NUREG-0800

U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

3.8.4 OTHER SEISMIC CATEGORY I STRUCTURES

REVIEW RESPONSIBILITIES

Primary ~~-~~- Organization responsible for structural analysis reviews

Secondary ~~-~~- Organization responsible for reviews of material and coolability of the fuel assembly (Appendix D)

I. AREAS OF REVIEW

This section describes the review of areas relating to all ~~Seismic~~seismic Category I structures ~~and other safety related structures that may not be classified as Seismic Category I,~~ other than the containment and its interior structures, and other structures important to safety that may not be classified as seismic Category I.

The specific areas of review are as follows:

1. ~~1.~~ Description of the Structures. The staff reviews the descriptive information, including plans and sections of each structure, to establish that there is sufficient information to define the primary structural aspects and elements relied upon for the structure to perform the intended safety~~-related~~ function. The staff also reviews the relationship between adjacent structures, including the separation provided or structural ties, if any. The following describes the major plant structures that are reviewed and the descriptive information reviewed for each:

USNRC STANDARD REVIEW PLAN

This Standard Review Plan (SRP), NUREG-0800, has been prepared to establish criteria that the U.S. Nuclear Regulatory Commission (NRC) staff responsible for the review of applications to construct and operate nuclear power plants intends to use in evaluating whether an applicant/licensee meets the NRC regulations. The SRP is not a substitute for the NRC regulations, and compliance with it is not required. However, an applicant is required to identify differences between the design features, analytical techniques, and procedural measures proposed for its facility and the SRP acceptance criteria and evaluate how the proposed alternatives to the SRP acceptance criteria provide an acceptable method of complying with the NRC regulations.

The SRP sections are numbered in accordance with corresponding sections in Regulatory Guide (RG) 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)." Not all sections of RG 1.70 have a corresponding review plan section. The SRP sections applicable to a combined license application for a new light-water reactor (LWR) are based on RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)."

These documents are made available to the public as part of the NRC policy to inform the nuclear industry and the general public of regulatory procedures and policies. Individual sections of NUREG-0800 will be revised periodically, as appropriate, to accommodate comments and to reflect new information and experience. Comments may be submitted electronically by email to NRR_SRP@nrc.gov

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A. Containment Enclosure Building

The containment enclosure building, which may surround all or part of the primary concrete or steel containment structure, is primarily intended to reduce leakage during and after a loss-of-coolant accident (LOCA). Concrete enclosure buildings also protect the primary containment, which may be of steel or concrete, from outside hazards.

The enclosure building is usually constructed of either concrete or structural steel and metal siding.

If it is a concrete structure, it usually has the geometry of the containment. As applicable, the descriptive information reviewed is similar to that of a concrete containment in accordance with Subsection I.1 of NUREG-0800, Standard Review Plan (SRP)), Section 3.8.1.

If the building is constructed of structural steel and metal siding, the staff will review the general arrangement of the building, including its foundations, wall, and roof; any bracing and lateral ties provided for the stability of the building; the roof supports which may bear on the dome of the containment; and major corner and siding joint connections.

B. Auxiliary Building

The auxiliary building, which is usually adjacent to the containment and which may be shared by the two containments in two-unit plants, is usually of reinforced concrete and structural steel construction. The staff reviews the general arrangement of the structural walls, columns, floors, roof, and any removable sections.

C. Fuel Storage Building

The fuel storage building, which may be independent or part of the auxiliary building, is also constructed of reinforced concrete and structural steel. It houses the new fuel storage area and the spent fuel pool. In addition to the information reviewed for the auxiliary building, the staff will evaluate the general arrangement of the spent fuel pool, including its foundations, walls, and wallsfloors.

D. Control Building

The control room is located in most plants within the auxiliary building. However, where it is located in a separate building, usually called the control building, the staff reviews the building as a separate structure. To provide missile protection and shielding, this building is usually made of reinforced concrete. The descriptive information reviewed is similar to that reviewed for the auxiliary building.

E. Diesel Generator Building

In some plants, the emergency diesel generators are located within the auxiliary building. However, diesel generators may also be located in a separate building called the diesel generator building. Again, this is usually a reinforced concrete structure, and the descriptive information reviewed is similar to that reviewed for the auxiliary building.

F. Other Structures

In most plants, there are several miscellaneous seismic Category I structures and other structures that may be important to safety related but, because of other design provisions, may not be classified as Seismicseismic Category I. (e.g., radwaste building). These structures are usually made either of reinforced concrete or structural steel, or a combination of the two. The descriptive information reviewed for such structures is similar to that reviewed for the auxiliary building. Among such structures are pipe and electrical conduit tunnels, water and fuel tanks, waste storage facilities, stacks, intake structures, pumping stations, and cooling towers.

Distribution systems including their supports (e.g., cable trays, conduit, heating, ventilation, and air conditioning, and piping), and equipment supports are reviewed in accordance with SRP Sections 3.9.2 and 3.9.3. Intervening structural elements between these distribution systems and equipment supports and building structural steel/concrete (e.g., steel platforms, building frame members, embedment plates, and building steel members beyond the jurisdictional boundary of supports to mechanical components) are reviewed under this SRP section.

Further, the reviewer may encounter special structures that are not located in the immediate vicinity of the site. When the failure of any such structure could affect- the safety of the plant, it should be designed to withstand the effects of a safe-shutdown earthquake (SSE), and the surface faulting should be comparable to that of the nuclear plant itself. Examples of such structures include emergency cooling water tunnels, embankments, concrete dams, and water wells. These structures are reviewed on a case-by-case basis, and safety assessments should consider the material underlying the structure and its location with respect to the site. The staff will review the descriptive information provided to ascertain the structural behavior of such structures, particularly with respect to seismic events and plant process conditions during which they are required to remain functional.

G. Masonry Walls

TheseIf used, these are walls, partitions, or radiation shields which are components of the structures listed above. They are constructed of concrete masonry units bonded with mortar in single or multiple widths and may be reinforced horizontally as well as vertically. Masonry walls without reinforcement should not be used to support seismic Category I structures, systems, and components (SSCs) nor in areas that contain seismic Category I SSCs. The staff will review the arrangement and configuration of these walls.

Some recent design (e.g., AP600 and AP1000)designs use modular construction methods for the major Seismicseismic Category- I structures. Wall modules are typically constructed from large prefabricated sections of steel plates spaced apart with intermittent steel members, joined with other modules at the site, and then filled with concrete. The concrete fill used in wall modules could be structural concrete with reinforcing (composite construction), or fill concrete of low strength and no reinforcing, or heavy concrete for radiation shielding. Floor modules consist of prefabricated steel members and plates which are combined with poured concrete to create a composite section. The design of modules to nuclear power plants, structural module design, fabrication, configuration, layout, and connections ~~will be~~are reviewed on a case-by-case basis.

2. Applicable Codes, Standards, and Specifications. The information pertaining to design codes, standards, specifications, ~~Regulatory Guides~~regulatory guides (RGs), and other industry standards that are applied in the design, fabrication, construction, testing, and surveillance of ~~Seismic~~seismic Category I structures is reviewed.

3. Loads and Loading Combinations. The review encompasses information pertaining to the applicable design loads and various load combinations thereof. The loads normally applicable to ~~Seismic~~seismic Category I structures include the following:

   A. Those loads encountered during construction of the ~~Seismic~~seismic Category I structures which include dead loads, live loads, prestress loads, temperature, wind, earth pressure, snow, rain, and ice, and construction loads that may be applicable such as material loads, personnel and equipment loads, horizontal and vertical construction loads, loads that are induced by the ~~proposed~~ construction sequence and by the differential settlements of the soil under and to the sides of the structures, erection and fitting forces, equipment reactions, and form pressure.

   B. Those loads encountered during normal plant startup, operation, and shutdown, including dead loads, live loads, thermal loads resulting from operating temperature, and hydrostatic loads such as those in spent fuel pools.

   C. Those loads to be sustained during severe environmental conditions, including those induced by the operating-basis earthquake (OBE) and the design wind specified for the plant. Subsection II.3.A defines the condition for which the OBE load is required for design of ~~Seismic~~seismic Category I structures.

   D. Those loads to be sustained during extreme environmental conditions, including those induced by the SSE and the design tornado and hurricane specified for the plant.

   E. Those loads to be sustained during abnormal plant conditions. Such abnormal plant conditions include the postulated rupture of high-energy piping. Loads induced by such an accident may include elevated temperatures and pressures within or across compartments and possibly jet impingement and impact forces associated with such ruptures.

   F. Those loads induced by hydrodynamic loads (e.g., Safety Relief Valves (SRV) and LOCAs) which ~~would~~could generate building vibration inertial loads ~~(~~, including floor response spectra~~)~~, and elevated temperatures.

The various combinations of the above loads that are normally postulated and reviewed include construction loads, normal operating loads, normal operating loads with severe environmental loads, normal operating loads with extreme environmental loads, normal operating loads with abnormal loads, normal operating loads with severe environmental and abnormal loads, and normal operating loads with extreme environmental and abnormal loads.

The loads and load combinations described above are generally applicable to all types of structures. However, other site-related loads might also be applicable. Such loads, which are not normally combined with abnormal loads, include those induced by floods, potential aircraft crashes (non-terrorism-related incidents), explosive hazards in proximity to the site, and projectiles and missiles generated from activities of nearby military installations.

4. Design and Analysis Procedures. The review of the design and analysis procedures used for ~~Seismic~~seismic Category I structures focuses on the extent of compliance with American Concrete Institute (ACI) 349, with ~~supplement~~supplemental guidance by RG 1.142 for concrete structures and American National Standard Institute (ANSI)/ American Institute of Steel Construction (AISC) N690-1994 including Supplement 2 (2004) for steel structures. The review includes the following areas:

   A. General assumptions on boundary conditions

   B. The expected behavior under loads and the methods by which vertical and lateral loads and forces are transmitted from the various elements to their supports and eventually to the foundation of the structure

   C. The computer programs that are used

   D. A design report on ~~Seismic~~seismic Category I structures (Appendix C)

   E. Performance of a structural audit (Appendix B)

   F. Design of the spent fuel pool and racks (Appendix D)

   G. Steel embedments (reviewed on the basis of Appendix B to ACI 349, with additional criteria provided by RG 1.142 and RG 1.199)

   H. Dynamic soil pressures on earth retaining walls and embedded walls for nuclear power plant structures (Subsection II.4H of this SRP section)

   The review of the design and analysis procedures used for other structures that are important to safety (e.g., radwaste structure) are reviewed against applicable staff guidance (e.g., RG 1.143 for the radwaste structure).

5. Structural Acceptance Criteria. The review includes the design limits imposed on the various parameters that serve to quantify the structural behavior of each structure and its components, with specific attention to stresses, strains, gross deformations, and factors of safety against structural failure. For each load combination specified, the allowable limits are compared with the acceptable limits delineated in Subsection II.5 of this SRP section.

6. Materials, Quality Control, Special Construction Techniques, and Quality Assurance. The review covers information on the materials used in the construction of ~~Seismic~~seismic Category I structures. Among the major materials of construction covered in the review are the concrete ingredients, the reinforcing bars and splices, and the structural steel and anchors.

   The staff reviews the quality control parameters that are proposed for the fabrication and construction of ~~Seismic~~seismic Category I structures, including nondestructive examination of the materials to determine physical properties, placement of concrete, and erection tolerances.

Special construction techniques, such as modular construction methods, if ~~proposed~~used, are reviewed on a case-by-case basis to determine their effects on the structural integrity of the completed structure.

In addition, the applicant should provide the following information:

A. The extent to which the materials and quality control programs comply to ACI 349, with additional criteria provided by RG 1.142 for concrete and ANSI/AISC N690-1994 including Supplement 2 (2004) for steel, as applicable

B. If welding of reinforcing bars is ~~proposed~~used, it should comply with American Society of Mechanical Engineers (ASME), Boiler and Pressure Vessel Code (Code) Section III, Division 2~~.~~, as supplemented with additional guidance provided in RG 1.136. Any exception to compliance should be supported with adequate justification.

7. Testing and Inservice Surveillance Programs. For ~~Seismic~~seismic Category I structures outside containment, the staff reviews information on structures monitoring and maintenance requirements.

For ~~Seismic~~seismic Category I structures, it is important to accommodate inservice inspection of critical areas. The staff reviews any special design provisions (e.g., providing sufficient physical access, providing alternative means for identification of conditions in inaccessible areas that can lead to degradation, remote visual monitoring of high-radiation areas) to accommodate inservice inspection of other seismic Category I structures.

Postconstruction testing and inservice surveillance programs for other seismic Category~~-~~ I structures, such as periodic examination of inaccessible areas, monitoring of ground water chemistry, and monitoring of settlements and differential displacements, are reviewed on a case-by-case basis.

8. Masonry Walls. Areas of review pertaining to masonry walls should include, at a minimum, those items identified in Appendix A to this SRP section.

9. Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC). For design certification (DC) and combined license (COL) reviews, the staff reviews the applicant's proposed ITAAC associated with the ~~structures, systems, and components (SSCs)~~SSCs related to this SRP section in accordance with SRP Section 14.3, "Inspections, Tests, Analyses, and Acceptance Criteria." The staff recognizes that the review of ITAAC cannot be completed until after the rest of this portion of the application has been reviewed against acceptance criteria contained in this SRP section. Furthermore, the staff reviews the ITAAC to ensure that all SSCs in this area of review are identified and addressed as appropriate in accordance with SRP Section 14.3.

10. COL Action Items and Certification Requirements and Restrictions. For a DC application, the review ~~will~~ also ~~address~~addresses COL action items~~ and~~, requirements, and restrictions (e.g., interface requirements and site parameters).

For a COL application referencing a DC, a COL applicant must address COL action items (referred to as COL license information in certain DCs) included in the referenced DC. Additionally, a COL applicant must address requirements and restrictions (e.g., interface requirements and site parameters) included in the referenced DC.

Review Interfaces

Other SRP sections interface with this section as follows:

1. The determination of structures that are subject to quality assurance programs in accordance with the requirements of Appendix B to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50 is performed in accordance with SRP Sections 3.2.1 and- 3.2.2. The review of safety-related structures is performed on that basis.

2. Determination of pressure loads from high-energy lines located in safety-related structures other than containment is performed in accordance with SRP Section 3.6.1. The loads thus generated are accepted for inclusion in the load combination equations of this SRP section.

3. The exclusion of postulated pipe ruptures from the design basis is generally referred to as the leak before break. The review of those applications that propose to eliminate consideration of design loads associated with the dynamic effects of pipe rupture is performed in accordance with SRP Section 3.6.3.

4. Determination of loads generated because of pressure under accident conditions is performed in accordance with SRP Section 6.2.1. The loads thus generated are accepted for inclusion in the load combinations in this SRP section.

5. The organization responsible for quality assurance performs the reviews of design, construction, and operations phase quality assurance programs under SRP Chapter 17. In addition, while conducting regulatory audits in accordance with Office Instruction NRR-LIC-111 or NRO-REG-108, "Regulatory Audits," the technical staff may identify quality-related issues. If this occurs, the technical staff should contact the organization responsible for quality assurance to determine if an inspection should be conducted.

~~The specific acceptance criteria and review procedures are contained in the referenced SRP sections.~~

6. Review of the Probabilistic Risk Assessment is performed under SRP Section 19.

II. ACCEPTANCE CRITERIA

Requirements

Acceptance criteria are based on meeting the relevant requirements of the following Commission regulations:

1. 10 CFR 50.55a and 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 1 as they relate to SSCs being designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed.

2. GDC 2, as it relates to the design of the safety-related structures being able to withstand the most severe natural phenomena such as wind, tornadoes, hurricanes, floods, and earthquakes and the appropriate combination of all loads.

3. GDC 4, as it relates to safety-related structures being appropriately protected 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.

4. GDC 5, as it relates to safety-related structures not being shared among nuclear power units, unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions.

5. 10 CFR Part 50, Appendix B, as it relates to the quality assurance criteria for nuclear power plants.

6. 10 CFR 52.47(b) (1), which requires that a DC application contain the proposed ITAACs that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a ~~plant~~facility that incorporates the DC ~~is built~~has been constructed and will ~~operate~~be operated in ~~accordance~~conformity with the DC, the provisions of the Atomic Energy Act ~~(AEA), and~~, the ~~U.S. Nuclear Regulatory~~ Commission's ~~(NRC)~~rules and regulations~~;~~.

7. 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 ~~AEA, and the NRC~~Atomic Energy Act, the Commission's rules and regulations.

SRP Acceptance Criteria

Specific SRP acceptance criteria acceptable to meet the relevant requirements of the ~~NRC~~Commission's regulations identified above are as follows for the review described in this SRP section. The SRP is not a substitute for the ~~NRC~~Commission's regulations, and compliance with it is not required. However, an applicant is required to identify differences between this SRP section and the design features, analytical techniques, and procedural measures proposed for ~~its~~the facility ~~and the SRP acceptance criteria~~, and ~~evaluate~~discussing how the proposed alternatives ~~to the SRP acceptance criteria~~ provide acceptable methods of ~~compliance~~complying with the ~~NRC~~ regulations that underlie the SRP acceptance criteria.

1. ~~1.~~ Description of the Structures. The descriptive information in the Safety Analysis Report (SAR) is considered acceptable if it meets the criteria set forth in SRP Section 3.8.4 and RG 1.206. New or unique design features that are not specifically covered in RG 1.70 or RG 1.206 may require a more detailed review. The reviewer determines the additional information that may be needed to accomplish a meaningful review of the structural aspects of such new or unique features.

   RG 1.206 provides the basis for evaluating the description of structures to be included in a DC or a COL application.

RG 1.70 provides guidance for information to be submitted with an application for construction permit (CP) or operating license (OL).

2. ~~2.~~ Applicable Codes, Standards, and Specifications. The design, materials, fabrication, erection, inspection, testing, and surveillance, if any, of ~~Seismic~~seismic Category I structures are covered by codes, standards, and guides that are either applicable in their entirety or in portions thereof. A list of such documents follows:

Codes/Specifications	Title
ACI 349	"Code Requirements for Nuclear Safety-Related Concrete Structures" (with additional criteria provided in RG 1.142)
ANSI/AISC N690-1994 including Supplement 2 (2004)	"Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities"

Regulatory Guides	
1.69	"Concrete Radiation Shields for Nuclear Power Plants"
1.91	"Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants"
1.115	"Protection Against Low-Trajectory Turbine Missiles"
1.127	"Inspection of Water-Control Structures Associated with Nuclear Power Plants"
1.136	"Design Limits, Loading Combinations, Materials, Construction, and Testing of Concrete Containments"
1.142	"Safety-Related Concrete Structures for Nuclear Power Plants (Other Than Reactor Vessels and Containments)"
1.143	"Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in LWR Plants"
1.160	"Monitoring the Effectiveness of Maintenance at Nuclear Power Plants"
1.199	"Anchoring Components and Structural Supports in Concrete"

~~3.~~ 1.221 Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants

3. Loads and Load Combinations. The specified loads and load combinations are acceptable if found to be in accordance with the guidance given below:

A. Concrete Structures

All loads and load combinations are to be in accordance with ACI 349 ~~and~~, with additional guidance provided by RG 1.142. Supplemental criteria on the use of loads and load combinations are presented below.

Dead loads include hydrostatic loads and, for equipment supports, include static and dynamic head and fluid flow effects.

Live loads include any movable equipment loads and other loads which vary with intensity and occurrence, such as soil pressure. The dynamic effects of lateral soil pressure should be accounted for in accordance with the provisions of Subsection II.4(H) of this SRP section. For equipment supports, live loads also include loads resulting from vibration and any support movement effects. Alternate load cases, in which the magnitudes and locations of the live loads are arranged so that the design includes worst-case conditions, should be investigated, as appropriate.

As noted in Appendix S to 10 CFR Part 50, the OBE is associated only with plant shutdown and inspection unless specifically selected by the applicant as a design input. If the OBE is set at one-third or less of the SSE ground motion, an explicit ~~response~~analysis or design ~~analysis~~ is not required. If the OBE is set at a value greater than one-third of the SSE, an analysis and design must be performed to demonstrate that the ~~Seismic~~seismic Category I structures remain functional and are within applicable stress, strain, and deformation limits. SRP Section 3.7 provides further guidance on the use of OBE.

For structures or structural components subjected to hydrodynamic loads resulting from LOCA and/or SRV actuation, the consideration of such loads should be as indicated in the appendix to SRP Section 3.8.1. Fluid~~-~~-structure interaction associated with these hydrodynamic loads and those from earthquakes should be taken into account.

The design of concrete structures needs to consider the loads and load combinations that may occur during their construction. These loads consist of dead loads, live loads, temperature, wind, snow, rain, ice, and construction loads that may be applicable such as material loads, personnel and equipment loads, horizontal construction loads, erection and fitting forces, equipment reactions, and form pressure. Structural Engineering Institute (SEI)/American Society of Civil Engineers (ASCE) Standard 37 gives additional guidance on construction loads. This standard provides supplemental guidance, and in cases where the criteria in the standard and in the Code/SRP conflict, then the Code/SRP shall govern.

The analysis should consider other site-related or plant-related loads applicable to ~~Seismic~~seismic Category I structures outside the containment such as floods, explosive hazards in proximity to the site, potential aircraft crashes (non-terrorism-related incidents), and missiles generated from activities of nearby military installations or turbine failures. The inclusion of these loads and the related load combinations are reviewed on a case-by-case basis.

B. Steel Structures

All loads and load combinations are to be in accordance with AISC N690-1994 including Supplement 2 (2004). This specification uses the allowable stress design (ASD) method. The supplemental criteria on the use of loads and load combinations presented above for concrete structures also apply to steel structures.

4. 4. Design and Analysis Procedures. The design and analysis procedures used for Seismicseismic Category I structures, including assumptions about boundary conditions and expected behavior under loads, are acceptable if found to be in accordance with the following:

A. For concrete structures, the procedures are in accordance with ACI 349, as supplemented by RG 1.142. The design and analysis of anchors (steel embedments) used for component and structural supports on concrete structures are acceptable if found in accordance with Appendix B to ACI 349, as supplemented by RG 1.199.

B. The design and analysis methods described in Subsections II.4 of SRP Sections 3.8.1 and 3.8.2, which apply to the other seismic Category I concrete and steel structures, respectively, also need to be considered. Items to be considered include assumptions on boundary conditions, transient and localized loads, and shrinkage and cracking of concrete.

C. For steel structures, the procedures are in accordance with ANSI/AISC N690-1994, including Supplement 2 (2004).

D. Computer programs are acceptable if the validation provided follows the procedures delineated in Subsection II.4.E of SRP Section 3.8.1.

E. The design report is considered acceptable if it contains the information specified in Appendix C to this SRP section.

F. The structural audit is conducted in accordance with the provisions of Appendix B to this SRP section.

G. The design of the spent fuel pool and racks is considered acceptable when it meets the criteria of Appendix D to this SRP section.

H. Consideration of dynamic lateral soil pressures on embedded walls is acceptable if the lateral earth pressure loads are evaluated for the governing of the following three cases. These are (1) lateral earth pressure equal to the sum of the static earth pressure plus the dynamic earth pressure calculated in accordance with ASCE 4-98, Section 3.5.3.2;(2); (2) lateral earth pressure equal to the sum of the static earth pressure plus the dynamic earth pressure calculated using an embedded SSI/FEM Finite Element Model (FEM) analysis model; and (3) lateral earth pressure equal to the fraction of the passive earth pressure that is effectively mobilized, which is dependent on the relative magnitude of the wall displacements against the soil that may occur for a given wall configuration. For case (3), the analysis should include, as a minimum, the fraction of the passive earth pressure assumed in the stability calculations performed in accordance with SRP Section 3.8.5.

ASCE 4-98 Section 3.5.3.2(2) describes a method based on the well-known elastic solution by Wood (1973). This method assumes linear elastic strains in a homogeneous soil mass, a rigid wall with fixed base supported on stiff soil, and no displacement or sliding of the wall base relative to the underlying soil. Soil dynamics and wave propagation effects in the soil-wall system are also not considered. These assumptions may not be satisfied, for example, in the case of massive structures in deep soil sites where rocking could be important. Nevertheless, for cases where the assumptions of Wood's solution are realistic, the method yields conservative estimates of the dynamic pressures.

To account for a broad range of kinematic conditions, heterogeneity of the soil, as well as soil dynamics and wave propagation effects, a second method should be included based on soil-structure interaction (SSI) analysis of an embedded SSI/FEM model, as described in SRP Section 3.7.2. A limitation of such analysis is that it also assumes linear (or equivalent-linear) elastic strains in the soil. Therefore, a third method based on passive pressure should also be included to account for potential inelastic strains.

The staff reviews the validity of the assumptions that are the basis of each of these three methods and the extent to which they correspond to the actual site conditions. In particular, the staff reviews the SSI/FEM model used in method (2)- to ensure it is appropriate to this type of application.

If other effects such as structure-soil-structure interaction are important, these should be included in addition to the pressures computed using the methods described above.

If these methods are shown to be overly conservative for the cases considered, then the staff reviews alternative methods on a case-by-case basis. For earth retaining walls that are not restrained by a building, the guidance in ASCE 4-98 Sections 3.5.3.1 through 3.5.3.3 is acceptable.

I. The design of masonry walls is considered acceptable when it meets the requirements of Appendix A of this SRP.

J. The design of structures that use modular construction methods are reviewed and evaluated on a case-by-case basis. NUREG/CR-6486 provides guidance related to the use of modular construction methods. Appendix B to NUREG/CR-6486 includes ~~proposed~~ modular construction review criteria.-

~~5.~~ K. The design and analysis procedures for the structures important to safety are considered acceptable if they are in accordance with relevant guidance including RGs (e.g., RG 1.143 for radwaste structures.

5. Structural Acceptance Criteria. For each of the loading combinations delineated in Subsection II.3 of this SRP section, the structural acceptance criteria appear in ACI ~~349~~

and 349, with additional guidance provided by RG 1.142 for concrete structures, and AISC N690-1994, including Supplement 2 (2004), for steel structures.

The structural acceptance criteria for structures that use modular construction methods are evaluated on a case-by-case basis. See Subsection II.4.J of this SRP for information.

6. 6. Materials, Quality Control, and Special Construction Techniques. For Seismicseismic Category I structures outside the containment, the materials and quality control programs are acceptable if found in accordance with the codes and standards indicated in Subsection I.6 of this SRP section.

Special construction techniques, if any, are evaluated on a case-by-case basis. For modular construction, reviewers evaluate the materials, quality control, and special construction techniques on a case-by-case basis. See Subsection II.4.J of this SRP section for more information.

7. 7. Testing and Inservice Surveillance Requirements. For Seismicseismic Category I structures outside containment, structures monitoring and maintenance requirements are acceptable if the program is in accordance with 10 CFR 50.65 and RG 1.160.

For water control structures, inservice inspection programs are acceptable if in accordance with RG 1.127. Water control structures covered by this program include concrete structures, embankment structures, spillway structures and outlet works, reservoirs, cooling water channels and canals and intake and discharge structures, and safety and performance instrumentation.

For Seismicseismic Category I structures, it is important to accommodate inservice inspection of critical areas. The staff considers that monitoring and maintaining the condition of other seismic Category I structures isare essential for plant safety. The staff reviews any special design provisions (e.g., providing sufficient physical access, providing alternative means for identification of conditions in inaccessible areas that can lead to degradation, remote visual monitoring of high-radiation areas) to accommodate inservice inspection of other seismic Category I structures on a case-by-case basis.

For plants with nonaggressive ground water/soil (i.e., pH > 5.5, chlorides < 500 ppm, sulfates <1500 ppm), an acceptable program for normally inaccessible, below-grade concrete walls and foundations is to (1) examine the exposed portions of below-grade concrete, when excavated for any reason, for signs of degradation; and (2) conduct periodic site monitoring of ground water chemistry, to confirm that the ground water remains nonaggressive.

For plants with aggressive ground water/soil (i.e., it exceeds any of the limits noted above), an acceptable approach is to implement a periodic surveillance program to monitor the condition of normally inaccessible, below-grade concrete for signs of degradation.

8. 8. Masonry Walls. Appendix A to this SRP section contains the acceptance criteria for masonry walls.

Technical Rationale

The technical rationale for application of these acceptance criteria to the areas of review addressed by this SRP section is discussed in the following paragraphs:

1. 1. Compliance with 10 CFR 50.55a requires that SSCs be designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the importance of the safety function to be performed.

   This section of the SRP cites RGs 1.69, 1.91, 1.115, 1.127, 1.136, 1.142, 1.143, 1.160, 1.199, and 1.199221, to provide guidance regarding construction, quality control, tests, and inspections that are acceptable to the staff. ACI 349, as supplemented by RG 1.142, and ANSI/AISC N690-1994, including Supplement 2 (2004), contain basic specifications for concrete and steel structures, respectively. These guides and specifications impose specific restrictions to ensure that SSCs will perform their intended safety function.

   Meeting these requirements and criteria provides added assurance that the SSCs described here will perform their safety function and limit the release of radioactive materials.

2. 2. Compliance with GDC 1 requires that SSCs important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of their safety function that a quality assurance program be established and implemented, and that sufficient and appropriate records be maintained. Where generally recognized codes and standards are used, they shall be identified and evaluated to determine their applicability, adequacy, and sufficiency and shall be supplemented as necessary to assure a quality product in keeping with the required safety function.

   This SRP section describes staff positions related to static and dynamic loadings and evaluation programs for structures other than containment. It also describes acceptable materials, design methodology, quality control procedures, construction methods, and inservice inspections, as well as documentation criteria for design and construction controls.

   This section cites ACI 349, ANSI/AISC N690--1994, including Supplement 2 (2004), and RGs to provide guidance describing design methodology, materials testing, and construction techniques that are commensurate with the importance of the safety function to be performed. Conformance with these requirements imposes specific restrictions to ensure that structures other than the containment will perform acceptably, commensurate with their intended safety function, when designed in accordance with the above standards.

   Meeting these requirements and criteria provides added assurance that the SSCs described here will perform their intended safety function.

3. 3. Compliance with GDC 2 requires that SSCs important to safety be designed to withstand the effects of expected natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. The design bases for these SSCs shall reflect appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena.

   To ensure that structures other than containment of a nuclear power plant are designed to withstand natural phenomena, it is necessary to consider the most severe natural phenomena that have been historically reported with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated. These data should be used to specify the design requirements of nuclear power plant components to be evaluated as part of CP, OL, COL, and early site permit (ESP) reviews, or for site parameter envelopes in the case of DCs, thereby ensuring that components important to safety will function in a manner that will maintain the plant in a safe condition.

This SRP section provides detailed acceptance criteria and cites appropriate regulatory guidance for design methodology, materials testing, and construction techniques acceptable to the staff. GDC 2 requires that structures other than containment be designed to withstand the effects of natural phenomena combined with those of normal and accident conditions without loss of capability to perform their safety function. Load combinations and specifications cited in this SRP section provide acceptable engineering criteria to accomplish that function.

Meeting these requirements provides added assurance that safety-related structures will be designed to withstand the effects of natural phenomena and will perform their intended safety function.

4. ~~4.~~ Compliance with GDC 4 requires that nuclear power plant SSCs important to safety be designed to accommodate the effects of and be compatible with environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including LOCAs, and be appropriately protected 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.

This SRP section provides methods acceptable to the staff to assure compliance with GDC 4. The methods include load combinations, acceptance criteria, standards, and codes. Meeting this ~~requirement~~criterion provides assurance that structures other than containment will withstand loads from internal events, such as those described above, and from external sources such as explosive hazards in proximity to the site, potential aircraft crashes (non-terrorism-related incidents), and missiles generated from activities of nearby military installations or turbine failures, thus decreasing the probability that these events would damage structures other than containment and cause release of radioactive material.

Meeting these requirements provided added assurance that structures will not fail in function as designed, thus providing protection against lost of their structural integrity.

5. ~~5.~~ Compliance with GDC 5 prohibits the sharing of structures important to safety among nuclear power units unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions, including, in the event of an accident in one unit, an orderly shutdown and cooldown of the remaining units.

The requirements of GDC 5 are imposed to ensure that the use of common structures in multiple-unit plants will not significantly affect the orderly and safe shutdown and cooldown in one plant in the event of an accident in another. Loads from normal operation and design-basis accidents are combined in the load combination equations so that the resulting structural designs provide for mutual independence of shared structures.

Meeting this requirement provides added assurance that structures other than the containment and its associated components are capable of performing their required safety function even if they are shared by multiple nuclear power units.

6. ~~6.~~ Compliance with 10 CFR Part 50, Appendix B requires that applicants establish and maintain a quality assurance program for the design, construction, and operation of SSCs.

This SRP section provides guidance specifically related to the design, construction, testing, and inservice surveillance of structural concrete and steel in nuclear power plants. Subsection II.2 of this SRP section cites ACI 349, with additional guidance provided by RG 1.142, ANSI/AISC N690-1994, including Supplement 2 (2004), and RGs 1.127 and 1.160 to satisfy the requirements of 10 CFR Part 50, Appendix B.

Meeting these requirements provides added assurance that structures covered in this SRP section will meet the requirements of 10 CFR Part 50, Appendix B and thus perform their intended safety function.

III. REVIEW PROCEDURES

~~The reviewer will select material from the procedures described below, as may be appropriate for a particular case.~~

These review procedures are based on the identified SRP acceptance criteria. For deviations from these acceptance criteria, the staff should review the applicant's evaluation of how the proposed alternatives provide an acceptable method of complying with the relevant NRC requirements identified in Subsection II.

~~1.~~ In accordance with 10 CFR 52.47(a)(8), (21), (22), and 10 CFR 52.79(a)(17), and (20), for new reactor license applications submitted under 10 CFR Part 52, the applicant is required to (1) address the proposed technical resolution of unresolved safety issues and medium- and high-priority generic safety issues which are identified in the version of NUREG-0933 current on the date up to 6 months before the docket date of the application and which are technically relevant to the design; (2) demonstrate how the operating experience insights have been incorporated into the plant design; and, (3) provide information necessary to demonstrate compliance with any technically relevant portions of the Three Mile Island requirements set forth in 10 CFR 50.34(f), except paragraphs (f)(1)(xii), (f)(2)(ix), and (f)(3)(v). These cross-cutting review areas should be addressed by the reviewer for each technical subsection and relevant conclusions documented in the corresponding Safety Evaluation Report (SER) section.

1. Description of the Structures. After the type of structure and its functional characteristics are identified, the staff obtains information on similar ~~and~~other seismic Category I structures previously licensed ~~plants~~ for reference. Such information, which is available in SARs and amendments of previous license applications, enables identification of differences for the case under review. These differences require additional scrutiny and evaluation. New and unique features that have not been used in the past are of particular interest and are thus examined in greater detail.

The reviewer evaluates the information furnished in the SAR for completeness in accordance with RG 1.70 for a CP or an OL (for applications submitted in accordance with 10 CFR Part 50) or RG 1.206 for a DC or a COL (for application submitted in accordance with 10 CFR Part 52).

2. ~~2.~~ Applicable Codes, Standards, and Specifications. The reviewer compares the list of codes, standards, guides, and specifications with the list in Subsection II.2 of this SRP section. The reviewer verifies that the appropriate code or guide is used and that the applicable edition and stated effective addenda are acceptable.

3. ~~3.~~ Loads and Loading Combinations. The reviewer verifies that the loads and load combinations are as conservative as those specified in Subsection II.3 of this SRP section. The reviewer identifies any deviations from the acceptance criteria for loads and load combinations that have not been adequately justified as unacceptable and transmits these findings to the applicant.

4. ~~4.~~ Design and Analysis Procedures. The reviewer verifies that for the design and analysis procedures, the applicant is utilizing the specifications for concrete and steel structures found in ACI 349, with additional guidance provided by RG 1.142, and ANSI/AISC N690-1994, including Supplement 2 (2004), respectively.

The reviewer verifies the validity of any computer programs used in the design and analysis of the structure in accordance with the acceptance criteria delineated in Subsection II.4.E of SRP Section 3.8.1.

The reviewer ensures that the applicant has met the provisions specified in Subsection II.4 of this SRP section regarding design report, structural audits, and design of spent fuel pool and racks.

As discussed in Subsection II.4.I of this SRP section, reviewers evaluate the use of modular construction methods on a case-by-case basis utilizing guidance provided in NUREG/CR-6486.

5. ~~5.~~ Structural Acceptance Criteria. The reviewer compares the limits on allowable stresses and strains in the concrete, reinforcement, structural steel, etc., with the corresponding allowable stresses specified in Subsection II.5 of this SRP section. If the applicant proposes to exceed some of these limits for some of the load combinations and at some localized points on the structure, the reviewer evaluates the justification provided to show that structural integrity will not be affected. If the reviewer determines such justification to be inadequate, the proposed deviations are identified and transmitted to the applicant with a request for adequate justification and bases.

6. ~~6.~~ Materials, Quality Control, and Special Construction Techniques. The reviewer compares the materials, quality control procedures, and any special construction techniques with those referenced in Subsection II.6 of this SRP section. If a new material not used in previous licensed cases is used, the reviewer asks the applicant to provide sufficient test and user data to establish the acceptability of such a material. Similarly, the reviewer evaluates any new quality control procedures or construction techniques to ensure that there will be no degradation of structural quality that might affect structural integrity.

7. ~~7.~~ Testing and Inservice Surveillance Requirements. For ~~Seismic~~seismic Category I structures outside containment, the reviewer verifies that monitoring and maintenance requirements for structures are in accordance with 10 CFR 50.65 and RGs 1.127 and~~-~~ 1.160.

Any special design provisions (e.g., providing sufficient physical access, providing alternative means for identification of conditions in inaccessible areas that can lead to degradation, remote visual monitoring of high-radiation areas) to accommodate inservice inspection of other seismic Category I structures are reviewed on a case-by-case basis.

The reviewer evaluates any other testing and inservice surveillance programs on a case-by-case basis.

8. ~~8.~~ Masonry Walls. The reviewer should ensure that the applicant meets the requirements identified in Appendix A to this SRP section.

9. ~~9.~~ Design Certification/Combined License Application Reviews. For review of a DC application, the reviewer should follow the above procedures to verify that the design, including requirements and restrictions (e.g., interface requirements and site parameters), set forth in the Final Safety Analysis Report (FSAR) meets the acceptance criteria. DCs have referred to the FSAR as the design control document. The reviewer should also consider the appropriateness of identified COL action items. The reviewer may identify additional COL action items; however, to ensure these COL action items are addressed during a COL application, they should be added to the DC FSAR.

For review of a COL application, the scope of the review is dependent on whether the COL applicant references a DC, an ESP or other NRC approvals (e.g., manufacturing license, site suitability report or topical report).

For review of both DC and COL applications, SRP Section 14.3 should be followed for the review of ITAAC. The review of ITAAC cannot be completed until after the completion of this section.

IV. EVALUATION FINDINGS

The reviewer verifies that the applicant has provided sufficient information and that the review and calculations (if applicable) support conclusions of the following type to be included in the staff's ~~Safety Evaluation Report (SER).~~SER. The reviewer also states the bases for those conclusions.

The staff concludes that the design of safety-related structures other than containment or containment interior structures is acceptable and meets the relevant requirements of 10 CFR 50.55a and GDCs 1, 2, 4, and 5. This conclusion is based on the following:

1. The applicant has met the requirements of 10 CFR 50.55a and GDC 1 with respect to ensuring that the safety-related structures other than containment are designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the safety function to be performed by meeting the guidelines of RGs and industry standards indicated below.

2. The applicant has met the requirements of GDC 2 by designing the safety-related structures described in this section to withstand the most severe earthquake that has been established for the site with sufficient margin and the combinations of the effects of normal and accident conditions with the effects of environmental loadings such as earthquakes and other natural phenomena.

3. The applicant has met the requirements of GDC 4 by ensuring that the design of the safety-related structures are capable of withstanding the dynamic effects associated with missiles, pipe whipping, and discharging fluids.

4. The applicant has met the requirements of GDC 5 by demonstrating that SSCs are not shared between units or that, if shared, the applicant has demonstrated that sharing will not impair their ability to perform their intended safety function.

5. The applicant has met the requirements of Appendix B because the quality assurance program provides adequate measures for implementing guidelines relating to structural design audits.

6. The criteria used in the analysis, design, and construction of all the plant ~~Seismic~~seismic Category I structures to account for anticipated loadings and postulated conditions that may be imposed on each structure during its service lifetime conform with established criteria, codes, standards, and specifications acceptable to the regulatory staff. These include the positions of RGs 1.69, 1.91, 1.94, 1.115, 1.127, 1.136, 1.142, 1.143, 1.160, 1.199, and 1.~~199~~221, and industry standards ACI 349 and ANSI/AISC N690-1994, including Supplement 2 (2004).

7. The use of these criteria as defined by applicable codes, standards, and specifications, the loads and loading combinations, the design and analysis procedures, the structural acceptance criteria, the materials, quality control, and special construction techniques, and the testing and inservice surveillance requirements provide reasonable assurance that, in the event of winds, tornadoes, hurricanes, earthquakes, and various postulated accidents occurring within the structures, the structures will withstand the specified design conditions without impairment of structural integrity or the performance of required safety functions.

For DC and COL reviews, the findings will also summarize the staff's evaluation of requirements and restrictions (e.g., interface requirements and site parameters) and COL action items relevant to this SRP section.

In addition, to the extent that the review is not discussed in other SER sections, the findings will summarize the staff's evaluation of the ITAAC, including design acceptance criteria, as applicable.

V. IMPLEMENTATION

The staff will use this SRP section in performing safety evaluations of DC applications and license applications submitted by applicants pursuant to 10 CFR Part 50 or 10 CFR Part 52. ~~Except when the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the~~The staff will use the method described herein to evaluate conformance with ~~Commission~~the Commission's regulations.

~~The provisions of this SRP section apply to reviews of applications submitted six months or more after the date of issuance of this SRP section, unless superseded by a later revision. The referenced RGs contain implementation schedules for conformance to parts of the method discussed in this section.~~
The application must contain an evaluation of the standard plant design against the SRP revision in effect 6 months before the docket date of the application. The application must identify and describe all differences between the standard plant design and this SRP section,

and discuss how the proposed alternative provides an acceptable method of complying with the regulations that underlie the SRP acceptance criteria.

VI. REFERENCES

1. 10 CFR 50.55a, "Codes and Standards."

2. 10 CFR 50.65, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants."

3. 10 CFR Part 50, Appendix A, General Design Criterion 1, "Quality Standards and Records."

4. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena."

5. 10 CFR Part 50, Appendix A, General Design Criterion 4, "Environmental and Dynamic Effects Design Bases."

6. 10 CFR Part 50, Appendix A, General Design Criterion 5, "Sharing of Structures, Systems, and Components."

7. 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants."

8. 10 CFR Part 50, Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants."

9. 10 CFR Part 52, "Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants."

10. ACI 349, "Code Requirements for Nuclear Safety Related Concrete Structures," American Concrete Institute.

11. ANSI/AISC N690-1994, including Supplement 2 (2004), "Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities."

12. ASCE 4-98, "Seismic Analysis of Safety-Related Nuclear Structures and Commentary," American Society of Civil Engineers (Section 3.5.3.2 for embedded walls and Sections 3.5.3.1 through 3.5.3.3 for earth retaining walls).

13. ASME Boiler and Pressure Vessel Code, Section III, Division 2, "Code for Concrete Reactor Vessels and Containments," ASME.

14. NUREG/CR-6486, "Assessment of Modular Construction for Safety-Related Structures at Advanced Nuclear Power Plants," March 1997.

15. RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)."

16. RG 1.69, "Concrete Radiation Shields for Nuclear Power Plants."

17. RG 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants."

18. RG 1.91, “Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants.”

19. RG 1.115, “Protection Against Low Trajectory Turbine Missiles.”

20. RG 1.127, “Inspection of Water-Control Structures Associated with Nuclear Power Plants.”

21. RG 1.136, "Design Limits, Loading Combinations, Materials, Construction, and Testing of Concrete Containments."

~~21.~~22. RG 1.142, “Safety-Related Concrete Structures for Nuclear Power Plants.”

~~22.~~23. RG 1.143, “Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in LWR Plants.”

~~23.~~24. RG 1.160, “Monitoring the Effectiveness of Maintenance at Nuclear Power Plants.”

~~24.~~25. RG 1.199, “Anchoring Components and Structural Supports in Concrete.”

~~25.~~26. SEI/ASCE 37, “Design Loads on Structures During Construction,” American Society of Civil Engineers, 2002.

~~26~~27. Wood, J. H., “Earthquake-induced Soil Pressures on Structures.” EERL Report 73-05, Earthquake Engineering Research Laboratory, California Institute of Technology, 1973.

APPENDIX A TO SRP SECTION 3.8.4

CRITERIA FOR SAFETY-RELATED MASONRY WALL EVALUATION

This appendix provides minimum design considerations and criteria for the review- of safety--related masonry walls that will meet the design standards specified in Subsection II of this SRP- section.

1. General ~~Requirements~~Considerations

The materials, testing, analysis, design, construction, and inspection related to the design and construction of safety-related concrete masonry walls should conform to the applicable requirements contained in Uniform Building Code~~c~~ 1979, unless the provisions to this criteria specify otherwise.

The use of other industrial codes, such as ACI 531, ATC 3-06, or National Concrete Masonry Association (NCMA;), is also acceptable. However, when the provisions of these codes are less conservative than the corresponding provisions of these criteria, their use should be justified on a case-by-case basis.

The reviewer will evaluate the use of new or updated design standards such as ACI 530 and the International Building Code ~~(IBC)~~ on a case-by-case basis to assure that they achieve the same level of safety as the above-referenced standards.

No unreinforced masonry walls ~~will be~~are permitted in new construction.

2. Loads and Load Combinations

The loads and load combinations should include consideration of normal loads, severe environmental loads, extreme environmental loads, and abnormal loads. The following load combinations should apply (for definition of load terms, see SRP Section 3.8.4, Subsection II.3).

A. Service Load Conditions

(1) D + L

(2) D + L + E

(3) D + L + W

If thermal stresses from T_0 and R_0 exist, they should be included in the above combinations, as follows:

(1a) $D + L + T_0 + R_0$

(1b) $D + L + T_0 + R_0 + E$

(1c) $D + L + T_0 + R_0 + W$

Check load combination for controlling condition for maximum L and for no L.

B. Extreme Environmental, Abnormal, Abnormal/Severe Environmental, and Abnormal/Extreme Environmental Conditions

(4) $D + L + T_0 + R_0 + E'$

(5) $D + L + T_0 + R_0 + W_t$

(6) $D + L + T_a + R_a + 1.5\ P_a$

(7) $D + L + T_a + R_a + 1.25\ P_a + 1.0\ (Y_r + Y_j + Y_m) + 1.25\ E$

(8) $D + L + T_a + R_a + 1.0\ P_a + 1.0\ (Y_r + Y_j + Y_m) + 1.0\ E'$

In combinations (6), (7), and (8), the maximum values of P_a, T_a, R_a, Y_r, Y_j, and Y_m, including an appropriate dynamic load factor, should be used unless a time-history analysis is performed to justify otherwise. Combinations (5), (7), and (8) and the corresponding structural acceptance criteria should be satisfied first without the tornado missile load in (5) and without Y_r, Y_j, and Y_m in (7) and (8). In the review of these loads, local section strength capacities may be exceeded under these concentrated loads, provided that there will be no loss of function of any safety-related system.

Both cases of L having its full value or being completely absent should be checked.

3. Allowable Stresses

Allowable stresses provided in ACI 531-~~-~~79, shall be supplemented by the following modifications/exceptions.

A. When wind or seismic loads (OBE) are considered in the loading combinations, no increase in the allowable stresses is permitted. See Subsection II.3 of this SRP for further guidance regarding the OBE.

B. Use of allowable stresses corresponding to a special inspection category should be substantiated by demonstration of compliance with the NRC recommended inspection criteria.

C. All the tensile stresses will be resisted by reinforcement.

D. For load conditions which represent extreme environmental, abnormal, abnormal/severe environmental and abnormal/extreme environmental conditions, the allowable working stress may be multiplied by the factors shown in the following table:

Type of Stress	Factor
Axial or flexural compression	2.5
Bearing	2.5

Reinforcement stress except shear	2.0 but not to exceed 0.9 fy
Shear reinforcement and/or bolts	1.5
Masonry tension parallel to bed joint	1.5
Shear carried by masonry	1.3
Masonry tension perpendicular to bed joint for reinforced masonry	0.0

Note: When anchor bolts are used, the design should prevent facial spalling of masonry unit.

4. Design and Analysis Considerations

A. The analysis should follow established principles of engineering mechanics and take into account sound engineering practices.

B. The assumptions and modeling techniques used should give proper consideration to boundary conditions, cracking of sections, if any, and the dynamic behavior of masonry walls.

C. Damping values to be used for dynamic analysis should be those for reinforced concrete in accordance with guidance provided in RG 1.61.

D. The seismic analysis should account for the variations and uncertainties in mass, materials, and other pertinent parameters used.

E. The analysis should consider both in-plane and out-of-plane loads.

F. The analysis should consider interstory drift effects.

G. In new construction, no unreinforced masonry wall is permitted; also, all grout in concrete masonry walls should be consolidated by vibration.

H. For masonry shear walls, the minimum reinforcement requirements shall be as provided in ACI 531.

I. The acceptance of special construction (e.g., multiwythe, composite) or other items not covered by the code ~~will be~~are reviewed on a case-by-case basis.

J. Applicants should submit for review the quality assurance/quality control (QA/QC) information.

In the event QA/QC information is not available, a field survey and a test program reviewed and approved by the NRC staff should be implemented to ascertain the conformance of masonry construction to design drawings and specifications (e.g., rebar and grouting).

K. The criteria recommended in SRP Section 3.5.3 should apply for masonry walls requiring protection from spalling and scabbing resulting from accident pipe reaction (Y_r), jet impingement (Y_j), and missile impact (Y_m).

5. Revision of Criteria

The criteria will be revised, as appropriate, based on experience gained during review and additional information developed through testing and research.

6. References

A. ~~A.~~ ACI 530, “Building Code Requirements for Masonry Structures.”

B. ~~B.~~ ACI 531-79, “Building Code Requirements for Concrete Masonry Structures,” and ACI 531R-79, “Commentary.”

C. ~~C.~~ ATC 3-06, “Tentative Provisions for the Development of Seismic Regulations for Buildings, Applied Technology Council,” 1978.

D. ~~D.~~ International Building Code.

E. ~~E.~~ ~~Regulatory Guide~~RG 1.61, “Damping Values for Seismic Design of Nuclear Power Plants.”

F. ~~F.~~ NCMA, “Specification for the Design and Construction of Load-Bearing Concrete
Masonry,” National Concrete Masonry Association (NCMA), August 1979.

G. ~~G.~~ “Trojan Nuclear Plant Concrete Masonry Design Criteria Safety Evaluation Report Supplement,” November 1980.

H. ~~H.~~ Uniform Building Code, 1979 Edition.

APPENDIX B TO SRP SECTION 3.8.4

STRUCTURAL DESIGN AUDITS

1. Introduction

10 CFR Part 50, Appendix B, requires, in part, that the design control measures shall provide for verifying or checking the adequacy of design, such as by the performance of design reviews, by the use of alternate or simplified calculational methods or by the performance of a suitable testing program. This appendix provides requirements and guidelines for implementation of structural design audits.

2. Objectives

The audit has the following objectives:

A. To investigate the manner in which the applicant has implemented the structural design criteria that it committed to use for the facility

B. To verify that the key structural design calculations have been conducted in an acceptable way

C. To identify and assess the safety significance of those areas where the plant structures were designed and analyzed using methods other than those recommended by the SRP section

3. Preliminary Arrangements

The Licensing Project Manager (LPM) arranges for the audit. The reviewer prepares the audit agenda, including specific areas of interest, and forwards it to the applicant at least 30 days before the date of the audit. The LPM should notify the appropriate Inspection & Enforcement Regional Office personnel, as well as any intervening parties, about the forthcoming audit.

4. Conduct of the Audit

A. Overview of the Plant Design

The applicant should present an overview of each of the key structures including a brief description, assumptions, modeling techniques, and technique features of design, as well as any deviations from those committed to in the SARs.

B. Audit of Design Calculations

The auditing personnel review the design calculations for the structures identified during the review of the applicant's design report. The participants in the audit should discuss and resolve any questions such as those regarding the structural modeling, analysis, proportioning of the members, and computer runs. If resolution of the questions requires additional engineering data from and further analysis by the applicant, the specific follow-up action items should be identified and noted in the meeting minutes for subsequent resolution.

5. Exit Meeting

An exit meeting is held at the conclusion of the audit to discuss and summarize the audit findings, generic issues pertaining to the design, specific action items, and the schedules for resolution of the action items.

6. Minutes of the Audit

The LPM is responsible for preparation of the audit minutes.

7. After-Audit Meetings

Review of the applicant's response to the action items may necessitate additional meeting(s) between the staff and the applicant to explain certain parts of the responses.

8. Input to the Safety Evaluation Report

The audit is an integral part of the review process. Resolution of the action items, together with appropriate consideration of other safety aspects, should constitute the major basis for the staff's preparation of the SER.

APPENDIX C TO SRP SECTION 3.8.4

DESIGN REPORT

Seismic Category I Structures

I. OBJECTIVE

The primary objective of the design report provided by the applicant is to supply the reviewer with design and construction information more specific than that contained in the SARs. This information can assist the reviewer in planning and conducting a structural audit. For this review, the information must be in quantitative form representing the scope of the actual design computations and the final design results. The design report should also provide criteria for reconciliation between design and as-built conditions.

II. STRUCTURAL DESCRIPTION AND GEOMETRY

1. Structural Geometry and Dimensions
2. Key Structural Elements and Description
3. Floor Layout and Elevations
4. Conditions of Vicinity and Supports
5. Special Structural Features

III. STRUCTURAL MATERIAL REQUIREMENTS

1. Concrete

    A. Compressive Strength
    B. Modulus of Elasticity
    C. Shear Modulus
    D. Poisson's Ratio

2. Reinforcement

    A. Yield Stress
    B. Tensile Strength
    C. Elongation

3. Structural Steel

    A. Grade
    B. Ultimate Tensile Strength
    C. Yield Stress

4. Prestressing Stage (if applicable)

    A. Type of System (manufacturer)
    B. Description of Tendons
    C. Description of Surcharge
    D. Tendons and Sheeting Layout
    E. Dome Prestressing

5. Foundation Media

    A. General Description
    B. Unit Weight
    C. Shear Modulus
    D. Angle of Internal Friction
    E. Cohesion
    F. Bearing Capacity

6. Special Considerations

IV. STRUCTURAL LOADS

1. Live and Dead Load Floor Plans
2. Determination of Transient and Dynamic Loads
3. Manufacturer's Data on Equipment Loads
4. Environmental Loads
5. Torsional Effects

V. STRUCTURAL ANALYSIS AND DESIGN

1. Design Computations of Critical Elements
2. Stability Calculations
3. Engineering Drawings Including Details of Connections and Joints
4. Discussion of Unique Features and Problem Resolution

VI. SUMMARY OF RESULTS

1. The Required Sections
2. The Provided Sections
3. Breakdown of Individual Load Contributions
4. Tabulation of Capacities of the Section Versus Capacities Required for Different Failure Modes (Bending, Shear, Axial Load)
5. Margins of Safety Provided

VII. CONCLUSIONS

APPENDIX D TO SRP SECTION 3.8.4

GUIDANCE ON SPENT FUEL POOL RACKS

I. INTRODUCTION

Regulatory Guide 1.29, “Seismic Design Classification” classifies spent fuel pool racks as ~~Seismic~~seismic Category I structures. Spent fuel pool racks should be treated as safety-related components for determining Quality Assurance requirements (10 CFR Part 50, Appendix B) and periodic condition monitoring requirements (10 CFR 50.65 “Maintenance Rule”).

This appendix describes acceptance criteria for review of spent fuel pool racks and the associated structures, which would meet the acceptance criteria specified in Subsection II of this SRP section. A secondary review responsibility would include the review of the material limits associated with the fuel assembly in the fuel storage racks and the effect of rack deformations on the coolability of the fuel assembly.

1. Description of the Spent Fuel Pool and Racks

The applicant should provide descriptive information including plans and sections showing the spent fuel pool in relation to other plant structures in order to define the primary structural aspects and elements relied on to perform the safety-related functions of the spent fuel pool, pool liner, and racks. The main safety function of the spent fuel pool, including the liner, and the racks is to maintain the spent fuel assemblies in a safe configuration through all environmental and abnormal loadings (such as earthquakes~~)~~), and impacts from drop of a spent fuel cask, drop of a spent fuel assembly, or drop of any other heavy object during routine spent fuel handling.

The following indicates the major structural elements reviewed and the extent of the descriptive information required:

A. Support of the Spent Fuel Racks - The applicant should describe the general arrangements and principal features of the horizontal and vertical supports to the spent fuel racks and indicate the methods of transferring the loads on the racks to the fuel pool wall and the foundation slab. All gaps (clearance or expansion allowance) and sliding contacts should be indicated. The discussion should cover the extent of interfacing between the rack system and the fuel pool walls and base slab (i.e., interface loads, response spectra, etc.).

If connections of the racks are made to the base and to the side walls of the pool such that the pool liner may be perforated, the applicant should indicate the provisions for avoiding leakage of radioactive water from the pool.

B. Fuel Handling - The organization responsible for postulation of a drop accident and quantification of the drop parameters reviews the criteria related to fuel handling. The findings of the review are evaluated for the purpose of integrity of the racks and the fuel pool, including the fuel pool liner, in view of a postulated fuel-handling accident. The applicant should provide sketches and sufficient details of the fuel-handling system to facilitate this review.

2. Applicable Codes, Standards, and Specifications

Construction materials should conform to American Society of Mechanical Engineers, (ASME),ASME, Boiler and Pressure Vessel Code, (Code), Section III, Division 1, Subsection NF. All materials should be selected to be compatible with the fuel pool environment to minimize corrosion and galvanic effects.

Design, fabrication, and installation of spent fuel racks of stainless steel material may be performed based on ASME Code, Section III, Division 1, Subsection NF requirements for Class 3 component supports.

3. Seismic and Impact Loads

For new plants, dynamic input data such as floor response spectra or ground response spectra are developed using the criteria described in SRP Section 3.7.

For operating plants where dynamic data are available (e.g., ground response spectra for a fuel pool supported by the ground, floor response spectra for fuel pools supported- on soil where SSI was considered in the pool design, or a floor response spectra for a fuel pool supported by the reactor building), the design and analysis of a replacement rack system may be performed using the existing plant seismic design basis. As an alternate, the seismic analysis of spent fuel pool racks may be conducted- using an updated plant seismic design basis developed using the criteria described in SRP Section 3.7. .

For free-standing spent fuel pool racks, which are potentially subject to sliding, uplift, and impact between racks and with the pool walls, time-varying seismic excitation along three orthogonal directions (2 horizontal and vertical) should be imposed simultaneously.

For fully supported spent fuel pool racks, the response spectra analysis (RSA) method is acceptable. The peak response from each direction is combined in accordance with RG 1.92. If response spectra are available for a vertical and horizontal direction only, the same horizontal response spectra may be applied along the other horizontal direction.

The effects of submergence in water need to be addressed in the spent fuel rack structural analysis. The effects of submergence are evaluated by the staff on case-by-case basis.

Because of gaps between fuel assemblies and the walls of the guide tubes, additional loads will be generated by the impact of fuel assemblies during a postulated seismic excitation. Additional loads resulting from this impact effect may be determined by estimating the kinetic energy of the fuel assembly. The maximum velocity of the fuel assembly may be estimated to be the spectral velocity associated with the natural frequency of the submerged fuel assembly. Loads thus generated should be considered for local as well as overall effects on the walls of the rack and the supporting framework.

It should be demonstrated that the consequent loads on the fuel assembly do not lead to damage of the fuel.

_Damage of the fuel refers to structural elements of a fuel assembly (including the fuel rod cladding) which are stressed beyond the material allowable limits (established in terms of either strength or strain limits) such that the fuel rods are no longer able to provide confinement for contained radioactive fission materials.

An evaluation considering pertinent failure modes (such as buckling, etc.) should be performed to demonstrate that when subject to the consequent loads resulting from the various load combinations described in Table 1, the structural elements of the fuel assembly will not exceed appropriate material allowable limits. Irradiation embrittlement effects, as well as pool temperature effects on the material properties, should be adequately accounted for in establishing the material allowable limits. Evaluations based on testing results to demonstrate structural integrity of the fuel assembly may also be acceptable, provided that the testing configurations and parameters are consistent with those for the fuel assembly being evaluated. To this end, the testing results ~~will be~~are evaluated on a case-by-case basis in determining the structural integrity of the fuel assembly.

The evaluation should also confirm that any fuel assembly deformation resulting from the applicable load combinations does not degrade the coolable configuration of the fuel assembly to an unacceptable level.

Loads generated from other postulated impact events may be acceptable, if the total mass of the impacting missile, the maximum velocity at the time of impact, and the ductility ratio of the target material used to absorb the kinetic energy are described.

4. Loads and Load Combinations

Information pertaining to the applicable design loads and their various combinations should be provided. If applicable, any change in the temperature distribution resulting from a proposed modification to an existing spent fuel rack configuration should be identified. The temperature gradient across the rack structure that results from the differential heating effect between a full and an empty cell should be indicated and incorporated in the design of the rack structure. Maximum uplift forces available from the crane should be indicated and include consideration of these forces in the design of the racks and the analysis of the existing pool floor, if applicable.

The fuel pool racks and the fuel pool structure, including the pool slab and fuel pool liner, should be evaluated for accident load combinations which include the impact of the spent fuel cask, the heaviest postulated load drop, and/or accidental drop of the fuel assembly from the maximum height.

The review will evaluate the acceptable limits (strain or stress limits) on a case-by-case basis, but in general, the applicant is required to demonstrate that the functional capability and/or the structural integrity of each component is maintained.

The specific loads and load combinations are acceptable if they conform to the applicable portions of SRP 3.8.4, Subsection II.3, and Table 1 provided in this Appendix.

5. Design and Analysis Procedures

American National Standards Institute, N210-76, "Requirements for Light Water Reactor Spent Fuel Storage Facilities at Nuclear Power Plants, Design," provides general information regarding design of spent fuel pool racks.

Details of the mathematical model, including a description of how the important parameters are obtained, should be provided. The details should include the methods used to incorporate any gaps between the support systems and gaps between the fuel bundles and the guide tubes; the methods used to lump the masses of the fuel bundles and the guide tubes; the methods used to account for the effect of sloshing water on the pool walls; and the effect of submergence on the mass, the mass distribution, and the effective damping of the fuel bundle and the fuel racks.

Design and analysis procedures in accordance with SRP 3.8.4, Subsection II, are acceptable. The effect of gaps, sloshing water, and increase of effective mass and damping resulting from submergence in water should be quantified.

If the spent fuel racks are designed to be free standing (i.e., without connections to the pool walls/floor), then their response involves a complex combination of motions that includes sliding, rocking, and twisting and involves impacts between the fuel assemblies and the fuel cell walls, rack-to-rack, and rack-to-wall. In view of this, the seismic analysis of these fuel racks is typically performed using nonlinear dynamic time history analysis methods. For nonlinear seismic analysis of the racks, multiple time histories should be performed in accordance with the criteria for nonlinear analysis described in SRP 3.7.1, unless otherwise justified. For the free standing rack analyses, the entire range of the coefficient of friction for the rack material in water should be considered between the rack legs and the pool floor as well as the other contact surfaces (e.g., rack-to-rack impacts, rack-to-wall impacts). NUREG/CR-5912 provides further guidance on the design and analysis of free-standing fuel racks.

The seismic input motion to the racks should consider the spectra at the rack base and the wall of the spent fuel pool that typically is obtained from the overall seismic building SSI analysis. It is acceptable to envelop the seismic motion at these two locations for the input loading to the racks. This approach is also applicable to free standing racks because seismic inertial loading can be transferred from the pool walls through the water in the pool to the racks. Alternative methods that may be used should be provided and reviewed on a case-by-case basis.

When pool walls are used to provide lateral restraint at higher elevations, the applicant should provide a determination of the flexibility of the pool walls and the capability of the walls to sustain such loads. If the pool walls are flexible (having a fundamental frequency less than 33 hertz), the floor response spectra corresponding to the lateral restraint point at the higher elevation are likely to be greater than those at the base of the pool. To use the response spectrum approach in such a case, the following two separate analyses should be performed:

A. A spectrum analysis of the rack system using response spectra corresponding to the highest support elevation provided that there is not significant peak frequency shift between the response spectra at the lower and higher elevations

B. A static analysis of the rack system by subjecting it to the maximum relative support displacement

The resulting stresses from the two analyses above should be combined by the absolute sum method.

To determine the flexibility of the pool wall, it is acceptable for the applicant to use equivalent mass and stiffness properties obtained from calculations similar to those described in "Introduction to Structural Dynamics," McGraw-Hill Book Co., New York, 1964, by Biggs, John M. Should the fundamental frequency of the pool wall model be higher than or equal to 33 hertz, it may be assumed that the response of the pool wall and the corresponding lateral support to the new rack system are identical to those of the base slab, for which appropriate floor response spectra or ground response spectra may already exist.

6. Structural Acceptance Criteria

Table 1 of this Appendix provides the structural acceptance criteria, in accordance with ASME Code, Section III, Division 1, Subsection NF. When considering compression loads, Subsection NF, Paragraph 3300, specifies additional criteria that must be satisfied to preclude buckling.

For impact loading, the ductility ratios used to absorb kinetic energy in the tensile, flexural, compressive, and shearing modes should be quantified. In the consideration of the effects of seismic loads, factors of safety against gross sliding and overturning of racks and rack modulus under all probable service conditions should be in accordance with SRP Section 3.8.5, Subsection II.5. This position on factors of safety against sliding and tilting need not be met provided that the applicant meets any one of the following conditions:

A. Detailed nonlinear dynamic analyses show that the amplitudes of sliding motion are minimal and impact between adjacent rack modules or between a rack module and the pool walls is prevented provided that the factors of safety against tilting are within the allowable values provided in SRP Section 3.8.5, Subsection II.5.

B. Any sliding and tilting motion will be contained within suitable geometric constraints such as thermal clearances, and any impact resulting from the clearances is incorporated.

The fuel pool structure should be designed for the loads imposed by the racks. The fuel pool liner leak-tight integrity should be maintained, or the functional capability of the fuel pool should be demonstrated.

7. Materials, Quality Control, and Special Construction Techniques

The applicant should describe materials, quality control procedures, and any special construction techniques; the sequence of installation of the new fuel racks; and the precautions to be taken to prevent damage to the stored fuel during re-racking at an operating plant.

If connections between the rack and the pool liner are made by welding, the welder, as well as the welding procedure for the welding assembly, should be qualified in accordance with the applicable code.

For spent fuel pool racks fabricated from aluminum, ~~American Society of Civil Engineers~~ASCE, Suggested Specification for Structures of Aluminum Alloys 6061-T6 and 6067-T6 and "Specification for Aluminum Structures" (issued by The Aluminum Association) contain the guidance regarding material properties.

TABLE 1

Load Combination	Acceptance Limit
D + L $D+L+T_o$ $D+L+T_o+E$	ASME Code Section III, Subsection NF Level A service limits for Class 3
$D+L+T_a+E$ $D+L+T_o+P_f$	ASME Code Section III, Subsection NF Level B service limits for Class 3
$D+L+T_a+E'$	ASME Code Section III, Subsection NF Level D service limits for Class 3
$D+L+F_d$	The functional capability of the fuel racks should be demonstrated
Limit Analysis	
Load Combination	Acceptance Limit

1.7 (D + L) 1.7 (D + L + T_o) 1.7 (D + L + E + T_o) 1.7 (D + L + E + T_a) 1.7 (D + L + T_o + P_f) 1.1 (D + L + T_a+ E')	ASME Code Section III, Subsection NF, paragraph 3340

Notes:

1. The abbreviations in the table above are those used in Subsection II.3 of SRP 3.8.4 where each term is defined, except for T_a, F_d, and P_f. T_a is defined here as the highest temperature associated with the postulated abnormal design conditions. F_d is the force caused by the accidental drop of the heaviest load from the maximum possible height. P_f is the upward force on the racks caused by a postulated stuck fuel assembly.

2. Deformation limits specified by the design specification limits should be satisfied and such deformation limits should preclude damage to the fuel assemblies.

3. The provisions of ASME Code, Section III, Division 1, Subsection NF were amended consistent with regulatory positions contained in RG 1.124 "Service Limits and Loading Combinations for Class 1 Linear-Type Component Supports."

II. REFERENCES

~~1. Regulatory Guide1.29, "Seismic Design Classification."~~

~~2. Regulatory Guide 1.92, "Combining Modal Responses and Spatial Components in Seismic Response Analysis."~~

~~3. Regulatory Guide1.124, "Service Limits and Loading Combinations for Class 1 Linear-Type Component Supports."~~

1. ~~4. American Society of Mechanical Engineers,~~ASCE Suggested Specification for Structures of Aluminum Alloys 6061-T6 and 6067-T6.

2. ASME Boiler and Pressure Vessel Code, Section III, Division 1.

3. ~~5. American National Standards Institute~~ANSI, N210-76, "Requirements for Light Water Reactor Spent Fuel Storage Facilities at Nuclear Power Plants, Design."

~~6. American Society of Civil Engineers, Suggested Specification for Structures of Aluminum Alloys 6061-T6 and 6067-T6.~~

~~7. The Aluminum Association, Specification for Aluminum Structures.~~

4. ~~8.~~ Biggs, John M., "Introduction to Structural Dynamics~~,~~," McGraw-Hill Book Co., New York, 1964.

5. 9. RG 1.29, "Seismic Design Classification."

6. RG 1.92, "Combining Modal Responses and Spatial Components in Seismic Response Analysis."

7. RG 1.124, "Service Limits and Loading Combinations for Class 1 Linear-Type Component Supports."

8. NUREG/CR-5912, "Review of the Technical Basis and Verification of Current Analysis Methods Used to Predict Seismic Response of Spent Fuel Storage Racks," October 1992.

9. The Aluminum Association, "Specification for Aluminum Structures."

PAPERWORK REDUCTION ACT STATEMENT

The information collections contained in the Standard Review Plan are covered by the requirements of 10 CFR Part 50 and 10 CFR Part 52, and were approved by the Office of Management and Budget, approval number 3150-0011 and 3150-0151.

PUBLIC PROTECTION NOTIFICATION

The NRC may not conduct or sponsor, and a person is not required to respond to, a request for information or an information collection requirement unless the requesting document displays a currently valid OMB control number.

SRP Section 3.8.4
"Other Seismic Category 1 Structures"

Description of Changes

Revision 3 to SRP Section 3.8.4 updates Revision 2 of this section, dated March 2007, to reflect the following changes:

1. This SRP section is administratively updated by the Office of New Reactors, per request from Juan D. Peralta, Branch Chief, Quality and Vendor Branch 1, Division of Construction, Inspection, and Operational Programs, memorandum dated February 17, 2010 (ADAMS Accession No. ML10090148).

Description of Changes

Section 3.8.4 "OTHER SEISMIC CATEGORY I STRUCTURES"

This SRP section affirms the technical accuracy and adequacy of the guidance previously provided in Revision 3, dated May 2010 of this SRP. See ADAMS Accession No.ML100630323.

I. AREAS OF REVIEW

1. Enhanced SRP Section 3.8.4 I.3 "Loads and Load Combinations" item A, to include loads induced by the construction sequence and differential settlements. See item 2 in SRP Section 3.8.5, "Description of Changes, II Acceptance Criteria," for the technical rationale for this change.

II. ACCEPTANCE CRITERIA

1. Revised SRP Section 3.8.4 II.4 "Design and Analysis Procedures" item H, to include enhanced guidance to compute dynamic soil pressures on embedded walls. The technical rationale for this change is as follows.

   The computation of seismically induced lateral soil pressures on embedded walls is acknowledged to be complex and dependent on many factors. Under static at-rest conditions, the soil pressures are primarily controlled by soil type, soil compaction (or relative density), and groundwater conditions. For granular materials, typically placed as backfill in the immediate vicinity of the wall, the static at-rest pressures at a given depth are estimated by K_o x σ_V, where σ_V is the vertical intergranular stress due to the weight of the soil above the depth of interest and K_o is called the at-rest coefficient of earth pressure. The parameter K_o is typically estimated to be approximately 0.5.

   Under seismic conditions, the pressures change from the static case and are primarily controlled by the relative motion developed between the wall or structure and the free-field. If the wall or structure moves away from the soil, these dynamically induced pressures decrease from the static at-rest pressures. This stress state is termed the active state. The minimum value of this active state is estimated for ordinary conditions as K_a x σ_V, where K_a is called the Rankine active coefficient of earth pressure. The value of K_a is less than K_o and is approximately 0.33. If the wall or structure moves into the surrounding soil, the pressures increase above the static at-rest condition. This increased stress state is termed the passive state. The maximum value of this passive state is estimated for ordinary conditions as K_p x σ_V, where K_p is called the Rankine passive coefficient of earth pressure. For ordinary granular soils, the value of K_p is approximately 3.0 or more.

   For typical granular materials, it is expected that the total pressures acting on the wall under seismic conditions will change from the static at-rest case to no less than the Rankine active pressure and to no more than the Rankine passive pressure. Therefore, for ordinary granular materials, the total horizontal pressure coefficients (static plus dynamic) can be expected to vary during the seismic motions from about 0.5 to no less than 0.33 and to no more than 3.0.

For more general soil materials that possess both cohesive and frictional shear strength, the formulation of the maximum and minimum Rankine states is more complex to delineate. Nevertheless, under seismic conditions, the total horizontal pressures are also bounded by the maximum and minimum Rankine states in a similar way as typical granular materials.

It is important to note that the magnitude of soil deformations required to fully develop the maximum and minimum Rankine states could be relatively large. The kinematic configuration of the problem is thus fundamental. This is the reason why the seismic design of embedded or basement walls (so-called “non-yielding” walls or “restrained” walls, that are fixed at the base, at the top, and possibly at other intermediate bracing points) should be clearly differentiated from the seismic design of earth retaining walls (so-called “yielding” or “unrestrained” walls, that are free to displace or rotate at the base).

In the case of unrestrained retaining walls, the standard seismic design approach is the Mononobe-Okabe method which is based on the assumed development of the minimum active state that is modified to include, in a pseudo-static manner, the additional horizontal and vertical seismic inertial loads exerted by the soil. The active state assumption is valid in this case because a stand-alone retaining wall is free to deform away from the soil but is unlikely to deform into the soil.

In the case of restrained embedded walls, the typical configuration of the problem precludes the development of the minimum active state assumption. In NPP applications, the embedded walls are not stand-alone but are part of a much larger and more massive structure that, under seismic conditions, interacts dynamically with the surrounding soil in a complex oscillatory manner. The maximum passive state condition is a potential upper bound that would correspond to the walls being pushed into the soil by the overall motion of the structure. However, the magnitude of soil deformations/strains computed from typical seismic ~~soil structure interaction (~~SSI~~)~~ analysis indicates that this magnitude is much smaller than what is required to fully develop the maximum passive state. As a result, seismic design practice in the past has been based on methods that assume linear elastic or equivalent-linear elastic soil stresses/strains.

It is clear that the true stress/strain state in the soil under seismic conditions is likely to deviate from the inelastic limit states discussed above. Important additional factors to consider are:

- Kinematics of the problem. Significant differences in the pressure distribution profile and the stress/strain state in the soil could occur depending on whether the embedded walls are assumed rigid or flexible, whether the base of the walls are allowed to rotate or slide relative to the soil, whether the structure is supported on stiff or flexible soil, and whether the overall motion of the structure includes a significant rocking component or not.

- Heterogeneity of the soil mass. An additional complication occurs if there is significant difference in stiffness between different backfill and in situ soil layers, and especially if the structure is partially embedded in rock. In the latter case, a large stress discontinuity is expected in the interface region between soil and rock.

- In typical NPP configurations, linear or equivalent-linear strains would tend to produce conservative estimates of pressures; however, there may be specific configurations for which the opposite occurs.

- Separation of the soil from the wall.

- Structure-soil-structure interactions between structures.

- Effects of groundwater on static and dynamic soil pressure.

Field measurements and experimental investigations confirm the wide variation in soil pressures depending on the different factors identified above. Therefore, the ~~proposed~~ enhancement to the SRP describes three methods to compute seismically induced lateral soil pressures on embedded walls, which should bound the uncertainties in the estimates for most design situations. The governing pressures of the three methods should be considered in the design. The governing pressures should also be determined based on the pressure distribution that generates the maximum member forces used for design of the foundation walls.

The first two methods are based on linear or equivalent-linear elastic assumptions, while the third method is based on the passive pressure and accounts for inelastic strains, albeit in a simplified manner. A clarification is also made relative to the passive pressure; the intent is to ensure that all or part of the passive pressure is incorporated in the design regardless of whether the maximum passive state condition has been reached in the soil (as indicated above, the latter is rarely the case for embedded walls in NPP structures). The displacement-dependent fraction of the passive pressure that is effectively mobilized can be determined from nonlinear FEM computations or from experimental results.

The ~~proposed~~ enhancement also emphasizes the review of the analysis assumptions. This is important because soil pressures can vary substantially depending on the different factors identified above. Conservative assumptions are thus critical.

The second method has been added to the SRP in light of recent NPP designs, in which seismic soil pressures have been computed using an embedded SSI/FEM analysis model. This is a general approach that is appropriate under the linear elastic or equivalent-linear elastic strain assumption and may address some of the issues discussed above. However, a careful review is still needed to ensure the validity of the modeling for this type of application. For example, the computed pressures may be overestimated in the upper soil layers near the surface. Also, the strain iterated soil profiles utilized in typical SSI analysis may not be consistent with the range of strains expected in the backfill soil adjacent to the walls.

Best estimate, lower bound, and upper bound soil properties should be considered in the second method if the SSI analysis performed in accordance with SRP Section 3.7.2 includes those soil cases.

Hydrodynamic effects on dynamic soil pressures are difficult to estimate accurately but are generally not a concern except for backfill soils with high permeability. In most design situations where saturated conditions exist, it is sufficient to compute the effects of ground water on dynamic soil pressures on the basis of saturated unit soil weight.

APPENDIX D

1. ~~1.~~ Revised Introduction section to include guidance on quality assurance and periodic condition monitoring. See item 3 below for the technical rationale for this change.

2. ~~2.~~ Revised Item 3, "Seismic and Impact Loads" to enhance guidance on seismic analysis of racks and fuel assemblies. See item 3 below for the technical rationale for this change.

3. ~~3.~~ Revised Item 4, "Loads and Load Combinations" to clarify the guidance for applicable design loads and the combinations for these loads. The technical rationale for this change is as follows.

In accordance with Appendix D to SRP Section 3.8.4, the staff has requested information from DC and COL applicants regarding the ability of spent fuel assemblies to withstand the loads imparted on them during a ~~safe shutdown earthquake (SSE).~~SSE. As indicated in Appendix D to SRP Section 3.8.4, the acceptance criteria related to the design of spent fuel racks requires, in part, that the structural integrity of the spent fuel contained within the racks be maintained during a seismic event. The spent fuel racks are designed as seismic Category I to protect the contained spent fuel assemblies. In addition, it is necessary to evaluate the spent fuel assemblies to ensure that when subject to ASME Service Level D loads, the design material allowable values, when adjusted to the spent fuel pool temperature, will not be exceeded for the spent fuel assembly components. The technical approaches taken by the applicants to demonstrate fuel assembly structural integrity have been diverse, requiring considerable staff effort before a conclusion of structural adequacy could be reached. To address this, the staff formed the Spent Fuel Working Group (SFWG).

Based on its assessment of recent applicant submittals, the staff's SFWG has recommended (1) the addition of secondary review responsibilities assigned to the organization responsible for the review of the fuel system design; and (2) an addendum to Appendix D of SRP Section 3.8.4. The secondary review responsibilities would include the review of the material limits associated with the fuel assembly in the fuel storage racks and the effect of rack deformations on the coolability of the fuel assembly. The addendum to Appendix D would address the apparent deficiency in Appendix D, which is the lack of specific guidance related to establishing an acceptable value for the structural capacity of spent fuel cladding. The SFWG arrived at this conclusion due to the fact that it is apparent that licensees and applicants are able to adequately estimate the loading imparted on a spent fuel bundle. However, the challenge lies in determining whether the cladding can withstand these imparted loads. This challenge is exacerbated by the fact that there is no design code applicable to the structural design of spent fuel rods.

In addressing the inconsistency of spent fuel structural integrity reviews, the addendum to Appendix D should afford a greater degree of guidance to reviewers that will facilitate the deliberate and accurate assessment of spent fuel structural integrity.

Spent fuel pool racks are ~~Seismic~~seismic Category I, and Appendix D states "The main safety function of the spent fuel pool, including the liner, and the racks is to maintain the spent fuel assemblies in a safe configuration…." It has come to the attention of staff reviewers that~~ ~~ at least some licensees and applicants consider spent fuel pool racks to be ~~non-safety~~nonsafety- related, do not invoke the Appendix B quality assurance requirements for spent fuel pool racks, and exclude spent fuel pool racks from Maintenance Rule Condition Monitoring programs.

The ~~proposed~~ addition to the first paragraph of Appendix D should clarify the staff's position.

Appendix D, as currently written, provides the staff's guidance for spent fuel pool re-racking at operating plants, in order to provide significantly increased spent fuel storage. This was necessitated by the lack of available off-site storage facilities for spent nuclear fuel. Consequently, the wording of Appendix D is in need of updating to be more generically applicable, now that new reactors are being designed and constructed.

4. ~~4.~~ Revised Item 6 "Structural Acceptance Criteria" to enhance the guidance for acceptance criteria in accordance with ASME Code, Section III, Division 1, Subsection NF. See item 3 above for the technical rationale for this change.

5. ~~5.~~ Revised Table 1 to enhance the guidance on acceptance limits and the guidance on load combinations, when performing a limit analysis. The technical rationale for this change is as follows.

A change was made in Table 1 of Appendix D, for the acceptance limit under the heading "Limit Analysis." Since ASME Code Section III, Appendix XVII was deleted, the acceptance limit was replaced with ASME Code Section III, Subsection NF, Paragraph 3340, which provides acceptance limits for performing a limit analysis.

6. ~~6.~~ Removed references to ~~Regulatory Guides~~RG 1.60, 1.61~~,~~ and 1.76.