfied the relevant requirements of the regulations delineated in Subsection 3.7.1.3 of this SER.

3.7.2 Seismic System Analysis

3.7.2.1 *Introduction*

This FSAR section addresses the seismic analysis methods and acceptance criteria used for the ESBWR seismic Category I structures. Seismic Category I structures are designed to withstand the effects of the SSE event and to maintain the specified design functions. This section applies to building structures that constitute primary structural systems. The reactor pressure vessel (RPV) is not a primary structural component; but it is considered as another part of the primary system of the RB for the purpose of dynamic analysis because of its dynamic interaction with the supporting structure. Seismic Category II and NS structures are designed or physically arranged (or both) to prevent the SSE from causing unacceptable structural interactions with or the failure of seismic Category I SSCs. The ESBWR method for a standard plant seismic analysis of the Category I structures is in Section 3.7.2 of ESBWR DCD Tier 2, Revision 9.

3.7.2.2 *Summary of Application*

Section 3.7.2 and Appendices 3A and 3C of the Fermi 3 COL FSAR, Revision 6, incorporate by reference Section 3.7.2 and Appendices 3A and 3C of ESBWR DCD Revision 9. In addition, in FSAR Section 3.7.2 and Appendices 3A and 3C, the applicant provides the following:

Supplemental Information

- EF3 SUP 3.7-4

In FSAR Subsection 3.7.2.4, the applicant presents the site-specific SSI analyses for the RB/FB and the CB performed for the Fermi 3 site conditions. The SSI analyses considered site conditions with and without the engineered granular backfill placed above the top of the Bass Islands Group rock. The FSAR includes a comprehensive set of the SSI analysis results (e.g., enveloping structural loads, maximum vertical accelerations, and floor response spectra) and their comparisons against corresponding DCD values.

- EF3 SUP 3.7-5

In FSAR Subsection 3.7.2.8, the applicant addresses the requirements for site-specific analyses of Non-Category I structures both within and outside the scope of the DCD and including the turbine building (TB), service building (SB), ancillary diesel building (ADB), and radwaste building (RWB).

In FSAR Subsection 3.7.2.14, the applicant indicates that the "site-specific stability evaluation against overturning" is in FSAR Section 3.8.5.

- EF3 SUP 3A.5-1

In FSAR Appendix 3A, Section 3A.5.3, the applicant indicates that the SASSI2010 computer program was used for all site-specific SSI and structure-soil-structure interaction (SSSI) analyses using the direct method (DM) or the modified subtraction method (MSM) of analysis described in FSAR Subsection 3.7.2.4.1.3. The staff reviewed the computer programs used in the site-specific analysis along with the review of the FSAR Section 3.7.2.

- EF3 SUP 3C-1

In FSAR Appendix 3C, the applicant describes the computer codes used in the Fermi 3 site-specific SSI analysis—including the computer code SASSI2010. The staff reviewed the computer programs used in the site-specific analysis along with a review of FSAR Section 3.7.2.

Conceptual Design Information

- EF3 CDI

The applicant indicates in FSAR Section 3A.1 that FSAR Chapter 2 describes site-specific geotechnical data, which are compatible with the site enveloping parameters considered in the standard design. The staff reviewed this information as it relates to the site-specific SSI analysis along with the review of the FSAR Section 3.7.2.

The applicant indicates in FSAR Section 3A.2 that FSAR Figure 2.1-204 depicts the site plan. The staff used this information in reviewing the FSAR Section 3.7.2.

3.7.2.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is in NUREG–1966. In addition, the relevant requirements of the Commission regulations for the seismic system analysis, and the associated acceptance criteria, are in Section 3.7.2 of NUREG–0800. The specific requirements include the following:

- 10 CFR Part 50, Appendix A, GDC 2, as it relates to the seismic design basis to reflect appropriate consideration of the most severe earthquakes historically reported for the site and surrounding area with a sufficient margin for the limited accuracy, quantity, and period of time in which historical data have been accumulated. In addition, SSCs important to safety should be designed to withstand the effects of earthquakes without losing the capability to perform their intended safety functions.

- 10 CFR Part 50, Appendix S, as it relates to the SSE ground motion in the free-field at the foundation level of the structures to be an appropriate response spectrum with a peak ground acceleration of at least 0.1 g; and if the OBE is chosen to be less than or equal to one-third of the SSE ground motion, it is not necessary to conduct explicit response or design analyses in accordance with Section IV.(2)(i)(A) of 10 CFR Part 50, Appendix S, and the requirement of taking into account SSI effects.

In addition, the acceptance criteria and regulatory guidance associated with the review of FSAR Section 3.7.2 include the following:

- SRP Section 3.7.2 guidance to review methods for site-specific seismic analysis and modeling of structures to ensure that they accurately and/or conservatively represent the behavior of SSCs during postulated seismic events.

- DC/COL-ISG-1, "Interim Staff Guidance on Seismic Issues of High Frequency Ground Motion," and DC/COL-ISG-017 in reviewing the seismic input and the SSI dynamic model acceptability for the Fermi 3 site.

- RG 1.61 to determine the acceptability of the damping values used in the structural model.

3.7.2.4 *Technical Evaluation*

As documented in NUREG–1966, NRC staff reviewed and approved Section 3.7.2 and Appendices 3A and 3C of the ESBWR DCD. The staff reviewed Section 3.7.2 and Appendices 3A and 3C of the Fermi 3 COL FSAR Revision 6, and checked the referenced ESBWR DCD to ensure that the combination of the information in the COL FSAR and the information in the ESBWR DCD appropriately represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and the information incorporated by reference address the required information relating to this section.

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[1] See *"Finality of Referenced NRC Approvals"* in SER Section 1.2.2, for a discussion on the staff's review related to verification of the scope of information to be included in a COL application that references a design certification.

The staff reviewed the following information in the Fermi 3 COL FSAR:

Supplemental Information

- EF3 SUP 3.7-4
- EF3 SUP 3A.5-1
- EF3 SUP 3C-1

Conceptual Design Information

- EF3 CDI

Soil-Structure Interaction

Site-Specific SSI Analysis

SRP Section 3.7.2 provides the guidance on the review of the seismic analysis of seismic Category I structures. Specifically, the NRC staff's review includes an assessment of the methods used in the seismic analysis to account for SSI effects, including the validation of the computer programs used in the analysis.

As indicated in FSAR Section 2.5.4 and Figures 2.5.4-201 through 2.5.4-204, the RB/FB and the CB structures at the Fermi 3 site are partially embedded in the Bass Islands Group rock. Therefore, the underlying soil media are in fact rock media. In the case of the FWSC, the structure is supported on a block of concrete fill that bears on the Bass Islands Group rock. A block of concrete fill is also located in the gap between the RB/FB and the CB.

Engineered granular backfill is used to fill the site excavation surrounding the power block structures. This backfill is placed above the top of the Bass Islands Group rock up to the plant grade level and is depicted in FSAR Figures 2.5.4-201, 2.5.4-202, and 2.5.4-203. FSAR Subsection 2.5.4.5.4.2 describes the material properties and specifications of the engineered granular backfill.

Site-specific SSI analyses for the RB/FB and the CB were performed for the site conditions with and without the presence of the engineered granular backfill. These analyses are documented in FSAR Subsection 3.7.2.4 and in Sargent & Lundy Reports SL-011864 Revision 1, "Licensing Basis SSI Analyses of Reactor Building/Fuel Building and Control Building Summary Report," (ML13210A144); and SL-011956 Revision 1, "SSI Analyses of Reactor Building/Fuel Building and Control Building with Engineered Backfill Summary Report," (ML13360A176).

Site-specific SSI analyses were also performed to account for the SSSI effect of the RB/FB and FWSC on the CB, considering the presence of the engineered granular backfill. These analyses are documented in Sargent & Lundy Report SL-011960 Revision 0, "SSSI Sensitivity Studies of CB and FWSC with Engineered Backfill Summary Report," (ML13232A006).

The staff reviewed calculations pertinent to the site-specific SSI and SSSI analyses during the onsite audit on November 18 through 22, 2013, (ML14028A245). The staff also reviewed calculations pertaining to the validation and verification of the computer program used in the site-specific SSI and SSSI analyses during the onsite audit on March 19 through 21, 2013, (ML13149A515). This program is further discussed later in this section under "Computer Programs Verification and Validation Issues."

The site-specific SSI and SSSI analyses for the RB/FB and the CB structures were performed by the applicant to address the following site-specific issues:

- To confirm that the ESBWR DCD standard plant design is applicable to the Fermi 3 site-specific conditions where the RB/FB and the CB structures are partially embedded in the Bass Islands Group rock, with engineered granular backfill surrounding the structures from the top of the rock to the plant grade level. These site-specific conditions deviate from the soil cases considered in the SSI analyses described in ESBWR DCD Tier 2, Appendix 3A.

- To demonstrate that the standard plant design is applicable to the Fermi 3 site-specific conditions, even though the ESBWR DCD requirements for the engineered granular backfill that surrounds the seismic Category I structures are not being met for the RB/FB and the CB structures. Specifically, ESBWR DCD Tier 2, Table 2.0-1 states that the minimum shear wave velocity of the material surrounding the embedded walls of these structures should be greater than 300 m/s (1000 ft/s). In accordance with Footnote (16) to ESBWR DCD Tier 2, Table 2.0-1; ESBWR DCD Tier 1, Section 5.0, "Site Parameters"; and Footnote (6) to ESBWR DCD Tier 1, Table 5.1-1; site-specific SSI analyses are required to demonstrate the adequacy of the standard plant design for sites not meeting the ESBWR DCD soil parameter requirements.

Site-specific SSI analyses for the FWSC structure were not performed by the applicant. The staff finds this acceptable because the two issues identified above are not applicable to the FWSC. First, because the FWSC at the Fermi site is supported on a block of concrete fill that bears on the Bass Islands Group rock, the FWSC is therefore not partially embedded in the Bass Islands Group rock. Second, as described in ESBWR DCD Tier 2, Subsection 3.7.1.1, the FWSC is essentially a surface-founded structure (embedded 2.35 m [7.7 ft]) with no embedded walls. Therefore, the requirement in ESBWR DCD Tier 2 Table 2.0-1 for material surrounding the embedded walls is not applicable to the FWSC. Because the site-specific FIRS for the FWSC is bounded by the ESBWR CSDRS, and all other requirements in ESBWR DCD Tier 2, Table 2.0-1 are met, the staff concludes that the standard plant design for the FWSC is applicable to the Fermi 3 site without further site-specific SSI analyses.

The various SSI and SSSI case analyses performed by the applicant are summarized in Table 3.7.2-1 and Table 3.7.2-2 of this SER. In these tables, DM and MSM refer to the "Direct Method" and "Modified Subtraction Method" of the SASSI2010 program, respectively. (See the discussion below under "*SSI Analysis Method.*") BE, LB and UB refer to the "Best Estimate"; "Lower Bound"; and "Upper Bound" subsurface material profiles, respectively. (See the discussion below under "*Strain Compatible Dynamic Subsurface Material Properties.*")

Strain Compatible Dynamic Subsurface Material Properties

The site-specific SSI analyses considered the three site-specific subsurface material profiles that are documented in FSAR Tables 3.7.1-206 through 3.7.1-211. The staff finds these profiles acceptable because they account for the effects of the potential variability in the properties of the soils and rocks at the site and are consistent with SRP Acceptance Criterion 3.7.2.II.4. The three profiles are designated as BE, LB, and UB. For the LB and UB profiles, the SSI analyses considered separate cases with and without the engineered granular backfill surrounding the structures. For the BE profile, the SSI analyses considered only the case without the backfill.

The staff's review of the above information is in Subsection 3.7.1.4 of this SER. The staff notes that the subsurface material profiles documented in FSAR Tables 3.7.1-206 through 3.7.1-211 were slightly adjusted in the SSI analyses to ensure that layer thicknesses and mesh dimensions would match the characteristics of the embedded portions of the structures, as well as to address finite element aspect ratios and model passing frequencies (see the discussion below under "*SSI Analyses of Structural Models*"). During the onsite audit on November 18 through 22, 2013, (ML14028A245) the staff confirmed that the effect of these adjustments on the SSI analyses was negligible, and the SSI analyses are therefore acceptable.

The subsurface material profiles used in the SSI analyses—with the adjustments described above—are documented in Sargent & Lundy Reports SL-011864 Revision 1 (ML13210A144) and SL-011956 Revision 1 (ML13360A176).

FIRS Compatible Ground Motion Time History

The site-specific SSI analyses considered three orthogonal components (two horizontal and one vertical) of ground motion time histories described in FSAR Subsection 3.7.1.1.5. These time histories were developed to be in-column motions at the bottom of the RB/FB and the CB basemat elevations and are compatible with the site-specific FIRS of the RB/FB and the CB (designated as "enhanced SCOR FIRS") described in FSAR Section 3.7.1. The staff finds that these ground motion time histories are acceptable control motions for the site-specific SSI analyses performed by the applicant.

The staff's review of the above information is in Subsection 3.7.1.4 of this SER.

SSI Analysis Method

The applicant performed site-specific SSI analyses following the methodology in ESBWR DCD Tier 2, Appendices 3A.5 and 3A.5.2, which is based on the frequency domain complex response approach using the SASSI2000 program. Structural responses were computed in terms of maximum absolute accelerations, maximum forces and moments, and floor response spectra (FRS) at the key locations in the structures identified in ESBWR DCD Tier 2, Appendix 3A, as well as seismic lateral soil pressures acting on below-grade exterior walls (seismic soil pressures are reviewed in Subsection 3.8.4.4 of this SER). The above methodology is acceptable to the staff because it is the same methodology applied in the ESBWR DCD and is consistent with SRP Acceptance Criterion 3.7.2.II.4.

However, the applicant used the SASSI2010 program instead of the SASSI2000 program in the site-specific SSI analyses. To ensure the acceptability of the SASSI2010 program for use in the site-specific SSI analyses at Fermi 3, the applicant performed validation and verification analyses. The staff's review of this validation and verification effort is described below under "Computer Programs Verification and Validation Issues," where the staff concludes that the SASSI2010 program is acceptable for the site-specific SSI analyses at the Fermi 3 site.

To perform the SSI analysis of embedded structures such as the RB/FB and the CB, the SASSI2010 program may use the DM (also known as the "Flexible Volume Method"), the MSM, or the SM ("Subtraction Method"). The DM is the most accurate but also the most computationally intensive method. If not implemented properly, the SM could potentially result in erroneous and non-conservative SSI responses when compared to the DM.

FSAR Subsection 3.7.2.4.1.3 indicates that the site-specific SSI analyses were performed using either the DM or the MSM, but not the SM. Current staff guidance regarding the use of the DM versus the MSM is in SRP Section 3.7.2 Revision 4, SRP Acceptance Criterion 3.7.2.II.4. Although the guidance states that the DM should be used to the extent practical, the MSM is also identified as an alternative for very large computer models where it is not feasible to use the DM. The guidance recommends the use of reduced-size computer models (e.g., quarter models) to perform direct comparisons between the MSM and the DM solutions and to draw conclusions that can be extrapolated to the full-size models.

In accordance with the above guidance, the applicant performed additional benchmark studies for those SSI case analyses that required the use of the MSM in SASSI2010 because of the computational limitations with the size of the computer models (SSI analyses of cases RBFB2UB-MSM and RBFB2LB-MSM for the RB/FB and CB4-FWSC1UB-MSM and CB4-FWSC1LB-MSM for the CB).

The benchmark studies discussed below used reduced-size models and the same site-specific subsurface material profiles (UB with backfill considered) and input motions as the full-size models. The benchmark studies performed were as follows:

- Direct DM versus the MSM comparison of a quarter-size model of the RB/FB determined that two layers of interaction nodes were necessary in the implementation of the MSM to obtain essentially identical results as the DM for the frequency range of interest. The two layers of interaction nodes were located at the plant grade elevation of +4.65 m (15.26 ft) and at the elevation of -2.025 m (-6.644 ft), in the portion of the SSI model known as the "excavated volume."

- Direct DM versus the MSM comparison of a full-size model of the CB determined that two layers of interaction nodes were necessary in the implementation of the MSM to obtain essentially identical results as the DM for the frequency range of interest. The two layers of interaction nodes were located at the plant grade elevation of +4.50 m (14.76 ft) and at the elevation of -2.00 m (6.56 ft).

- Direct DM versus the MSM comparison of a half-size model of the FWSC determined that a single layer of interaction nodes was required in the implementation of the MSM to obtain essentially identical results as the DM for the frequency range of interest. The layer of interaction nodes was located at the plant grade elevation of +4.50 m (14.76 ft).

The results of these benchmark studies are documented in Sargent & Lundy Reports SL-011814 Revision 0, "Modified Subtraction Method (MSM) Reactor Building/Fuel Building Benchmark Summary Report," (ML13127A034); SL-011874 Revision 0, "Modified Subtraction Method (MSM) Control Building Benchmark Summary Report," (ML13175A263); and SL-011863 Revision 0, "Modified Subtraction Method (MSM) Firewater Service Complex Benchmark Summary Report," (ML13175A264). The benchmark studies were reviewed by the staff during the onsite audit on November 18 through 22, 2013, (ML14028A245). The staff notes that the benchmark studies of the CB and the FWSC were necessary for the SSSI analyses discussed below under "*SSSI Analysis*."

The staff reviewed the reduced-size models used in the benchmark studies to ensure that they were representative of the full-size models in terms of dynamic characteristics, foundation width-to-depth ratio, embedment depth, subsurface material profiles, and input motions. The staff also reviewed the DM versus the MSM comparisons of structural responses in terms of transfer functions, maximum absolute accelerations, maximum forces and moments, FRS at the key locations in the structures identified in ESBWR DCD Tier 2, Appendix 3A, and the seismic lateral soil pressures acting on below-grade exterior walls. The staff confirmed that the results are essentially identical for the frequency range of interest to the Fermi 3 site conditions.

On the basis of the benchmark studies performed using reduced-size computer models and the staff guidance discussed above, the staff concludes that the applicant's implementation of the MSM in SASSI2010 is acceptable because the full-size models used the same number of layers of interaction nodes identified in the benchmark studies. The staff's review of the SSI and SSSI analyses is documented in Sargent & Lundy Reports SL-011956 Revision 1 (SSI analyses with engineered granular backfill) and SL-011960 Revision 0 (SSSI analyses with engineered granular backfill), respectively. The review confirmed the acceptability of the applicant's implementation of the MSM and thus resolved the issue.

SSI Analyses of Structural Models

The site-specific SSI models of the RB/FB and the CB consist of (a) lumped-mass stick models that consider shear, bending, torsion, and axial deformations of the buildings; (b) single-degree-of-freedom (SDOF) oscillators connected to the stick models and used to represent the out-of-plane seismic response of flexible slabs in the buildings; (c) plate finite elements arranged in a uniform mesh that was used to represent the exterior walls below grade and the basemats; (d) brick finite elements arranged in a uniform mesh that was used to model the portion of the subsurface backfill/rock medium where the structures are embedded (known as the "excavated volume"); and (e) horizontal layers of infinite extension used to represent the subsurface profile of the backfill/rock medium. It should be noted that the exterior walls below grade and the basemats match the lateral perimeter and bottom boundary of the excavated volume.

FSAR Subsection 3.7.2.4.1.4 indicates that the site-specific SSI model configurations are the same as those in ESBWR DCD Tier 2, Figures 3A.7-8 through 3A.7-10 for the RB/FB and DCD Figures 3A.7-11 through 3A.7-13 for the CB, except that the vertical and horizontal spacing of the excavated soil volume nodes and boundary—items (c) and (d) above—are adjusted to closely match the site-specific subsurface profile layers and to address model passing frequencies. The staff finds this model configuration acceptable, as discussed below.

The site-specific SSI model configurations are depicted in FSAR Figures 3.7.2-201 through 3.7.2-203 (the RB/FB model without backfill and designated as model RBFB1 in SER Table 3.7.2-1 below); FSAR Figures 3.7.2-203a through 3.7.2-203c (the RB/FB model with backfill and designated as model RBFB2 in SER Table 3.7.2-1 below); FSAR Figures 3.7.2-204 through 3.7.2-206 (the CB model without backfill and designated as model CB1 in SER Table 3.7.2-2 below); and FSAR Figures 3.7.2-206a through 3.7.2-206c (the CB model with backfill and designated as model CB2 in SER Table 3.7.2-2 below).

FSAR Subsection 3.7.2.4.1.4 indicates that the stick models and the SDOF oscillators for the RB/FB and the CB—items (a) and (b) above—are the same as those described in ESBWR DCD Tier 2 Section 3A.7, “Analysis Models,” and depicted in DCD Figure 3A.7-4 (RB/FB) and Figure 3A.7-6 (CB). The stick models and the SDOF oscillators used in the site-specific SSI models are therefore acceptable because they are the same as those used in the ESBWR DCD for the same purpose, and they are consistent with SRP Acceptance Criterion 3.7.2.II.3.C.

To ensure that the dynamic response of the site-specific SSI models is adequate for the frequency range of interest, the uniform finite element meshes used to represent the excavated soil volumes and their boundaries—items (c) and (d) above—should be sufficiently refined to address criteria (1) the horizontal dimensions (both East-West and North-South directions) should not exceed 20 percent of the shear wavelength of the corresponding layer at the passing frequency of the model; (2) the vertical dimension should not exceed 20 percent of the shear wavelength of the corresponding layer at the passing frequency of the model; and (3) the aspect ratio of the plate and brick finite elements used in the mesh should not exceed 1:3, as identified by the applicant in the validation and verification study for the SASSI2010 program, which is discussed later in this section under “Computer Programs Verification and Validation Issues.” Per the Interim Staff Guidance DC/COL-ISG-1, the passing frequency of the SSI models should be at least 50 Hz.

The staff reviewed the finite element meshes of the corresponding excavated volumes depicted in FSAR Figures 3.7.2-201 through 3.7.2-203, FSAR Figures 3.7.2-203a through 3.7.2-203c, FSAR Figures 3.7.2-204 through 3.7.2-206, and FSAR Figures 3.7.2-206a through 3.7.2-206c. The staff concluded that the mesh sizes meet the criteria identified above except for the SSI analyses of cases RBFB2LB-MSM and CB2LB-DM (the LB subsurface profile with backfill considered). For these cases, the staff concluded that the passing frequency of the SSI models is approximately 19 Hz and thus deviates from the guidance in DC/COL-ISG-1.

The staff reviewed the horizontal layers of the infinite extension used to represent the subsurface profiles of the backfill/rock medium—item (e) above—as documented in Sargent & Lundy Reports SL-011956 Revision 1 (SSI analyses with engineered granular backfill) and SL-011960 Revision 0 (SSSI analyses with engineered granular backfill). The staff concluded that the thickness of the rock layers in the models satisfies the limiting criterion of 20 percent of the shear wavelength at the passing frequency of the model. However, the SSI analyses of cases RBFB2LB-MSM and CB2LB-DM (the LB subsurface profile with backfill considered), the thickness of the backfill layers did not satisfy the criterion and resulted in a passing frequency of approximately 19 Hz, which is consistent with the staff's finding for the finite element meshes of the excavated volumes.

The staff's assessment concluded that the deviation from the guidance identified above is not a technical concern for the following reasons. First, the site-specific seismic responses computed for the UB subsurface profile with and without considering the backfill are more sensitive to the frequency content of input motions above 19 Hz. These are accurately captured in the analyses because they are based on SSI models that have the required 50 Hz passing frequency. Second, the reduced passing frequency for the SSI analyses of cases RBFB2LB-MSM and CB2LB-DM reflects an insufficient mesh/layer refinement in the backfill portions of the models only—the mesh/layer dimensions in the rock portions are adequate. Third, a review of site-specific seismic responses in the structures computed for SSI analyses of cases RBFB2LB-MSM and CB2LB-DM indicates that these cases are generally almost always bounded by the other case analyses that have the required 50 Hz passing frequency. This is because SSI effects at the Fermi 3 site are dominated by the interaction between the structures and the rock in which they are embedded. Fourth, the reduced passing frequency for the SSI analyses of cases RBFB2LB-MSM and CB2LB-DM does not affect the seismic lateral soil pressures computed for these cases because these are mainly due to low frequency responses (i.e., below 19 Hz).

On the basis of these considerations for items (a) through (e) identified above, the staff finds that the site-specific SSI models documented in FSAR Subsection 3.7.2.4.1.4 meet SRP Acceptance Criteria 3.7.2.II.3 and 3.7.2.II.4 and are therefore acceptable. ESBWR DCD Tier 2, Table 3A.6-1 identifies several modifications to the basic stick models of the RB/FB and the CB for purposes of evaluating the effects of parameter variations on the seismic responses. FSAR Subsection 3.7.2.4.1 indicates that in the site-specific SSI analyses, the basic stick models designated as "base" were used. These base models considered the concrete to be "uncracked," which is represented by assuming the full value of the concrete modulus of elasticity.

In the supplemental response to RAI 03.07.02-9 Item 4 (Attachment 15 to DTE Letter NRC3-13-0036, ML13354B536), the applicant further clarified that OBE damping ratios were used for the structural elements in all SSI and SSSI analyses. In the RB/FB models, OBE damping values of 4 percent and 3 percent were used for reinforced concrete elements and welded steel elements, respectively. In the CB models, OBE damping values of 4 percent were used for the reinforced concrete elements.

The staff finds the above modeling assumptions acceptable given the overall moderate magnitude of the site-specific stress levels induced throughout the RB/FB and the CB structures. As discussed below under "*SSI Analysis Results—Enveloping Maximum Structural Loads*," and "*SSI Analysis Results—Enveloping Single-Degree-of-Freedom Oscillator Response,*" the site-specific seismic loads are bounded by the seismic loads considered in the standard design—in some cases by a significant margin. Therefore, per SRP Acceptance Criterion 3.7.1.II.2 and RG 1.61 guidance, the use of uncracked section properties and OBE damping is conservative and are thus acceptable.

SSI Case Analyses

The various SSI case analyses performed by the applicant are summarized in SER Tables 3.7.2-1 and 3.7.2-2. Site-specific SSSI analyses of cases are also included in these tables for completeness. SSSI analyses are discussed below under "*SSSI Analysis*."
The three site-specific subsurface material profiles BE, LB, and UB account for the variability in the subsurface material properties at the Fermi 3 site, as discussed earlier in Subsection 3.7.1.4 of this SER. For the LB and UB profiles, the SSI analyses considered separate cases with and without the backfill surrounding the structures. For the BE profile, the SSI analyses considered only the case without the backfill. The staff finds this acceptable because the dynamic properties of the LB and UB profiles with backfill effectively bound the corresponding properties of the BE profile with the backfill. The staff concludes that the SSI and SSSI cases summarized in SER Tables 3.7.2-1 and 3.7.2-2 provide sufficient information for the staff to determine the acceptability of the ESBWR standard plant design at the Fermi 3 site.

SSI Analysis Results—Transfer Functions

Sargent & Lundy Reports SL-011864 Revision 1 (SSI analyses without engineered granular backfill) and SL-011956 Revision 1 (SSI analyses with engineered granular backfill) document the transfer functions computed for the site-specific SSI case analyses. These reports present results for the following key locations identified in DCD Appendix 3A:

- RB/FB: top of basemat, refueling floor, reinforced concrete containment vessel (RCCV) top slab, top of vent wall, top of reactor shield wall (RSW), top of RPV.

- CB: top of basemat and top of roof slab.

The staff reviewed the transfer function plots and found them to be generally smooth, with a sufficient density of calculated frequency points in the frequency range of interest. Although some isolated sharp spikes were noted in a few of the plots because of the interpolation scheme used by the SASSI2010 program, these spikes had no observable impact on the seismic response or the FRS.

Therefore, the staff concludes that the site-specific SSI analyses performed by the applicant with the SASSI2010 program were implemented in a manner consistent with the frequency domain complex response method described in ESBWR DCD Tier 2, Appendix 3A.

SSI Analysis Results—Enveloping Maximum Structural Loads

FSAR Tables 3.7.2-203a through 3.7.2-203e document the envelope of the maximum seismic forces and moments in the different stick models of the RB/FB complex obtained from the site-specific SSI case analyses and compare these to the corresponding values in ESBWR DCD Tier 2, Tables 3A.9-1a through 3.A.9-1e. The comparisons are as follows:

- RB/FB stick (FSAR Table 3.7.2-203a and DCD Table 3A.9-1a): maximum ratio of site-specific seismic loads to corresponding DCD values is approximately 67 percent.

- RCCV stick (FSAR Table 3.7.2-203b and DCD Table 3A.9-1b): maximum ratio of site-specific seismic loads to corresponding DCD values is approximately 68 percent.

- Vent Wall/Pedestal stick (FSAR Table 3.7.2-203c and DCD Table 3A.9-1c): maximum ratio of site-specific seismic loads to corresponding DCD values is approximately 51 percent.

- RSW stick (FSAR Table 3.7.2-203d and DCD Table 3A.9-1d): maximum ratio of site-specific seismic loads to corresponding DCD values is approximately 60 percent.

- RPV stick (FSAR Table 3.7.2-203e and DCD Table 3A.9-1e): maximum ratio of site-specific seismic loads to corresponding DCD values is approximately 86 percent.

FSAR Table 3.7.2-204 documents the envelope of the maximum seismic forces and moments in the CB obtained from the site-specific SSI case analyses and compares these to the corresponding values in ESBWR DCD Tier 2, Table 3A.9-1f. The comparison is as follows:

- CB stick (FSAR Table 3.7.2-204 and DCD Table 3A.9-1f): maximum ratio of site-specific seismic loads to corresponding DCD values is approximately 72 percent.

FSAR Tables 3.7.2-205a through 3.7.2-205d document the envelope of the maximum absolute vertical accelerations in the different stick models of the RB/FB complex obtained from the site-specific SSI case analyses and compare these to the corresponding values in ESBWR DCD Tier 2, Tables 3A.9-3a through 3.A.9-3d. The comparisons are as follows:

- RB/FB stick (FSAR Table 3.7.2-205a and DCD Table 3A.9-3a): maximum ratio of site-specific vertical accelerations to corresponding DCD values is approximately 46 percent.

- RCCV stick (FSAR Table 3.7.2-205b and DCD Table 3A.9-3b): maximum ratio of site-specific vertical accelerations to corresponding DCD values is approximately 41 percent.

- Vent Wall/Pedestal stick (FSAR Table 3.7.2-205c and DCD Table 3A.9-3c): maximum ratio of site-specific vertical accelerations to corresponding DCD values is approximately 44 percent.

- RSW stick (FSAR Table 3.7.2-205d and DCD Table 3A.9-3d): maximum ratio of site-specific vertical accelerations to corresponding DCD values is approximately 45 percent.

FSAR Table 3.7.2-206 documents the envelope of the maximum absolute vertical accelerations in the CB obtained from the site-specific SSI case analyses and compares these to the corresponding values in ESBWR DCD Tier 2, Table 3A.9-3g. The comparison is as follows:

- CB stick (FSAR Table 3.7.2-206 and DCD Table 3A.9-3g): maximum ratio of site-specific vertical accelerations to corresponding DCD values is approximately 41 percent.

Based on the above comparisons, the staff concludes that the site-specific envelope of maximum seismic forces and moments and maximum absolute vertical accelerations in the different stick models of the RB/FB and the CB are bounded by the corresponding values in ESBWR DCD Tier 2, Section 3A.9.1. This finding is acceptable and indicates that the standard plant design is applicable to the RB/FB and the CB at the Fermi 3 site.

SSI Analysis Results—Enveloping Single-Degree-of-Freedom Oscillator Response

FSAR Table 3.7.2-205e documents the envelope of the maximum absolute vertical accelerations for the SDOF flexible slab oscillators in the RB/FB obtained from the site-specific SSI case analyses and compares these to the corresponding values in ESBWR DCD Tier 2, Table 3.A.9-3e. The comparison is as follows:

- RB/FB (FSAR Table 3.7.2-205e and DCD Table 3A.9-3e): maximum ratio of site-specific vertical accelerations to corresponding DCD values is approximately 75 percent.

FSAR Table 3.7.2-206 documents the envelope of the maximum absolute vertical accelerations for the SDOF flexible slab oscillators in the CB obtained from the site-specific SSI case analyses and compares these to the corresponding values in ESBWR DCD Table 3A.9-3g. The comparisons are as follows:

- CB (FSAR Table 3.7.2-206 and DCD Table 3A.9-3g): maximum ratio of site-specific vertical accelerations to corresponding DCD values is approximately 75 percent.

Based on the above comparisons, the staff concludes that the site-specific envelope of maximum absolute vertical accelerations for the SDOF flexible slab oscillators in the RB/FB and the CB are bounded by the corresponding values in ESBWR DCD Tier 2, Section 3A.9.1. This is acceptable and indicates that the standard plant design is applicable to the RB/FB and the CB at the Fermi 3 site.

SSI Analysis Results—Enveloping Floor Response Spectra

FSAR Figures 3.7.2-207a through 3.7.2-209f present the envelopes of the 5-percent damped FRS at the key locations in the RB/FB (top of basemat, refueling floor, RCCV top slab, top of vent wall, top of RSW, top of RPV) obtained from the site-specific SSI case analyses and compare these to the corresponding enveloping FRS in ESBWR DCD Tier 2, Section 3A.9.2.

FSAR Figures 3.7.2-210a through 3.7.2-212b present the envelopes of the 5-percent damped FRS at the key locations in the CB (top of basemat and top of roof slab) obtained from the site-specific SSI case analyses and compare these to the corresponding enveloping FRS in ESBWR DCD Tier 2, Section 3A.9.2.

Based on the above comparisons, the staff concludes that the site-specific FRS at the key locations in the RB/FB and the CB are bounded by the corresponding enveloping

FRS in ESBWR DCD Tier 2, Section 3A.9.2, by a substantial margin. This finding is acceptable and indicates that the standard plant design is applicable to the RB/FB and the CB at the Fermi 3 site.

SSSI Analysis

To evaluate the SSSI effect of the RB/FB and the FWSC on the CB, the applicant performed site-specific SSSI analyses that adhered to the same methodologies described in ESBWR DCD Tier 2, Section 3A.8.11. These analyses are documented in the Sargent & Lundy Report SL-011960 Revision 0 (SSSI analyses with engineered granular backfill).

The staff notes that the RB/FB is considerably more massive than the CB is, so the SSSI effect of the RB/FB on the CB is thus more significant than the effect of the CB on the RB/FB. On this basis, the applicant did not evaluate the SSSI effect of the CB on the RB/FB. The staff reviewed the ESBWR DCD and determined that the basis provided by the applicant for neglecting the SSSI effect of the CB on the RB/FB is consistent with the seismic analysis methodology described in ESBWR DCD Tier 2, Section 3A.8.11 and is therefore acceptable.

To evaluate the SSSI effect of the RB/FB on the CB, the applicant performed the SSSI analyses denoted as CB3UB-DM and CB3LB-DM in SER Table 3.7.2-2 below. These analyses considered the presence of the backfill above the rock and were performed in two steps. In the first step, the ground motion responses at the center of the CB basemat location in the free-field were obtained from the SSI analyses of the RB/FB with backfill considered (SSI analyses of cases RBFB2UB-MSM and RBFB2LB-MSM). In the second step, the ground motion responses computed in the first step were used as input motions to SSI analyses of the CB, thus capturing the SSSI effect of the RB/FB on the CB. This method is the same as the one described in ESBWR DCD Tier 2, Section 3A.8.11.

To evaluate the SSSI effect of the FWSC on the CB, the applicant performed the SSSI analyses denoted as CB4-FWSC1UB-MSM and CB4-FWSC1LB-MSM in SER Table 3.7.2-2, below. These analyses considered the presence of the backfill above the rock and used fully coupled models in which both the CB and the FWSC were represented together with the subsurface material. The input motions applied to the coupled CB4-FWSC1 models were the in-column motions corresponding to the SSI FIRS for the CB applied at the bottom of the CB basemat. This method is the same as the one described in ESBWR DCD Tier 2, Section 3A.8.11.

The site-specific SSSI analyses described above used the same model representation of the RB/FB and the CB structures and the UB and LB subsurface profiles used in the other SSI case analyses, which the staff reviewed and accepted as discussed above under *"SSI Analyses of Structural Models."* The passing frequency of the models used for SSSI analyses of cases CB3LB-DM and CB4-FWSC1LB-MSM is approximately 19 Hz, which deviates from the guidance in DCD/COL-ISG-1. The staff concluded that this deviation is not a safety concern for several reasons discussed above under *"SSI Analyses of Structural Models*," which are also applicable to the SSSI analyses of the models.

For the site-specific SSSI analyses, the model representation of the FWSC structure consisted of a lumped-mass stick model, with plate finite elements used to represent the basemat described in ESBWR DCD Tier 2, Section 3A.7. The excavated volume for the FWSC extended from the bottom of the concrete fill under the basemat up to plant grade elevation. The concrete fill under the basemat was modeled with brick finite elements and was considered part of the structure. The staff finds the model representation of the FWSC acceptable because it uses the same stick model as the one used in the EBSWR DCD for the same purpose; and the finite element mesh used to represent the concrete fill satisfies the acceptance criteria for the aspect ratio and the passing frequency discussed above under *"SSI Analyses of Structural Models,"* which are consistent with SRP Acceptance Criterion 3.7.2.II.3.C.

The staff reviewed the structural responses computed from the site-specific SSSI analyses in terms of transfer functions, maximum absolute accelerations, maximum forces and moments, and the 5-percent damped FRS at the key locations in the CB identified in ESBWR DCD Tier 2, Appendix 3A. These results are documented in the Sargent & Lundy Report SL-011960 Revision 0 (ML13232A006). In reviewing the results, the staff observed the following:

The maximum ratio of site-specific seismic loads to corresponding ESBWR DCD values in the CB stick is approximately 65 percent (envelope of SSSI analyses of cases CB3UB-DM and CB3LB-DM) and 60 percent (envelope of SSSI analyses of cases CB4-FWSC1UB-MSM and CB4-FWSC1LB-MSM) compared to 72 percent obtained for the other SSI case analyses.

The maximum ratio of site-specific vertical accelerations to corresponding ESBWR DCD values in the CB stick is approximately 40 percent (envelope of SSSI analyses of cases CB3UB-DM and CB3LB-DM) and 39 percent (envelope of SSSI analyses of cases CB4-FWSC1UB-MSM and CB4-FWSC1LB-MSM) compared to 41percent obtained for the other SSI case analyses.

The maximum ratio of site-specific vertical accelerations to corresponding ESBWR DCD values for the SDOF flexible slab oscillators in the CB is approximately 62 percent (envelope of SSSI analyses of cases CB3UB-DM and CB3LB-DM) and 61 percent (envelope of SSSI analyses of cases CB4-FWSC1UB-MSM and CB4-FWSC1LB-MSM), compared to 75 percent obtained for the other SSI case analyses.

A comparison of 5-percent damped FRS at the key locations in the CB (top of basemat and top of roof slab) obtained from the various site-specific SSSI case analyses to the corresponding enveloping FRS in ESBWR DCD Tier 2, Section 3A.9.2 indicates that the latter bound the former by a significant margin.

Based on the above observation, the staff concludes that (a) at the Fermi 3 site, the SSSI effects on the CB are relatively minor; and (b) the structural responses computed from the site-specific SSSI analyses in terms of maximum absolute accelerations, maximum forces and moments, and the 5-percent damped FRS at the key locations in the CB identified in ESBWR DCD Tier 2, Appendix 3A are bounded by the corresponding values considered in the EBSWR DCD. Therefore, the standard plant design for the Fermi 3 site is acceptable.

The seismic lateral soil pressures acting on below-grade exterior walls of the CB and computed from the site-specific SSSI analyses discussed above were incorporated into the applicant's evaluations of the design of below-grade exterior walls of the CB. This issue was reviewed by the staff under Subsection 3.8.4.4 of this SER.

Supplemental Information

- EF3 SUP 3.7-5

Interaction of Non-Category I Structures with Seismic Category I Structures

FSAR Subsection 3.7.2.8 indicates that site-specific Non-Category I structures (outside the scope of the ESBWR DCD) are separated from seismic Category I structures by at least a distance equal to their height above grade. Therefore, the collapse of any site-specific Non-Category I structure will not cause the Non-Category I structure to strike a Seismic Category I structure. The locations of structures are depicted in FSAR Figure 2.1-204. The staff concludes that this is consistent with SRP Acceptance Criterion 3.7.2.II.8.A and is therefore acceptable.

FSAR Subsection 3.7.2.8 indicates that the design and analysis of the seismic Category II structures (TB; SB; and ADB) and the seismic Category NS RWB identified in ESBWR DCD Tier 2, Subsection 3.7.2.8 will be completed as part of the detailed design phase for the ESBWR standard plant design, per DCD Tier 2, Subsection 3.7.2.8.1 for the TB, Subsection 3.7.2.8.2 for the RWB, Subsection 3.7.2.8.3 for the SB, and Subsection 3.7.2.8.4 for the ADB; and DCD Tier 1 ITAAC Tables 2.16.8-1 for the TB, 2.16.9-1 for the RWB, 2.16.10-1 for the SB, and 2.16.11-1 for the ADB.

In addition, for the TB, RWB, SB, and ADB structures, FSAR Subsection 3.7.2.8 and Fermi 3 COL application Part 10 identify site-specific ITAAC and corresponding acceptance criteria that indicate the following:

- If the Fermi 3 soil properties do not meet the site parameters specified in the ESBWR DCD Tier 1, Table 5.1-1 and ESBWR DCD Tier 2, Table 2.0-1 (e.g., for the engineered granular backfill surrounding the embedded walls of these structures), then Fermi 3 site-specific SSI and SSSI analyses using the Fermi 3 site properties will be performed for the TB, RWB, SB, and ADB structures adhering to the same methodology specified in ESBWR DCD Tier 2, Appendix 3A; ESBWR DCD Tier 2, Subsections 3.7.2.8.1 for the TB, 3.7.2.8.2 for the RWB, 3.7.2.8.3 for the SB, and 3.7.2.8.4 for the ADB; and ESBWR DCD Tier 1 ITAAC Tables 2.16.8-1 for the TB, 2.16.9-1 for the RWB, 2.16.10-1 for the SB, and 2.16.11-1 for the ADB.

- The acceptance criteria consist of comparing the results of the site-specific SSI and SSSI analyses for the TB, RWB, SB, and ADB structures to the corresponding SSI and SSSI analyses performed for the standard plant design under the DCD and confirming that the standard plant design is adequate for the site-specific conditions at Fermi 3.

The site-specific ITAAC are in Fermi 3 COL application Part 10, Tables 2.4.15-1 (TB), 2.4.16-1 (RWB), 2.4.17-1 (SB), and 2.4.18-1 (ADB).

The staff believes that the applicant's intent was to provide a site-specific ITAAC that will ensure that site-specific SSI and SSSI analyses are performed if necessary to demonstrate that the standard plant design for the TB, SB, ADB, and RWB is adequate for the site-specific conditions at the Fermi 3 site. However, the language in FSAR Subsection 3.7.2.8 and in Part 10 of the COL application was not clear. Therefore, the staff proposed modifications to the ITAAC for better clarity with respect to the expectations of these analyses. The proposed modifications were discussed with the applicant during an open items call held on May 8, 2014, (ML14140A531). On the same day the applicant submitted a revised FSAR markup (ML14129A360) that documented the revisions to the ITAAC. The staff is tracking these revisions to FSAR Subsection 3.7.2.8 and Fermi 3 COL application Part 10, Tables 2.4.15-1 (TB), 2.4.16-1 (RWB), 2.4.17-1 (SB), and 2.4.18-1 (ADB) as **Confirmatory Item 3.7.2-1**.

Determination of Seismic Overturning Moments and Sliding Forces for Seismic Category I Structures

In FSAR Subsection 3.7.2.14, the applicant indicates that the site-specific stability evaluation against overturning is in FSAR Section 3.8.5. The staff's evaluation of FSAR Section 3.8.5 is in Subsection 3.8.5.4 of this SER.

Computer Programs Verification and Validation Issues

The applicant performed a verification and validation study of the SASSI2010 program to ensure the numerical accuracy, stability, and consistency of the results obtained using SASSI2010. In this study, the applicant implemented a set of 47 SSI test problems for which the solutions obtained using SASSI2010 were verified and validated against (a) analytical or numerical solutions available in the technical literature; (b) solutions obtained using SASSI2000 and accepted by the staff for the SSI analyses documented in the ESBWR DCD; and (c) solutions obtained using other computer codes. Although most of the test problems were generic, the applicant did consider several test problems that incorporated subsurface profiles and input motions that were representative of the Fermi 3 site; as well as the frequency range of interest to the Fermi 3 site-specific SSI and SSSI analyses.

The staff reviewed selected portions of the applicant's validation and verification calculations during the onsite audits on March 19 through 21, 2013, (ML13149A515) and November 18 through 22, 2013, (ML14028A245). Two test problems that incorporated subsurface profiles representative of the Fermi 3 site conditions and frequency range of interest are documented in the supplemental response to RAI 03.07.02-11 (Attachment 1 to DTE Letter NRC3-13-0023, ML13192A302).

The staff reviewed test problems performed using the DM of analysis in SASSI2010, which were considered relevant to the Fermi 3 site conditions. Additional benchmarking study of the MSM relative to the DM of analysis in SASSI2010 is separately discussed in this report under "*SSI Analysis Method*."

The staff's review yielded the following conclusions:

- For test problems with subsurface profiles representative of the Fermi 3 site conditions and passing frequencies up to 50 Hz, comparisons of impedance functions computed with SASSI2010 and those computed using an alternative program or published solutions were found to be acceptable for approximately 50 Hz for the LB rock profile.

- Test problems with subsurface profiles representative of the Fermi 3 site conditions and passing frequencies up to 50 Hz confirmed the numerical stability of the SASSI2010 solutions to the upper limit of Poisson's ratio of 0.48, which is of interest at the Fermi 3 site.

- Several test problems indicated that the aspect ratio of both plate and brick finite elements used to model the excavated volume of partially embedded structures needs to be limited to 1:3 in the horizontal and vertical directions.

Based on the above discussion and staff's on-site audits mentioned above, the staff concludes that the SASSI2010 program is acceptable for the specific conditions at the Fermi 3 site because the applicant has demonstrated the applicability of SASSI2010 at the Fermi 3 site up to a frequency of 50 Hz. The staff also confirmed that the aspect ratio limitation for plate and brick finite elements was implemented in the SSI and SSI analyses as discussed earlier in this SER.

Table 3.7.2-1 Summary of the Applicant's SSI Analyses for the RB/FB

Buildin g	Case ID	DCD Model	Analysis Case	SASSI2010 Method of Analysis	Control Motion	Soil/Rock Profile		
						LB	BE	UB
RB/FB	RBFB1UB-DM	"Base" (*)	SSI without engineered backfill	DM	FIRS			X
	RBFB1BE-DM		SSI without engineered backfill	DM			X	
	RBFB1LB-DM		SSI without engineered backfill	DM		X		
	RBFB2UB-MSM		SSI with engineered backfill	MSM				X
	RBFB2LB-MSM		SSI with engineered backfill	MSM		X		

SSI = soil-structure interaction; RB/FB = reactor building/fuel building; LB = lower bound; BE= best estimate; UB = upper bound; DM = direct method; FIRS = foundation input response spectra; MSM = modified subtraction method.

Note: (*) DCD "Base" model refers to the structural model described in DCD Table 3A.6-1.

Table 3.7.2-2 Summary of the Applicant's SSI Analyses for the CB

Building	Case ID	DCD Model	Analysis Case	SASSI2010 Method of Analysis	Control Motion	Subsurface Profile		
						LB	BE	UB
CB	CB1UB-DM	"Base" (*)	SSI without engineered backfill	DM	FIRS			X
	CB1BE-DM		SSI without engineered backfill	DM			X	
	CB1LB-DM		SSI without engineered backfill	DM		X		
	CB2UB-DM		SSI with engineered backfill	DM				X
	CB2LB-DM		SSI with engineered backfill	DM		X		
	CB3UB-DM		SSSI with engineered backfill	DM	Modified FIRS (**)			X
	CB3LB-DM		SSSI with engineered backfill	DM		X		
	CB4-FWSC1UB-MSM		SSSI with engineered backfill	MSM	FIRS			X
	CB4-FWSC1LB-MSM		SSSI with engineered backfill	MSM		X		

SSI = soil-structure interaction; CB = control building; LB = lower bound; BE= best estimate; UB = upper bound; DM = direct method; FIRS = foundation input response spectra; SSSI = structure-soil-structure interaction; MSM = modified subtraction method.

Notes:

(*) DCD "Base" model refers to the structural model described in DCD Table 3A.6-1.

(**) Modified FIRS refers to control motion based on FIRS, but modified to account for SSSI between the RB/FB and the CB.

3.7.2.5 *Post Combined License Activities*

Site-specific ITAAC and corresponding acceptance criteria for Non-Category I structures within the scope of the DCD are described in Fermi 3 COL application Part 10, Tables 2.4.15-1, 2.4.16-1, 2.4.17-1, and 2.4.18-1. The review of these site-specific ITAAC is in Subsection 3.7.2.4 of this SER under "Interaction of Non-Category I Structures with Seismic Category I Structures."

3.7.2.6 *Conclusion*

The NRC staff's finding related to information incorporated by reference is in NUREG–1966. NRC staff reviewed the application and checked the referenced DCD. The staff's review confirmed that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the Fermi 3 FSAR related to this section. All nuclear safety issues relating to the seismic system analysis that were incorporated by reference have been resolved.

The staff compared the supplemental information in the COL application to the relevant NRC regulations, the guidance in Section 3.7.2 of NUREG–0800, other NRC regulatory guides, and the Interim Staff Guidance. The staff finds that the applicant has adequately addressed the seismic system analysis with the exception of **Confirmatory Item 3.7.2-1**, in accordance with the acceptance criteria delineated in these guidance documents. On this basis, the staff concludes that the applicant has satisfied the relevant requirements of the regulations delineated in Subsection 3.7.2.3 of this SER.

3.7.3 Seismic Subsystem Analysis

Section 3.7.3 of the Fermi 3 COL FSAR, Revision 6, incorporates by reference, with no departures or supplements, Sections 3.7.3, "Seismic Subsystem Analysis," of the ESBWR DCD Revision 9. NRC staff reviewed the application and checked the referenced DCD to ensure that no issue relating to this section remained for review.[1] The NRC staff's review confirmed that no outstanding information is expected to be addressed in the COL FSAR related to this section. All nuclear safety issues relating to the seismic subsystem analysis have been resolved.

3.7.4 Seismic Instrumentation

3.7.4.1 *Introduction*

This FSAR section describes the seismic instrumentation systems as they relate to the capabilities and performance of the instruments to adequately measure the effects of earthquakes. The seismic instrumentation and associated equipment used to measure the plant responses to earthquake motion includes:

- One triaxial time-history accelerograph (THA) installed in the free-field; three THAs in the RB and two THAs in the CB.

- Recording and playback equipment

- Annunciators in the main control room.

3.7.4.2 *Summary of Application*

Section 3.7.4 of the Fermi 3 COL FSAR, Revision 6, incorporates by reference Section 3.7.4 of the ESBWR DCD, Revision 9. In addition, in Section 3.7.4, the applicant provides the following:

<u>*Supplemental Information*</u>

- EF3 SUP 3.7-6

In FSAR Section 3.7.4, the applicant adds the following commitment (COM 3.7-001):

> The seismic monitoring program described in this subsection, including the necessary test and operating procedures, will be implemented prior to receipt of fuel on site.

3.7.4.3 *Regulatory Requirements*

The regulatory basis of the information incorporated by reference is in NUREG–1966. In addition, the relevant requirements of the Commission regulations for the seismic

[1] See *"Finality of Referenced NRC Approvals"* in SER Section 1.2.2, for a discussion on the staff's review related to verification of the scope of information to be included in a COL application that references a design certification.

instrumentation, and the associated acceptance criteria, are in Section 3.7.4 of NUREG–0800. The specific requirements include the following:

- 10 CFR Part 50, Appendix S, requires instrumentation to be provided so that the seismic response of safety-related nuclear plant features can be evaluated promptly after an earthquake.
- 10 CFR Part 50.55a, "Codes and standards."

In addition, the acceptance criteria and regulatory guidance associated with the review of FSAR Section 3.7.4 is documented below:

- RG 1.12, Revision 2, "Nuclear Power Plant Instrumentation for Earthquakes"
- EPRI Report NP-6695, "Guidelines for Nuclear Plant Response to an Earthquake"
- EPRI Report NP-5930, "A Criterion for Determining Exceedance of the Operating Basis Earthquake"
- EPRI Technical Report TR-100082, "Standardization of the Cumulative Absolute Velocity," as permitted by RG 1.166
- RG 1.166, "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Postearthquake Actions"
- RG 1.167, "Restart of a Nuclear Power Plant Shut Down by a Seismic Event"

3.7.4.4 *Technical Evaluation*

As documented in NUREG–1966, NRC staff reviewed and approved Section 3.7.4 of the ESBWR DCD. The staff reviewed Section 3.7.4 of the Fermi 3 COL FSAR and checked the referenced ESBWR DCD to ensure that the combination of the information in the COL FSAR and the information in the ESBWR DCD appropriately represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and the information incorporated by reference address the required information relating to this section.

The staff reviewed the following information in the Fermi 3 COL FSAR:

<u>*Supplemental Information*</u>

- EF3 SUP 3.7-6

The applicant adds the following commitment (COM 3.7-001) in FSAR Section 3.7.4:

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[1] See *"Finality of Referenced NRC Approvals"* in SER Section 1.2.2, for a discussion on the staff's review related to verification of the scope of information to be included in a COL application that references a design certification.

> The seismic monitoring program described in this subsection, including the necessary test and operating procedures, will be implemented prior to receipt of fuel on site.

Based on the compliance of the proposed resolution with the general operability guidance for seismic equipment in RG 1.12, RG 1.166, and RG 1.167, the staff finds that the timing of the Commitment (COM 3.7-001) is appropriately scheduled before the initial fuel loading.

3.7.4.5 *Post Combined License Conditions*

The applicant identifies the following commitment:

- Commitment (COM 3.7-001) – Implement the seismic monitoring program described in this subsection [ESBWR DCD Subsection 3.7.4.5], including the necessary test and operating procedures, before the receipt of fuel onsite.

3.7.4.6 *Conclusion*

The NRC staff's finding related to information incorporated by reference is in NUREG–1966. NRC staff reviewed the application and checked the referenced DCD. The staff's review confirmed that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the Fermi 3 FSAR related to this section. There are no unresolved nuclear safety issues relating to the seismic instrumentation that were incorporated by reference.

The staff compared the supplemental information in the COL application to the relevant NRC regulations, the guidance in Section 3.7.4 of NUREG–0800, and other NRC regulatory guides. The staff finds that the applicant has addressed seismic instrumentation in accordance with the acceptance criteria delineated in these guidance documents. On this basis, the staff concludes that the applicant has satisfied the relevant requirements of the regulations delineated in Subsection 3.7.4.3 of this SER.

3.8 Seismic Category I Structures

3.8.1 Concrete Containment

Section 3.8.1 of the Fermi 3 COL FSAR, Revision 6, incorporates by reference, with no departures or supplements, Sections 3.8.1, “Concrete Containment,” of the ESBWR DCD Revision 9. NRC staff reviewed the application and checked the referenced DCD to ensure that no issue relating to this section remained for review.[1] The NRC staff’s review confirmed that no outstanding information is expected to be addressed in the COL FSAR related to this section. All nuclear safety issues relating to the concrete containment have been resolved.

3.8.2 Steel Components of the Reinforcement Concrete Containment

Section 3.8.2 of the Fermi 3 COL FSAR, Revision 6, incorporates by reference, with no departures or supplements, Sections 3.8.2,” Steel Components of the Reinforcement Concrete Containment,” of the ESBWR DCD Revision 9. NRC staff reviewed the application and checked the referenced DCD to ensure that no issue relating to this section remained for review.[1] The NRC staff’s review confirmed that no outstanding information is expected to be addressed in the COL FSAR related to this section. All nuclear safety issues relating to the concrete containment have been resolved.

3.8.3 Concrete and Steel Internal Structures of the Concrete Containment

Section 3.8.3 of the Fermi 3 COL FSAR, Revision 6, incorporates by reference, with no departures or supplements, Sections 3.8.3 “Concrete and Steel Internal Structures of the Concrete Containment,” of the ESBWR DCD Revision 9. NRC staff reviewed the application and checked the referenced DCD to ensure that no issue relating to this section remained for review.[1] The NRC staff’s review confirmed that no outstanding information is expected to be addressed in the COL FSAR related to this section. All nuclear safety issues relating to the concrete and steel internal structures of the concrete containment have been resolved.

3.8.4 Other Seismic Category I Structures

3.8.4.1 *Introduction*

This FSAR section describes the RB, CB, FB, and FWSC as other seismic Category I structures that are not inside the containment and that constitute the ESBWR standard plant design. In addition, this section describes the Non-Category I structures that could interact with these structures and with other structures important to safety.

3.8.4.2 *Summary of Application*

Section 3.8.4 and Appendix 3G of the Fermi 3 COL FSAR, Revision 6, incorporate by reference Section 3.8.4 and Appendix 3G of the ESBWR DCD, Revision 9. In addition, in FSAR Section 3.8.4, the applicant provides the following:

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[1] See *“Finality of Referenced NRC Approvals”* in SER Section 1.2.2, for a discussion on the staff’s review related to verification of the scope of information to be included in a COL application that references a design certification.

Supplemental Information

- EF3 SUP 3.8-1

In FSAR Subsection 3.8.4.5.6, the applicant provides supplemental information addressing the site-specific evaluation of the seismic lateral soil pressures acting on exterior walls of the RB/FB complex and the CB that are below grade and embedded in the soil media. This subsection also evaluates the design of these exterior walls for the seismic lateral soil pressures.

3.8.4.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is in NUREG–1966. In addition, the relevant requirements of the Commission regulations for other Seismic Category I structures, and the associated acceptance criteria, are in Section 3.8.4 of NUREG–0800. The specific requirements include the following:

- 10 CFR 50.55a and 10 CFR Part 50, Appendix A, GDC 1 as they relate to safety-related structures being designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed.

- 10 CFR Part 50, Appendix A, GDC 2, as it relates to the design of the safety-related structures that are capable of withstanding the most severe natural phenomena such as wind, tornadoes, hurricanes, floods, and earthquakes and the appropriate combination of all loads.

- 10 CFR Part 50, Appendix A, GDC 4, “Environmental and dynamic effects design bases”; as it relates to appropriately protecting safety-related structures against dynamic effects—including the effects of missiles, pipe whipping, and discharging fluids—that may result from equipment failures and from events and conditions outside the nuclear power unit.

- 10 CFR Part 50, Appendix A, GDC 5, “Sharing of structures, systems, and components”; as it relates to not sharing safety-related structures among nuclear power units, unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions.

- 10 CFR Part 50, Appendix B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants,” as it relates to the quality assurance criteria for nuclear power plants.

- 10 CFR 52.80(a), which requires that a COL application contain the proposed inspections, tests, and analyses, including those applicable to emergency planning, that the licensee shall perform, and the acceptance criteria that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, the facility has been constructed and will operate in conformity with the COL, the provisions of the Atomic Energy Act, and the Commission’s rules and regulations.

In addition, the acceptance criteria and regulatory guidance associated with the review of FSAR Section 3.8.4 include the following:

- SRP Section 3.8.4, to evaluate the combination of the incorporated information together with the supplementary information in this section to meet the relevant requirements of 10 CFR 50.55a; GDC 1, 2, 4, and 5 of Appendix A to 10 CFR Part 50; and Appendix B to 10 CFR Part 50.

- RG 1.221, "Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants."

3.8.4.4 *Technical Evaluation*

As documented in NUREG–1966, NRC staff reviewed and approved Section 3.8.4 of the ESBWR DCD. The staff reviewed Section 3.8.4 of the Fermi 3 COL FSAR and checked the referenced ESBWR DCD to ensure that the combination of the information in the COL FSAR and the information in the ESBWR DCD appropriately represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and the information incorporated by reference address the required information relating to this section.

The staff reviewed the following information in the COL FSAR:

Supplemental Information

- EF3 SUP 3.8-1

Structural Acceptance Criteria

Exterior Wall Design

SRP Section 3.8.4 provides guidelines for the staff's review. Specifically, the staff's review includes an assessment of the wall design for the site-specific seismic lateral soil pressures acting on seismic Category I exterior walls that are below grade and embedded in the soil media.

The review of seismic Category I exterior walls that are above grade, which are thus not subjected to seismic lateral soil pressures, is in Subsection 3.7.2.4 of this SER as part of the review of the overall site-specific seismic response of seismic Category I structures. As indicated in FSAR Section 2.5.4, Figures 2.5.4-201 through 2.5.4-204 depict that the RB/FB and CB are partially embedded in the Bass Islands Group rock. Therefore, the underlying soil media are in fact rock media. In the case of the FWSC, the structure is supported on a block of concrete fill, which bears on the Bass Islands Group rock. A block of concrete fill is also located in the gap between the RB/FB and CB.

Engineered granular backfill is used to fill the site excavation surrounding the power block structures. This backfill is placed above the top of the Bass Islands Group rock up

[1] See *"Finality of Referenced NRC Approvals"* in SER Section 1.2.2, for a discussion on the staff's review related to verification of the scope of information to be included in a COL application that references a design certification.

to the plant grade level, as shown in FSAR Figures 2.5.4-201, 2.5.4-202, and 2.5.4-203. FSAR Subsection 2.5.4.5.4.2 describes the material properties and specifications of the engineered granular backfill.

Therefore, below-grade exterior walls of the RB/FB and the CB bear against rock or concrete fill below the top of rock elevation and against the engineered granular backfill above this elevation. The FWSC has no below-grade walls, so seismic lateral soil pressures are not considered for the FWSC.

As shown in ESBWR DCD Tier 2, Figures 3G.1-6 and 3G.1-7, the RB/FB has three stories below grade. The walls of the RB/FB that are subjected to lateral soil pressures vertically span between elevations of +3.65 m (11.98 ft) and -1.00 m (-3.28 ft) (top span), -2.00 m (6.56 ft) and -6.40 m (-21 ft) (middle span), and -7.40 m (-24.28 ft) and -11.50 m (-37.73 ft) (bottom span). Stiff floor slabs and the basemat provide lateral support for these walls typically between elevations of +4.65 m (15.26 ft) and +3.65 m (11.98 ft) (floor slab), -1.00 m (-3.28 ft) and -2.00 m (-6.56 ft) (floor slab), -6.40 m (-21 ft) and -7.40 m (-24.28 ft) (floor slab), and -11.50 m (-37.73 ft) and -15.50 m (-50.85 ft) (basemat).

As shown in ESBWR DCD Tier 2, Figure 3G.2-3, the CB has two stories below grade. The walls of the CB that are subjected to lateral soil pressures vertically span between elevations of +4.15 m (13.61 ft) and -2.00 m (6.56 ft) (top span) and -2.50 m (-8.20 ft) and -7.40 m (-24.28 ft) (bottom span). Stiff floor slabs and the basemat provide lateral support for these walls, typically between elevations of +4.65 m (15.26 ft) and +4.15 m (13.61 ft) (floor slab), -2.00 m (6.56 ft) and -2.50 m (-8.20 ft) (floor slab), and -7.40 m (-24.28 ft) and -10.40 m (-34.12 ft) (basemat).

As indicated above, below-grade exterior walls of the RB/FB and the CB bear against rock or concrete fill below the top of rock elevation (approximately 11.40 m [37.40 ft] below the plant grade) and against the engineered granular backfill above this elevation. Because of the large discontinuity in stiffness between the rock/concrete and the granular backfill media in which the walls are embedded, standard methods for evaluating seismic lateral soil pressures—such as the method described in Subsection 3.5.3.2 of ASCE 4-98, “Seismic Analysis of Safety-Related Nuclear Structures and Commentary”—are not directly applicable to the Fermi 3 site because such methods are based on the assumption that the walls are embedded in a homogeneous soil medium. Therefore, the staff conducted a case-by-case review of the applicant's site-specific evaluations as discussed below.

The applicant's site-specific evaluations of seismic lateral soil pressures acting on below-grade exterior walls of the RB/FB and the CB are documented in FSAR Subsection 3.8.4.5.6 and with more details in the Sargent & Lundy Report SL-012018 Revision 1, “Evaluation of Reactor Building/Fuel Building and Control Building Dynamic Bearing Capacity, Foundation Stability, and Wall Seismic Soil Pressures Summary Report,” (ML13360A177). In these site-specific evaluations, the applicant used the results of the SSI and SSSI analyses described in FSAR Section 3.7.2, which are also documented in the Sargent & Lundy Reports SL-011864 Revision 1 (ML13210A144), SL-011956 Revision 1 (ML13360A176), and SL-011960 Revision 0 (ML13232A006).

The seismic lateral soil pressures were obtained from the resulting forces in the spring elements connected to the appropriate below-grade nodes of the various SSI and SSSI analysis models, which were specifically added to capture the lateral soil pressures from the SSI and SSSI analyses. The staff considers this to be an acceptable methodology for the Fermi 3 site conditions because it takes into account (a) the site-specific SSI and SSSI effects, and (b) the differences in stiffness between the rock and the granular backfill media in which the structures are embedded. The staff also notes that this SSI analysis-based methodology is consistent with the way the seismic design pressures were developed in the standard design, as described in DCD Tier 2, Sections 3G.1.5.2.1.13 and 3G.2.5.2.1.7.

The seismic lateral soil pressures obtained from the site-specific SSI and SSSI analyses are documented in FSAR Figures 3.8.4-201a through 3.8.4-201h for the RB/FB, FSAR Figures 3.8.4-202a through 3.8.4-202d for the CB (without SSSI effects), and FSAR Figures 3.8.4-203a and 3.8.4-203b for the CB (with SSSI effects). In these figures, the pressures exhibit a sharp peak at the elevation of the top of the rock, which reflects the stiffness discontinuity between the rock and the granular backfill media in which the walls are embedded. In the figures that correspond to SSI analyses without the granular backfill (FSAR Figures 3.8.4-201a, 3.8.4-201e, 3.8.4-202a, and 3.8.4-202c), there are no pressures above the elevation of the top of the rock because the granular backfill was not considered in the analysis of the models. However, these cases exhibit the largest pressure peaks at the elevation of the top of the rock.

In the figures for the RB/FB, the site-specific seismic lateral soil pressures are compared to the two pressure profiles considered in the standard design, which are: (a) seismic design pressures (DCD Tier 2, Subsection 3G.1.5.2.1.13), and (b) wall capacity passive pressures (DCD Tier 2, Subsection 3G.1.5.5). The staff notes that in the standard design, the wall capacity passive pressures are added to the at-rest soil pressures for the wall design so that the above comparison is appropriate. In the figures for the CB, the site-specific pressures are only compared to the seismic design pressures considered in the standard design (DCD Tier 2, Subsection 3G.2.5.2.1.7). The results of these comparisons indicate that the site-specific pressures for the RB/FB and the CB exceed the corresponding pressures considered in the standard design at some locations at elevations near the top of the rock.

To address this issue, the applicant performed additional evaluations to determine the impact of these exceedances on the design of below-grade exterior walls. These additional evaluations are documented in the Sargent & Lundy Report SL-012018 Revision 1 (ML13360A177). The applicant computed the maximum induced, out-of-plane bending moments and shear forces in the walls due to the site-specific seismic lateral soil pressures and compared them to the corresponding induced moments and shears in the walls due to the pressure profiles considered in the standard design. In all cases, the applicant determined that the Fermi 3 analyses were bounded by the analyses in the ESBWR DCD. The critical cases for the RB/FB were identified as (a) walls RA and RG (see DCD Tier 2, Figures 3G.1-1 and 3G.1-2 for the location of these walls); and (b) the bottom span (between elevations -7.40 m [-24.28 ft] and -11.50 m [-37.73 ft]), where the site-specific induced moments and shears range between 79 percent and 99 percent of the corresponding values resulting from the wall capacity passive pressure profiles considered in the standard design. The critical cases for the CB were identified as walls C1, C5, CA, and CD (see DCD Tier 2, Figures 3G.2-1 and 3G.2-2 for the location of these walls); and the bottom span (between elevations -2.50 m [-8.20 ft] and -7.40 m [-24.28 ft]), where the site-specific induced moments and shears range between 32 percent and 51 percent of the corresponding values resulting from the seismic design pressure profiles considered in the standard design.

The staff reviewed these evaluations and noted that at some locations, the site-specific seismic lateral soil pressures acting on below-grade exterior walls exceed the corresponding pressures considered in the standard design. However, the staff finds the standard design to be acceptable at the Fermi 3 site, because the site-specific member forces (moments and shears) induced in the walls by these pressures are bounded by the corresponding member forces considered in the standard design. The applicant's site-specific evaluation of the below-grade exterior walls design is therefore acceptable per SRP Acceptance Criterion 3.8.4.II.4.H.

Other Review Topics

Design for Hurricane Missiles for RTNSS-Related Structures

Based on RG 1.221, the staff requested in RAI 02.03.01-20 that the applicant update the site characteristic values in the Fermi 3 FSAR. As a related matter, the staff also requested the applicant to explain whether the loads from site-specific hurricane winds and hurricane-generated missiles per RG 1.221 were bounded by the loads generally considered in the ESBWR DCD and in particular, the loads for the site-specific hurricane missiles considered in the design for the regulatory treatment of nonsafety systems (RTNSS) and RTNSS-related structures identified in ESBWR DCD Tier 2, Appendix 19A.

The staff noted that in ESBWR DCD Tier 2, Tables 19A-3 and 19A-4 and ESBWR DCD Tier 2, Table 2.0-1, Footnote (3) indicates that the tornado missile design criterion is not applicable to Seismic Category NS and Seismic Category II buildings. However, for Seismic Category NS and Seismic Category II buildings that house RTNSS equipment, a hurricane missile criterion is specified so that barriers are designed for the impact from missiles generated by Category 5 hurricanes (a 3-second gust wind speed of 313.76 kilometers per hour (kph) [195 miles per hour (mph)]). The missile spectrum and missile velocities are in accordance with SRP Subsection 3.5.1.4, Revision 2, where the tornado wind speed replaced the hurricane wind speed.

During the onsite audit on April 23 through 27, 2012 (ML12207A471), the applicant explained that a response to RAI 02.03.01-20 was submitted on April 3, 2012 (ML12095A283). The staff reviewed the response and found that it did not address the issue of site-specific hurricane missiles considered in the design of RTNSS and RTNSS-related structures.

The applicant explained that for the hurricane missile design, consistent with the guidance in SRP Subsection 3.5.1.4, Revision 2, the missile velocities associated with the three missile types (1,800-kilogram [kg] [3,968-pound] automobile, 125-kg [275.57-pound] pipe, and the 2.54–centimeter (cm) [1-inch] diameter solid sphere) are taken as 35 percent of the assumed 313.76-kph (195-mph) hurricane wind, which is 109.4 kph (68 mph) (i.e., 0.35 x 195 mph = 68 mph). This information is specified in a GEH internal document that the staff reviewed and identified in the staff's audit report (ML12207A471).

The applicant also explained that by assuming the most conservative estimate of the RG 1.221 design-basis hurricane wind speed at the Fermi site of 209.2 kph (130 mph), missile velocities associated with the three missile types in RG 1.221 are 106.2 kph

(66 mph) for the 1,800-kg [3,968-pound] automobile; 78.84 kph (49 mph) for the 125-kg (275.57-pound) pipe; and 67.58 kph (42 mph) for the 2.54-cm (1-inch) diameter solid sphere.

Because conservative estimates of site-specific missile velocities computed in accordance with RG 1.221 are bounded by the corresponding DCD hurricane missile criterion (i.e., 109.4 kph [68 mph]), the staff concludes that the DCD hurricane missile criterion bounds the Fermi 3 site for the Seismic Category NS and Seismic Category II buildings that house RTNSS equipment.

3.8.4.5 *Post Combined License Activities*

There are no post COL activities related to this section.

3.8.4.6 *Conclusion*

The NRC staff's finding related to information incorporated by reference is in NUREG–1966. NRC staff reviewed the application and checked the referenced ESBWR DCD. The staff's review confirmed that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section. All nuclear safety issues relating to the other seismic Category I structures have been resolved.

The staff compared the supplemental information in the COL application to the relevant NRC regulations, the guidance in Section 3.8.4 of NUREG–0800, and other NRC regulatory guides. The staff finds that the applicant has adequately addressed the site-specific issues related to the design of other seismic Category I structures consistent with the acceptance criteria delineated in these guidance documents. On this basis, the staff concludes that the applicant has satisfied the relevant requirements of the regulations delineated in Subsection 3.8.4.3 of this SER.

3.8.5 Foundations

3.8.5.1 *Introduction*

This FSAR section addresses the foundations for all seismic Category I Structures. The ESBWR design employs separate reinforced concrete mat foundations for major seismic Category I Structures. The RB including the containment and the FB are built on a common foundation mat. The foundations of the CB and the FWSC are separate from each other and from the RB and FB foundations.

3.8.5.2 *Summary of Application*

Section 3.8.5 of the Fermi 3 COL FSAR, Revision 6, incorporates by reference Section 3.8.5 of the ESBWR DCD, Revision 9. In addition, in FSAR Section 3.8.5, the applicant provides the following:

Supplemental Information

- EF3 SUP 3.8-1

In FSAR Subsection 3.8.5.5.1, the applicant provides the following:

- Site-specific evaluations of foundation stability for the RB/FB and the CB.
- Site-specific evaluations of sliding stability for the block of concrete fill under the FWSC.
- Site-specific dynamic bearing pressure demands for the RB/FB and the CB against the corresponding DCD values and site-specific dynamic bearing pressure capacities reported in FSAR Section 2.5.4.

3.8.5.3 *Regulatory Basis*

The regulatory basis of the information incorporated by reference is in NUREG–1966. In addition, the relevant requirements of the Commission regulations for the review of the foundation, and the associated acceptance criteria, are in Section 3.8.5 of NUREG-0800. The specific requirements include the following:

- 10 CFR 50.55a and 10 CFR Part 50, Appendix A, GDC 1, as they relate to safety-related foundations being designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed.
- 10 CFR Part 50, GDC 2, as it relates to the design of the safety-related foundations that are capable of withstanding the most severe natural phenomena such as wind, tornadoes, hurricanes, floods, and earthquakes and the appropriate combination of all loads.
- 10 CFR Part 50, GDC 4, as it relates to appropriately protecting safety-related foundations against dynamic effects; including the effects of missiles, pipe whipping, and discharging fluids that may result from equipment failures and from events and conditions outside the nuclear power unit.
- 10 CFR Part 50, GDC 5, as it relates to not sharing safety-related foundations among nuclear power units unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions.
- 10 CFR Part 50, Appendix B, as it relates to quality assurance criteria for nuclear power plants.
- 10 CFR 52.80(a), which requires a COL application to contain the proposed inspections, tests, and analyses—including those applicable to emergency planning—that the licensee shall perform; and the acceptance criteria that are necessary and sufficient to provide reasonable assurance that if the inspections, tests, and analyses are performed and the acceptance criteria are met, the facility has been constructed and will operate in conformity with the COL; the provisions of the Atomic Energy Act; and Commission rules and regulations.

3.8.5.4 *Technical Evaluation*

As documented in NUREG–1966, NRC staff reviewed and approved Section 3.8.5 of the ESBWR DCD. The staff reviewed Section 3.8.5 of the Fermi 3 COL FSAR and checked the referenced ESBWR DCD to ensure that the combination of the information in the COL FSAR and the information in the ESBWR DCD appropriately represents the complete scope of information relating to this review topic.[1] The staff's review confirmed that the information in the application and the information incorporated by reference address the required information relating to this section.

The staff reviewed the following information in the COL FSAR:

<u>*Supplemental Information*</u>

- EF3 SUP 3.8-1

<u>Structural Acceptance Criteria</u>

Foundation Stability

SRP Section 3.8.5 provides guidelines to the staff for reviewing foundations of seismic Category I structures. Specifically, the staff's review includes an evaluation of the stability of the foundation against overturning, sliding, and flotation to ensure adequate safety margins.

The RB/FB complex foundation consists of a reinforced concrete basemat 4.0-m (13.12-ft) thick with plan dimensions of 70 m by 49 m (229.7 by 160.8 ft) (ESBWR DCD Tier 2 Figures 3G.1-1, 3G.1-6, and 3G.1-7). The CB foundation consists of a 3.0-m (9.84-ft) thick reinforced concrete basemat with plan dimensions of 30.3 m by 23.8 m (99.41 by 72.54 ft) (ESBWR DCD Tier 2 Figure 3G.2-1). The FWSC foundation consists of a 2.5-m (8.20-ft) thick reinforced concrete basemat with plan dimensions of 52 m by 20 m (170.6 by 65.62 ft) (ESBWR DCD Tier 2 Figure 3G.4-1). Other key dimensions of the foundations are in ESBWR DCD Tier 2 Table 3.8-13.

As indicated in FSAR Section 2.5.4, Figures 2.5.4-201 through 2.5.4-204, the RB/FB and the CB structures at the Fermi 3 site are partially embedded in the Bass Islands Group rock. Therefore, the underlying soil media are in fact rock media. In the case of the FWSC, the structure is supported on a block of concrete fill that bears on the Bass Islands Group rock. A block of concrete fill is also located in the gap between the RB/FB and the CB.

Engineered granular backfill is used to fill the site excavation surrounding the power block structures. This backfill is placed above the top of the Bass Islands Group rock up to the plant grade level, as shown in FSAR Figures 2.5.4-201, 2.5.4-202, and 2.5.4-203. FSAR Subsection 2.5.4.5.4.2 describes the material properties and specifications of the engineered granular backfill.

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[1] See *"Finality of Referenced NRC Approvals"* in SER Section 1.2.2, for a discussion on the staff's review related to verification of the scope of information to be included in a COL application that references a design certification.

The applicant's site-specific evaluations of foundation stability for the RB/FB and the CB are in FSAR Subsection 3.8.5.5.1, FSAR Tables 3.8.5-201 and 3.8.5-202, and with more details in the Sargent & Lundy Report SL-012018 Revision 1 (ML13360A177). In these site-specific evaluations, the applicant used the results of the SSI analyses described in FSAR Section 3.7.2, which are documented in the Sargent & Lundy Reports SL-011864 Revision 1 (ML13210A144) and SL-011956 Revision 1 (ML13360A176).

The staff reviewed selected portions of the applicant's foundation stability calculations for the RB/FB and the CB during the onsite audit on November 18 through 22, 2013 (ML14028A245).

Sliding Stability of the RB/FB and CB

To calculate the minimum factor of safety (FS) against sliding due to site-specific seismic loads, the applicant followed the method described in ESBWR DCD Tier 2, Subsection 3.8.5.5, which was accepted by the staff during the review of the ESBWR DCD and is therefore acceptable for the site-specific evaluation.

In this method, the FS is evaluated as the ratio of the total horizontal frictional resistance force to the horizontal seismic load. The FS was evaluated as a function of time, and the values reported in the FSAR correspond to a time instant that yields the lowest FS. The evaluation was performed separately in the two orthogonal horizontal directions.

The applicant considered a static friction coefficient of 0.7 to evaluate the frictional resistance along the sliding plane located at the bottom of the basemat shear keys, which is consistent with ESBWR DCD Tier 2, Subsection 3.8.5.5 and is the major contributor to the total horizontal frictional resistance force. The staff finds this value of 0.7 acceptable because it corresponds to an equivalent angle of internal friction of 35 degrees, which is lower (i.e., more conservative) than the site-specific equivalent Mohr-Coulomb angle of internal friction parameters reported for the Bass Islands Group rock in FSAR Table 2.5.4-208. These site-specific parameters are 53 degrees (upper bound), 48 degrees (mean), and 42 degrees (lower bound)—all greater than 35 degrees. In addition, FSAR Subsection 2.5.4.10.1 indicates that the angle of internal friction representative of the Bass Islands Group rock is 52 degrees, which is also greater than 35 degrees.

The applicant conservatively ignored the following three forces that would contribute to the total horizontal resisting force: (a) skin friction resistance provided by the basemat sides parallel to the direction of motion; (b) skin friction resistance provided by the outside vertical surface of shear keys parallel to the direction of motion; and (c) lateral bearing resistance acting against the shear keys opposite to the direction of motion. The applicant conservatively ignored any contribution from the engineered granular backfill placed above the rock.

In the case of the RB/FB, the applicant also conservatively ignored the lateral bearing resistance acting against the basemat opposite from the direction of motion. In other words, the only horizontal resistance force considered in the evaluation of the RB/FB results from friction along the sliding plane located at the bottom of the basemat shear keys.

In the case of the CB, for the SSI analyses without the engineered granular backfill (the SSI analyses denoted as CB1LB-DM, RBFB1BE-DM, and RBFB1UB-DM and listed in Tables 3.7.2-1 and 3.7.2-2 of this SER), a certain amount of lateral bearing resistance against the basemat opposite from the direction of motion was necessary to obtain an acceptable FS of 1.1. The staff reviewed the applicant's calculations, which are summarized in the Sargent & Lundy Report SL-012018 Revision 1. The staff determined that the allowable lateral bearing strength of the rock and concrete fill that surrounds the CB basemat substantially exceeds the lateral bearing force necessary for an FS of 1.1. The staff's conclusion is based on comparisons of (1) the necessary bearing force to the site-specific allowable bearing capacity of the rock reported in FSAR Table 2.5.4-227 (for dynamic loading conditions), and (2) the compressive strength of the concrete fill specified in FSAR Subsection 2.5.4.5.4.2. The applicant also determined that in this condition, the block of concrete fill between the RB/FB and the CB will not slide relative to the underlying rock (the staff estimated an FS in excess of 3.0 for the block against sliding). Therefore, the staff concludes that there is no transfer of horizontal seismic load from the CB to the RB/FB through the block of concrete.

The applicant determined that the minimum FS against sliding for the RB/FB is 1.22 (for the SSI analysis of case RBFB1BE-DM in the North-South direction without the engineered granular backfill; other SSI case analyses yield a higher FS). Similarly, the applicant determined that the minimum FS against sliding for the CB is 1.1 (for SSI analyses of cases CB1LB-DM, CB1BE-DM, and CB11UB-DM in East-West and North-South directions without the engineered granular backfill; other SSI case analyses yield a higher FS). All SSI analyses without the engineered granular backfill yield a lower FS than the corresponding SSI analyses with the engineered granular backfill.

The staff concludes that the reported FS were conservatively estimated using acceptable methodologies, and all are greater than or equal to the required minimum FS of 1.1 specified in SRP Acceptance Criterion 3.8.5.II.5. The reported FS are therefore acceptable.

Overturning Stability of the RB/FB and CB

To calculate the minimum FS against overturning due to site-specific seismic loads, the applicant followed the energy method described in DCD Tier 2, Subsection 3.7.2.14. This method was accepted by the staff during the review of the DCD and is therefore acceptable for the site-specific evaluation.

This method evaluates the FS as the ratio of the potential energy required to overturn the structure to the maximum kinetic energy imparted to the structure by the site-specific seismic motions. To compute the maximum kinetic energy, the applicant used the maximum absolute velocities obtained from the site-specific SSI analyses. The applicant conservatively assumed that the maximum absolute velocities at all mass degrees-of-freedom in both the horizontal and vertical directions occur at the same time instant. To compute the potential energy required to overturn the structure, the applicant conservatively ignored the potential energy caused by the effect of embedment.

The applicant determined that the minimum FS against overturning for the RB/FB is 2,262 (for SSI analysis of case RBFB1UB-DM in East-West direction, without the engineered granular backfill; other SSI analysis cases yield higher FS). Similarly, the applicant determined that the minimum FS against overturning for the CB is 1,733 (SSI analysis of case CB1BE-DM in East-West direction, without the engineered granular backfill; other SSI case analyses yield higher FS). All SSI analyses without the engineered granular backfill yield a lower FS than the corresponding SSI analyses with the engineered granular backfill.

The staff concludes that the reported FS were conservatively estimated using methodologies accepted by the staff during the review of the DCD, and all are greater than or equal to the required minimum FS of 1.1 specified in SRP Acceptance Criterion 3.8.5.II.5. Therefore, the reported FS are acceptable.

Flotation Stability of the RB/FB and CB

To calculate the minimum FS against flotation due to site-specific flooding, the applicant followed the method described in DCD Tier 2, Subsection 3.8.5.5 that was accepted by the staff during the review of the DCD. This method is therefore acceptable for the site-specific evaluation. This method evaluates the FS as the ratio of the sustained downward forces (i.e., dead load) to the sustained upward forces (i.e., buoyancy).

The site-specific evaluation considered the design-basis flood level to be 0.30 m (1 ft) below plant grade, which is higher than the maximum site-specific flood level of 1.20 m (4 ft) below grade reported in FSAR Table 2.0-201 and is therefore conservative.

The applicant determined that the minimum FS against flotation are 3.50 and 1.86 for the RB/FB and the CB, respectively. The staff concludes that the reported FS were conservatively estimated using methodologies accepted by the staff during the review of the DCD, and all are greater than or equal to the required minimum FS of 1.1 specified in SRP Acceptance Criterion 3.8.5.II.5. The reported FS are therefore acceptable.

Sliding Stability of the Block of Concrete Fill Below the FWSC

Although site-specific seismic SSI analyses of the FWSC were not required (see Subsection 3.7.2.4 of this SER), the applicant performed an evaluation of the sliding stability of the block of concrete fill under the FWSC basemat because this was not considered in the standard plant design. This evaluation is documented in FSAR Subsection 3.8.5.5.1.

The applicant followed the method described in DCD Tier 2, Subsection 3.8.5.5, which was accepted by the staff during the review of the DCD and is therefore acceptable for the site-specific evaluation. In this method, the minimum FS against sliding is evaluated as the ratio of the total horizontal frictional resistance force to the horizontal seismic load.

The horizontal seismic load was conservatively evaluated from the results of the SSI analyses reported in the DCD, because site-specific seismic SSI analyses of the FWSC were not performed. This approach is acceptable because the seismic loads considered in the DCD are based on the FWSC CSDRS, which bounds the site-specific FWSC FIRS and is explained in Subsection 3.7.1.4 of this SER.

The applicant determined that the minimum horizontal frictional resistance force in the concrete fill corresponds to the shear resistance on a shear plane below the FWSC basemat shear keys. To ensure that a minimum FS of at least 1.1 is obtained for this shear plane, the FSAR indicates that a shear-friction reinforcement will be placed in the concrete fill. The specific amount of reinforcement will be selected during the detailed design phase with a minimum design margin of 10 percent. The staff finds this reinforcement acceptable because it results in a minimum sliding FS of 1.1 for any shear plane in the concrete fill below the FWSC basemat shear keys and is consistent with SRP Acceptance Criterion 3.8.5.II.5.

Soil Bearing Pressures

SRP Section 3.8.5 provides guidelines for the staff to review issues related to the foundations of seismic Category I structures. Specifically, the staff's review includes an assessment of the foundations for their capability to receive loads from the structures and transmit these loads to the soil media with appropriate safety margins.

The applicant performed SSI analyses with and without considering the effects of the engineered granular backfill. All SSI analyses without the engineered granular backfill yield greater bearing pressures than the corresponding SSI analyses with the engineered granular backfill.

The applicant's site-specific evaluations of maximum dynamic soil-bearing pressures (i.e., maximum toe pressures under worst-case static plus seismic loads) for the RB/FB complex and the CB are in FSAR Subsection 3.8.5.5.2, FSAR Table 3.8.5-203, and with more details in the Sargent & Lundy Report SL-012018 Revision 1 (ML13360A177). In these site-specific evaluations, the applicant used the results of the SSI analyses described in FSAR Section 3.7.2, which are documented in the Sargent & Lundy Reports SL-011864 Revision 1 (ML13354B536) and SL-011956 Revision 1 (ML13360A176).

The staff reviewed selected portions of the applicant's dynamic soil-bearing pressure calculations for the RB/FB and the CB during the onsite audit on November 18 through 22, 2013 (ML14028A245).

To calculate the site-specific dynamic soil-bearing pressures, the applicant followed the “Modified Energy Balance” (MEB) method (ESBWR DCD Tier 2, Reference 3G.1-2). This is the same method referenced in ESBWR DCD Tier 2, Subsections 3G.1.5.5 and 3G.2.5.5, which was accepted by the staff during the review of the DCD and is therefore acceptable for the site-specific evaluation. The staff notes that the ESBWR DCD refers to this method as the “Energy Balance” method. The response to ESBWR RAI Letter Number 363—RAI 3.8-94, Supplement 05— (ML092430127) clarified that the MEB method was used in all ESBWR DCD evaluations.

To account for additional uplift pressures from the rotation of the basemat around the two horizontal axes, the applicant followed a conservative approach to evaluate and envelope two cases for the (a) potential uplift in the X direction together with a full contact length in the Y direction; and (b) potential uplift in the Y direction together with a full contact length in the X direction. This is the same approach accepted by the staff during the review of the DCD and is therefore found acceptable by the staff for the site-specific evaluation.

The applicant determined that the maximum site-specific dynamic pressure exerted by the RB/FB on the underlying rock is 2.05 megapascal (MPa) (297.31 pounds per square inch [psi]) (FSAR Table 3.8.5-203), which corresponding to the SSI analysis of case RBFB1UB-DM without the engineered granular backfill (other SSI case analyses yield lower bearing pressures). This value is greater than the value of 1.10 MPa (159.53 psi) value reported in ESBWR DCD Tier 2, Tables 2.0-1 and 3G.1-58 for the "hard" site condition, but less than 2.70 MPa (391.58 psi) value for the "medium" site condition.

Similarly, the applicant determined that the maximum site-specific dynamic pressure exerted by the CB on the underlying rock is 0.85 MPa (123.28 psi) (FSAR Table 3.8.5-203), corresponding to the SSI analysis of case CB1UB-DM without the engineered granular backfill (other SSI case analyses yield lower bearing pressures). This value is greater than the 0.42 MPa (60.91 psi) value reported in ESBWR DCD Tier 2, Tables 2.0-1 and 3G.2-27 for the "hard" site condition, but less than the 2.20 MPa (319.07 psi) value for the "medium" site condition.

As indicated above, the site-specific maximum dynamic soil-bearing pressures for the RB/FB and the CB exceed the values reported in the ESBWR DCD for the "hard" site condition, which is the DCD condition that most resembles the underlying rock at the Fermi 3 site. The staff finds this acceptable because the site-specific maximum dynamic soil-bearing pressures are bounded by the site-specific allowable dynamic bearing capacities of the underlying rock, which are reported in FSAR Tables 2.0-201 and 2.5.4-227 as 5.98 MPa (867.28 psi) for the RB/FB and 18.70 MPa (2712.1 psi) for the CB. The staff concludes that the maximum toe pressures exerted by the RB/FB and the CB structures, under worst-case static plus seismic loads, do not exceed the allowable dynamic bearing capacities of the underlying rock at the Fermi 3 site and therefore the dynamic pressures meet the guidance in SRP Acceptance Criterion 3.8.5.II.4.

Because the site-specific maximum dynamic soil-bearing pressures exceed the values reported in the ESBWR DCD, the staff evaluated whether the site-specific stresses induced in the RB/FB and CB basemats from load combinations that include seismic loads, also exceed the stresses considered in the standard design. The staff concluded that site-specific stresses induced in the RB/FB and CB basemats are bounded by the stresses considered in the standard design, as discussed below.

In the standard design described in ESBWR DCD Tier 2, Sections 3G.1.4, 3G.1.5, 3G.2.4, and 3G.2.5, three-dimensional linear-elastic finite element models of the RB/FB and the CB are used to analyze and design the basemats. In these DCD models, the underlying soil media are represented by elastic springs connected to the nodes at the bottom of the basemats. The stiffness of these springs corresponds to the "soft" site condition (see DCD Tier 2, Subsection 3G.1.4.2 and Table 3G.1-1 for the RB/FB and DCD Tier 2, Subsection 3G.2.4.2 and Table 3G.2-1 for the CB). The seismic loads (seismic shears, moments, and vertical accelerations) applied to the DCD models are shown in DCD Tier 2, Figures 3G.1-24, 3G.1-25, 3G.1-26, and Table 3G.1-9 for the RB/FB; and DCD Tier 2, Figure 3G.2-14 and Table 3G.2-5 for the CB.

ESBWR DCD Tier 2, Subsection 3.8.5.4 indicates that basemat deformations and stresses for the "soft" site condition were compared to the corresponding values obtained assuming a "hard" site condition. The "soft" site condition was found to control the standard design of the basemats.

The staff compared the seismic loads applied to the ESBWR DCD models of the RB/FB and the CB to the corresponding site-specific seismic loads reported in Tables 3 through

15 of the supplemental response to RAI 03.07.02-9 dated December 13, 2013 (ML13354B536). The staff concluded that the site-specific seismic loads are bounded by the seismic loads applied to the DCD models by a significant margin.

Based on the above considerations, as well as considering the linearity of the ESBWR DCD analysis models, the staff concludes that if the site-specific seismic loads were to be applied to the DCD models of the RB/FB and the CB with a soil spring stiffness representative of the underlying rock at the Fermi 3 site, the site-specific stresses induced in the RB/FB and CB basemats would be bounded by the stresses considered in the standard design by a substantial margin and are therefore consistent with SRP Acceptance Criterion 3.8.5.II.4.

Other Review Topics

Prevention of Alkali-Silica Reaction-Induced Concrete Degradation

Per SRP Section 3.8.5, the staff's review includes an assessment of the materials and quality control programs for concrete used in foundations and other elements of Seismic Category I structures in view of NRC Information Notice (IN) 2011-20, "Concrete Degradation by Alkali-Silica Reaction."

NRC IN 2011-20 (ML112241029) informs the licensees about the potential occurrence of alkali-silica reaction (ASR)-induced concrete degradation of a seismic Category I structure that occurred at the Seabrook Station Nuclear Power Plant. The IN indicates that the tests described in ASTM C227, "Standard Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)"; and ASTM C289, "Standard Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)"; may not accurately predict aggregate reactivity when dealing with late or slow-expanding aggregates containing strained quartz or micro-crystalline quartz. More appropriate in this regard are the updated testing standards in ASTM C1260, "Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)"; and ASTM C1293 "Standard Test Method for Determination of Length of Change of Concrete Due to Alkali-Silica Reaction."

Neither Revision 4 of the FSAR nor the DCD referenced the updated testing standards of ASTM C1260 and C1293, either directly or by reference to ACI 349-01, "Code Requirements for Nuclear Safety Related Concrete Structures," or the ASME Code (2004 Edition). During the onsite audit on April 23 through 27, 2012 (ML12207A471), the staff requested the applicant to explain the measures implemented in the FSAR to prevent the problems that IN 2011-20 describes. In particular, whether testing in accordance with the updated ASTM C1260 and C1293 will be performed during construction.

To address the staff's concerns, the applicant submitted markups to FSAR Table 1.9-204 and FSAR Subsection 2.5.4.12, (Attachment 1 to DTE Letter NRC3-12-0012, ML12097A556) that identify and specify the testing of the concrete aggregate for seismic Category I and RTNSS structures in accordance with the testing standards in ASTM C1260-07 and ASTM 1293-08b. The staff finds the applicant's information acceptable because, as indicated above, updated testing standards in ASTM C1260 and C1293 have been better predictors of aggregate reactivity. The staff subsequently confirmed that these changes were incorporated into Revision 5 of the FSAR, which resolves this issue.

3.8.5.5 *Post Combined License Activities*

There are no post COL activities related to this section.

3.8.5.6 *Conclusion*

The NRC staff's finding related to information incorporated by reference is in NUREG-1966. NRC staff reviewed the application and checked the referenced ESBWR DCD. The staff's review confirmed that the applicant has addressed the required information, and no outstanding information is expected to be addressed in the COL FSAR related to this section. All nuclear safety issues relating to seismic Category I foundations that were incorporated by reference have been resolved.

The staff compared the supplemental information in the COL application to the relevant NRC regulations, the guidance in Section 3.8.5 of NUREG–0800, and other NRC regulatory guides. The staff finds that the applicant has adequately addressed the site-specific issues related to the design of the foundations for Category I structures consistent with the acceptance criteria delineated in these guidance documents. On this basis, the staff concludes that the applicant has satisfied the relevant requirements of the regulations delineated in Subsection 3.8.5.3 of this SER.

3.8.6 Special Topics

Sections 3.8.6 of the Fermi 3 COL FSAR, Revision 6, incorporates by reference, with no departures or supplements, Sections 3.8.6," Special Topics," of the ESBWR DCD Revision 9. NRC staff reviewed the application and checked the referenced DCD to ensure that no issue relating to this section remained for review.[1] The NRC staff's review confirmed that no outstanding information is expected to be addressed in the COL FSAR related to this section. All nuclear safety issues relating to this section have been resolved.

[1] See *"Finality of Referenced NRC Approvals"* in SER Section 1.2.2, for a discussion on the staff's review related to verification of the scope of information to be included in a COL application that references a design certification.