



## U.S. NUCLEAR REGULATORY COMMISSION

# STANDARD REVIEW PLAN

### 3.8.5 FOUNDATIONS

#### REVIEW RESPONSIBILITIES

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

**Secondary** - None

#### I. AREAS OF REVIEW

The review covers areas relating to the foundations of all Seismic Category I structures.

The specific areas of review are as follows:

1. Description of the Foundations. The review covers descriptive information, including plans and sections of each foundation, to establish that sufficient information is provided to define the primary structural aspects and elements relied on to perform the foundation function. The review also addresses the relationship between adjacent foundations, including the methods of separation provided if such separation is used to minimize seismic interaction between the buildings. In particular, the review identifies the type of foundation and examines its structural characteristics. Among the various types of foundations reviewed are mat foundations and footings, including individual column footings, combined footings supporting more than one column, and wall footings supporting bearing walls. Some recent applications submitted for design certification (DC) use a single foundation mat for the nuclear island structures.

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### USNRC STANDARD REVIEW PLAN

This Standard Review Plan, NUREG-0800, has been prepared to establish criteria that the U.S. Nuclear Regulatory Commission 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's regulations. The Standard Review Plan is not a substitute for the NRC's 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 standard review plan sections are numbered in accordance with corresponding sections in Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)." Not all sections of Regulatory Guide 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 Regulatory Guide 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)."

These documents are made available to the public as part of the NRC's 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](mailto:NRR_SRP@nrc.gov).

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Other types of foundations that may be used include pile foundations, drilled caissons, caissons for waterfront structures such as a pumphouse, and rock anchor systems. The review addresses these types of foundations on a case-by-case basis.

The paragraphs below list major plant Category I foundations that are reviewed, together with associated descriptive information:

A. Containment Structure Foundation

The most commonly used type of foundation for both concrete and steel containments is a mat foundation, which is a flat thick slab supporting the containment, its interior structures, and any shield building surrounding the containment. For some pressurized-water reactor containments, the base mat has a central depression that forms the reactor cavity. The review addresses the general arrangement of the containment base slab, as described in Subsection I.1 of Standard Review Plan (SRP) Section 3.8.1, with particular emphasis on methods of transferring horizontal shears, such as those caused by earthquakes, to the foundation media. If shear keys are used for such purposes, the review covers the general arrangement of the keys. If waterproofing membranes are used, the review addresses their effect on the shear resistance of the foundation. In prestressed concrete containments with a tendon inspection gallery, the review includes the arrangement of the gallery and means of either isolating it from the remainder of the base slab or relying on it for some function such as resisting shears.

B. Containment Enclosure Building Foundation

If the containment enclosure building is constructed of reinforced concrete, it is usually supported on the same mat foundation that supports the containment.

If the containment enclosure building is constructed of structural steel and metal siding, it may surround only the exposed portion of the containment. In such a situation, the enclosure building columns are founded on individual or combined footings at grade level, on the roof of the buildings adjacent to or surrounding the containment, on the dome of the containment, or possibly on brackets anchored to the exterior face of the cylindrical wall of the containment. The review includes the general arrangement of such foundations, with particular emphasis on methods of isolating the enclosure building from other buildings in a lateral direction when this is preferable to minimize seismic interaction.

C. Auxiliary Building Foundation

The auxiliary building foundation is typically of a mat type, particularly if the supporting medium is soil.

The review addresses the general arrangement of the foundation, with particular emphasis on methods of transferring loads from the structure to the foundation media.

#### D. Other Category I Foundations

The foundations for other Seismic Category I structures, which may be one or a combination of several foundation types, are reviewed to an extent similar to that of the containment foundation. Among Seismic Category I structures with foundations subject to such a review are fuel storage buildings, control buildings, diesel generator buildings, intake structures, and cooling towers. The review also includes the foundations of safety-related structures that, because of other design provisions, are not classified as Seismic Category I.

2. Applicable Codes, Standards, and Specifications. The review addresses information pertaining to design codes, standards, specifications, regulatory guides, and other industry standards that are applied in the design, fabrication, construction, testing, and surveillance of Seismic Category I foundations.
3. Loads and Load Combinations. The review includes information pertaining to the applicable design loads and their various combinations. The loads normally applicable to Seismic Category I foundations are the same as those applicable to the structures that the foundations support. SRP Section 3.8.1, Subsection I.3 describes these loads for the containment foundation, and SRP Section 3.8.4, Subsection I.3 details such loads for all other Seismic Category I foundations.
4. Design and Analysis Procedures. The review assesses design procedures used for Seismic Category I foundations other than containment, emphasizing the extent of compliance with American Concrete Institute (ACI) 349, with additional guidance provided by Regulatory Guide (RG) 1.142, for concrete structures and the American National Standards Institute/American Institute of Steel Construction (ANSI/AISC N690-1994) including Supplement 2 (2004) specifications for steel structures. For containment foundations, the emphasis is on the extent of compliance with the procedures discussed in Subsection I.4 of SRP Section 3.8.1. The review includes analysis procedures used for Seismic Category I foundations with respect to the applicability of the theories on which these procedures are based.

Among the areas reviewed are the following:

- A. Assumptions about boundary conditions and the expected behavior of each foundation when subjected to the various design loads.
- B. Methods that transmit lateral loads and forces and overturning moments thereof from the structure to the foundation media. Such forces are mainly generated by environmental and abnormal plant conditions such as wind, tornadoes, earthquakes, and pipe ruptures. The review includes methods of determining overturning moments attributable to earthquakes, as described in SRP Section 3.7.2.
- C. Computer programs that are used in the design and analysis of Seismic Category I foundations.
- D. Category I structures design report (see Appendix C to SRP Section 3.8.4).
- E. A structural audit (see Appendix B to SRP Section 3.8.4).

Some recent applications submitted for DC use a single foundation mat for the nuclear island structures. For such designs, attention is given to bending, shear, and similar factors in the base mat that are attributable to uneven settlement, construction sequence, and mat flexibility. The review also considers the design of the junction of the sidewall and base mat, as well as stiff or soft spots in the underlying soil. Site-specific soil-bearing capacities are reviewed as part of SRP Section 2.5.4.

5. Structural Acceptance Criteria. The review assesses the foundation for its capability to receive loads from the structure and to transmit loads to the soil media, with appropriate safety margins.

The review addresses the design limits imposed on the various parameters that serve to quantify the structural behavior of each foundation, emphasizing the extent of compliance with the allowable limits delineated in Subsection II.5 of this SRP section. The review includes factors of safety against overturning and sliding to ensure adequate safety margins.

6. Materials, Quality Control, and Special Construction Techniques. The review assesses information on the materials used in the construction of Seismic Category I foundations. Among the major materials of construction reviewed are the following:

- A. Concrete ingredients
- B. Reinforcing bars and mechanical splices
- C. Structural steel
- D. Rock anchors, including any prestressing system

The review includes the quality control program proposed for the fabrication and construction of Seismic Category I foundations, including nondestructive examination of the materials to determine physical properties, placement of concrete, and erection tolerances.

The review addresses any proposed special construction techniques on a case-by-case basis.

In addition, for Seismic Category I foundations other than containment, the following information should be provided:

- A. The extent to which the materials and quality control programs comply with ACI 349, with additional guidance provided by RG 1.142, for concrete, and with ANSI/AISC N690-1994 including Supplement 2 (2004) for steel, as applicable.
- B. If welding of reinforcing bars is proposed, the design should comply with the applicable sections of American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (hereafter referred as Code), Section III, Division 2. Any exceptions taken to compliance should be justified.

The review of geological and seismological information to establish the free-field ground motion is performed as described in SRP Sections 2.5.1 and 2.5.2.

The review of the geotechnical parameters and methods employed in the analysis of free-field soil media and soil properties is conducted as described in SRP Sections 2.5.4 and 2.5.5.

7. Testing and Inservice Surveillance Programs. For Category I foundations, the review addresses information on structure monitoring and maintenance requirements.

It is important for Category I foundations to accommodate inservice inspection of critical areas. The review therefore assesses any special design provisions (e.g., providing sufficient physical access, furnishing alternative means for identification of conditions in inaccessible areas that can lead to degradation, conducting remote visual monitoring of high-radiation areas) to accommodate inservice inspection of Category I foundations.

The review of postconstruction testing and inservice surveillance programs for foundations, such as periodic examination of inaccessible areas, monitoring of ground-water chemistry, and monitoring of settlements and differential displacements, is on a case-by-case basis.

8. 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) 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.

9. COL Action Items and Certification Requirements and Restrictions. For a DC application, the review will also address 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 a quality assurance program in accordance with the requirements of Appendix B to 10 CFR Part 50 is performed under SRP Sections 3.2.1 and 3.2.2. The review of safety-related structures is performed on that basis.
2. The 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 included in the load combination equations of this SRP section.

3. The determination of loads generated by pressure under accident conditions is performed in accordance with SRP Section 6.2.1. The loads thus generated are included in the load combinations in this SRP section.
4. The review for quality assurance is coordinated and performed in accordance with Chapter 17.

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

## 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 safety-related structures being designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed.
2. GDC 2, as it relates to the design of the safety-related structures that are capable of withstanding the most severe natural phenomena such as wind, tornadoes, floods, and earthquakes and the appropriate combination of all loads.
3. GDC 4, as it relates to appropriately protecting safety-related structures against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit.
4. GDC 5, as it relates to not sharing safety-related structures among nuclear power units unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions.
5. Appendix B to 10 CFR Part 50, 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 inspections, tests, analyses, and acceptance criteria (ITAAC) 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 that incorporates the design certification is built and will operate in accordance with the design certification, the provisions of the Atomic Energy Act, and the NRC's 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 combined license, the provisions of the Atomic Energy Act, and the NRC's regulations.

### SRP Acceptance Criteria

Specific SRP acceptance criteria acceptable to meet the relevant requirements of the NRC's regulations identified above are as follows for the review described in this SRP section. The SRP is not a substitute for the NRC's 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 acceptable methods of compliance with the NRC regulations.

1. Description of the Foundation. The descriptive information in the safety analysis report (SAR) is acceptable if it meets the criteria in Section 3.8.5.1 of RG 1.206.

New or unique design features that are not specifically covered in RG 1.206 or RG 1.70 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. Applicable Codes, Standards, and Specifications. The design, materials, fabrication, erection, inspection, testing, and surveillance, if any, of Seismic Category I foundations are covered by codes, standards, and guides that apply either in their entirety or in part. Subsection II.2 of SRP Section 3.8.4 includes a list of such documents. In addition, the documents listed in Subsection II.2 of SRP Section 3.8.1 are acceptable for the containment foundation.
3. Loads and Load Combinations. The specified loads and load combinations used in the design of Seismic Category I foundations are acceptable if found to be in accordance with those combinations referenced in Subsection II.3 of SRP Section 3.8.1 for the containment foundation and with those combinations listed in Subsection II.3 of SRP Section 3.8.4 for all other Seismic Category I foundations.

In addition to the load combinations referenced above, the combinations used to check against sliding and overturning attributable to earthquakes, winds, tornadoes and against flotation because of floods are acceptable if found to be in accordance with the following:

- A.  $D + H + E$
- B.  $D + H + W$
- C.  $D + H + E'$
- D.  $D + H + W_t$
- E.  $D + F'$

Where  $D$ ,  $E$ ,  $W$ ,  $E'$ , and  $W_t$  are as referenced in Subsection II.3 of SRP Section 3.8.4, where  $H$  is the lateral earth pressure, and  $F'$  is the buoyant force of the design-basis flood. Justification should be provided for including live loads or portions thereof in these combinations.

As noted in Appendix S to 10 CFR Part 50, the operating-basis earthquake (OBE), designated as  $E$  above, is only associated with plant shutdown and inspection unless the applicant specifically selects it as a design input. If the OBE is set at one-third or less of the safe-shutdown earthquake (SSE) ground motion, an explicit response 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 Category I foundations remain functional and fall within applicable stress, strain, and deformation limits. SRP Section 3.7 provides additional guidance on OBE use.

4. Design and Analysis Procedures. The design and analysis procedures used for Seismic Category I foundations are acceptable if found to be in accordance with the following:
  - A. The design should consider the soil-structure interaction, hydrodynamic effect, and dynamic soil pressure.
  - B. For Seismic Category I concrete foundations other than the containment foundations, the procedures are in accordance with the ACI 349, with additional guidance provided by RG 1.142.
  - C. For Category I steel foundations, the procedures are in accordance with ANSI/AISC N690-1994 including Supplement 2 (2004).
  - D. For the containment foundation, if in accordance with the design and analysis procedures referenced in SRP Section 3.8.1, Subsection II.4.
  - E. The design report is acceptable if it satisfies the guidelines provided in SRP Section 3.8.4, Appendix C.
  - F. The structural audit is conducted in accordance with SRP Section 3.8.4, Appendix B.

Methods for determining the overturning moment attributable to an earthquake should be in accordance with the methods described in SRP Section 3.7.2. Computer programs are acceptable if the validation provided is found to be in accordance with the procedures delineated in Subsection II.4.E of SRP Section 3.8.1.

In addition to the above, the design and analysis procedures for the following details are reviewed on a case-by-case basis:

- A. Method for determination of the bending moments and shear forces in the foundation mat for seismic loads?



- B. Performance of the sliding analysis method and how the analysis adequately accounts for potential foundation mat liftoff effects, if appropriate? The method to calculate the factor of safety against sliding. If sliding resistance is the sum of shear friction along the base mat and passive pressures induced by embedment effects, how these effects are considered in an analysis based on a consistent lateral displacement criterion?
  - C. Evaluation of the capability of a foundation to transfer shear when waterproofing is used for a range of site conditions (soil sites with shear wave velocity of 1000 feet per second to hard rock)?
  - D. The definition of dead load for uplift evaluations (floatation and seismic overturning), including the treatment of the stored volume of water in any pools?
  - E. Detail explanation of how settlement (including potential effects of static or dynamic differential settlement) was considered. Evaluation and consideration of the effects of settlement on construction procedures. Evaluation of the allowable settlement (total and differential) that can be accommodated in the foundation/structures?
  - F. The maximum toe pressure for base mat design under worst-case static and dynamic loads and its justification.
  - G. The stiff and soft spots evaluation in the foundation soil to maximize the bending moments used in the design of the foundation mat.
  - H. Description of the design details of critical locations, such as the junction of sidewall and base mat and the junctions of base mat to sumps.
  - I. Detail explanation of the load path from all superstructures to the foundation mat to the subgrade. Discussion of any unique design features that occur in the load path (e.g., any safety-related function that the tendon gallery may have as part of the foundation in a prestressed containment or the connection of any internal structures to a steel containment and its supporting foundation).
  - J. Explanation of how loads attributable to construction are considered in the design. Some examples of items to be discussed include the excavation sequence and loads from the construction sequence of the foundation mat and walls, as well as the potential for loss of subgrade contact (e.g., because of loss of cement from a mud mat) that may lead to a differential pressure distribution on the mat.
5. Structural Acceptance Criteria. For the loading combinations referenced in the first paragraph of Subsection II.3 of this SRP section, the allowable limits that constitute the acceptance criteria are referenced in Subsection II.5 of SRP Section 3.8.1 for the containment foundation and in Subsection II.5 of SRP Section 3.8.4 for all other foundations. In addition, for the five other load combinations in Subsection II.3 of this SRP section, the factors of safety against overturning, sliding, and flotation are acceptable if found to be in accordance with the following:

Minimum Factors of Safety

<u>For Combination</u>	<u>Overturing</u>	<u>Sliding</u>	<u>Flotation</u>
a. -----	1.5	1.5	---
b. -----	1.5	1.5	---
c. -----	1.1	1.1	---
d. -----	1.1	1.1	---
e. -----	---	---	1.1

6. Materials, Quality Control, and Special Construction Techniques.

For the containment foundation, Subsection II.6 of SRP Section 3.8.1 references the acceptance criteria for materials, quality control, and any special construction techniques.

For all other Seismic Category I foundations, the materials and quality control programs are acceptable if found to be in accordance with the codes and standards indicated in Subsection I.6 of this SRP section. Special construction techniques, if any, are treated on a case-by-case basis.

7. Testing and Inservice Surveillance Requirements. For Category I foundations, structure monitoring and maintenance requirements are acceptable if found to be in accordance with 10 CFR 50.65 and RG 1.160.

For water control structures, inservice inspection programs are acceptable if found to be 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, as well as intake and discharge structures, and safety and performance instrumentation.

For Category I foundations, it is important to accommodate inservice inspection of critical areas. The staff considers monitoring and maintaining the condition of Category I foundations as essential for plant safety. Any special design provisions (e.g., providing sufficient physical access, supplying a means for identification of conditions in inaccessible areas that can lead to degradation, performing remote visual monitoring of high-radiation areas) to accommodate inservice inspection of Category I foundations are reviewed on a case-by-case basis.

For plants with nonaggressive ground water/soil (i.e., pH > 5.5, chlorides < 500 parts per million (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 for signs of degradation, when excavated for any reason, 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., exceeding 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.

Subsection II.7 of SRP Section 3.8.1 covers additional testing and surveillance requirements for the containment foundation. Design of any special foundations will be reviewed on a case-by-case basis.

### 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:

This rationale addresses Category I foundations other than containment. The technical rationale for containment foundations is the same as that for concrete containment, as discussed in Subsection II of SRP Section 3.8.1.

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 functions to be performed.

SRP Section 3.8.5 refers to a list of acceptable documents in SRP Section 3.8.4 that provide guidance regarding construction, quality control, tests, and inspections. ACI 349, with additional guidance provided by RG 1.142 and ANSI/AISC N690-1994 including Supplement 2 (2004) contains basic specifications for concrete and steel structures, respectively. These guides and specifications impose specific restrictions to ensure that the foundations of structures other than containment will perform their intended safety function.

Meeting these requirements provides additional assurance that the foundations of structures other than containment described in this section will perform their intended safety function and limit the release of radioactive materials.

2. Compliance with GDC 1 requires that (1) SSCs important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of their safety function, (2) a quality assurance program be established and implemented, and (3) sufficient and appropriate records be maintained. If generally recognized codes and standards are used, they should be identified and evaluated to determine their applicability, adequacy, and sufficiency and supplemented or modified as necessary to assure a quality product in keeping with the required safety function.

SRP Section 3.8.5, which also refers to SRP Section 3.8.4, describes acceptable criteria 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.

SRP Section 3.8.5, which also refers to SRP Section 3.8.4, cites ACI 349, ANSI/AISC N690-1994 including Supplement 2 (2004), and regulatory guides 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 provides assurance that the foundations of structures other than containment described in this section will perform their intended safety function.

3. Compliance with GDC 2 requires that the design of SSCs important to safety withstand the effects of expected natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, tsunamis, and seiches, without losing the 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 the design of structures other than containment of a nuclear power plant will withstand natural phenomena, it is necessary to consider the most severe natural phenomena that have been historically reported, allowing 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 construction permit, operating license, COL, and 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.

SRP Section 3.8.5, which also refers to SRP Section 3.8.4, provides detailed acceptance criteria and cites appropriate regulatory guidance for design methodology, materials testing, and construction techniques that are acceptable to the staff. GDC 2 requires that the design of structures other than containment be able to withstand the effects of natural phenomena combined with the effects of normal and accident conditions without losing the capability to perform their safety functions. The primary function of a foundation is to transmit the loads imposed by the superstructure to the foundation material, bedrock, and/or soil supporting the structure. Foundations must be designed to interact with the structures they support. Consequently, it is necessary to specify the most severe natural phenomena (e.g., earthquakes) likely to occur as a function of their frequency of occurrence. The load combinations and specifications cited in these SRP sections provide acceptable engineering criteria to accomplish that function.

Meeting these requirements provides added assurance that the design of foundations of structures other than containment will withstand the effects of natural phenomena and will perform their intended safety functions.

4. Compliance with GDC 4 requires that the design of nuclear power plant SSCs important to safety (1) accommodate the effects of, and be compatible with, environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents and (2) appropriately protect 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.

SRP Section 3.8.5, which also refers to SRP Section 3.8.4, provides acceptable methods including load combinations, acceptance criteria, standards, and codes to ensure compliance with GDC 4. Meeting this requirement provides assurance that the foundations of 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 (nonterrorist-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 provides assurance that the foundations of structures other than containment will not fail to function as designed, thus protecting against loss of their structural integrity.

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 the 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 ensure that the use of common structures in multiunit plants will not significantly affect orderly and safe shutdown and cooldown in one plant in the event of an accident in another. The load-combination equations combine loads from normal operation and from design-basis accidents so that the resulting structural designs provide for mutual independence of shared structures.

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

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.

SRP Section 3.8.5, which also refers to SRP Section 3.8.4, provides guidance specifically related to the design, construction, testing, and inservice surveillance of structural concrete and steel used in nuclear power plants. Subsection II.2 of SRP Section 3.8.4 cites ACI 349, with additional guidance provided by RG 1.142, ANSI/AISC N690-1994 including Supplement 2 (2004), and RG 1.127 and 1.160, to satisfy the requirements of Appendix B to 10 CFR Part 50.

Meeting these requirements provides additional assurance that the foundations of structures other than containment covered in this SRP section will meet the requirements of Appendix B to 10 CFR Part 50 and thus perform their intended safety functions.

### 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. Description of the Foundations. After the type of foundation and its structural characteristics are identified, information on similar and previously licensed plants is obtained for reference. Such information, which is available in SARs and amendments to previous license applications, enables the 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 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. Applicable Codes, Standards, and Specifications. The list of codes, standards, guides, and specifications is compared with the list referenced 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. Loads and Load Combinations. The reviewer verifies that the loads and load combinations are as conservative as those referenced and specified in Subsection II.3 of this SRP section. Any deviations from the acceptance criteria for loads and load combinations that have not been adequately justified are identified as unacceptable and transmitted to the applicant.
4. Design and Analysis Procedures. The reviewer verifies that, for the design and analysis procedures, the applicant has used the procedures in the applicable code as delineated in Subsection II.4 of this SRP section.

Any computer programs that are used in the design and analysis of the foundation are reviewed to verify their validity in accordance with the acceptance criteria delineated in Subsection II.4.E of SRP Section 3.8.1.

The reviewer verifies that the provisions of Subsection II.4 of this SRP section are met.

5. Structural Acceptance Criteria. The limits on allowable stresses and strains in the concrete, reinforcement, and structural steel and on factors of safety for overturning, sliding, and flotation are compared with the corresponding allowable values specified in Subsection II.5 of this SRP section. If the applicant proposes to deviate from these limits, it should be supported with adequate justification and evaluation.

6. Materials, Quality Control, and Special Construction Techniques. The materials, quality control procedures, and any special construction techniques are compared with those referenced in Subsection II.6 of this SRP section. If a new material not used in previously licensed cases is employed, the applicant is requested to provide sufficient test and user data to establish the acceptability of such a material. Similarly, any new quality control procedures or construction techniques are evaluated in detail to ensure that there will be no degradation of quality that might affect the structural integrity of the foundation.
7. Testing and Inservice Surveillance Programs. For Category I foundations, the reviewer verifies that structure monitoring and maintenance requirements are in accordance with 10 CFR 50.65 and RG 1.127 and 1.160.

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

For the containment foundation, testing and inservice surveillance programs are also reviewed in accordance with Subsection II.7 of SRP Section 3.8.1 for concrete containments. Any other testing and inservice surveillance programs for other Seismic Category I foundations are reviewed on a case-by-case basis.

8. 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 (DCD). 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 early site permit (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. The reviewer also states the bases for those conclusions.

The staff concludes that the design of the Seismic Category I foundations is acceptable and meets the relevant requirements of 10 CFR 50.55a, 10 CFR Part 50, Appendix B, and GDC 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 Seismic Category I foundations are designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the safety functions to be performed by meeting the guidelines of regulatory guides and industry standards indicated below.
2. The applicant has met the requirements of GDC 2 by designing the Seismic Category I foundation described in this section to withstand not only the most severe earthquake that has been established for the site with sufficient margin, but also 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 designs of Seismic Category I foundations 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, they have demonstrated that sharing will not impair their ability to perform their intended safety functions.
5. The applicant has met the requirements of 10 CFR Part 50, Appendix B because the quality assurance program provides adequate measures for implementing guidelines relating to structural design.
6. The criteria used in the analysis, design, and construction of all plant Seismic Category I foundations to account for anticipated loadings and postulated conditions that may be imposed upon each foundation during its service lifetime are in conformance with established criteria, codes, standards, and specifications acceptable to the NRC staff. These include meeting the positions of RG and industry standards listed in Subsection II.2 of SRP Section 3.8.1 for containment foundations and Subsection II.2 of SRP Section 3.8.4 for other Seismic Category I foundations.
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, earthquakes, and various postulated events, Seismic Category I foundations will withstand the specified design conditions without impairment of structural integrity and stability or the performance of required safety functions.

In addition to the above, the staff also concludes that the design of the Seismic Category I containment foundation is acceptable and meets the relevant requirements for containments as discussed in Subsection IV of SRP Section 3.8.1.

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 staff will use the method described herein to evaluate conformance with Commission 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 regulatory guides include the implementation schedules for conformance to parts of the method discussed herein.

## VI. REFERENCES

1. 10 CFR 50.55(a), "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. American Concrete Institute, ACI 349, "Code Requirements for Nuclear Safety-Related Concrete Structures."
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. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Division 2, "Code for Concrete Reactor Vessels and Containments."
13. Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants, LWR Edition."
14. Regulatory Guide 1.127, "Inspection of Water-Control Structures Associated with Nuclear Power Plants."
15. Regulatory Guide 1.142, "Safety-Related Concrete Structures for Nuclear Power Plants."
16. Regulatory Guide 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants."
17. Regulatory Guide 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)."

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**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.

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