Enclosures 1, 5 and 6 to this Letter Contain ~~Proprietary Information~~
Withhold Enclosures 1, 5 and 6 from ~~Public Disclosure in Accordance with 10 CFR 2.390~~

NEXTera ENERGY
SEABROOK

August 1,2016
10 CFR 50.90
Docket No. 50-443
SBK-L-16071

United States Nuclear Regulatory Commission
Attn.: Document Control Desk
Washington, D.C. 20555-0001

Seabrook Station

License Amendment Request 16-03
Revise Current Licensing Basis to Adopt a Methodology for the Analysis of Seismic Category I Structures with Concrete Affected by Alkali-Silica Reaction

In accordance with 10 CFR 50.90, *Application for amendment of license, construction permit, or early site permit,* NextEra Energy Seabrook, LLC (NextEra) requests an amendment to the license for Seabrook Station. Specifically, the proposed change revises the Seabrook Updated Final Safety Analysis Report (UFSAR) to include methods for analyzing seismic Category I structures with concrete affected by an alkali-silica reaction (ASR). NRC approval of this LAR will allow NextEra Energy Seabrook, LLC (NextEra) to proceed in an optimum, safe and effective manner toward a long-term solution for ASR degradation at Seabrook Station. The proposed methodology changes are necessary to reconcile the design basis of the containment building and other seismic Category I structures that are affected by ASR.

Enclosure 1 to this letter is proprietary, provides a description and assessment of the proposed change and provides the existing UFSAR pages (Attachment 1) marked up to show the proposed changes. To facilitate the staff's review of the proposed change, several additional references are enclosed to provide supporting detail. Enclosure 2 provides the non-proprietary version of MPR-4288, "Seabrook Station: Impact of Alkali-Silica Reaction on Structural Design Evaluations." Enclosure 3 provides the non-proprietary version of MPR-4273, "Seabrook Station – Implications of Large-Scale Test Program Results on Reinforced Concrete Affected by Alkali-Silica Reaction". Attachment 4 provides SG&H 160268-R-01, "Development of ASR Load Factors for Seismic Category I Structures (Including Containment) at Seabrook Station, Seabrook, NH." Enclosure 5 provides the proprietary version of MPR-4288. Enclosure 6 provides the proprietary version of MPR-4273. Enclosure 7 provides the non- proprietary version of NextEra Energy Seabrook's Evaluation of the Proposed Change. This letter is supported by an affidavit provided in Enclosure 8 setting forth the basis on which the information

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may be withheld from public disclosure by the Commission and addressing considerations listed in 10CFR2.390(b)(4). Accordingly, it is respectfully requested that the information which is proprietary be withheld from public disclosure in accordance with 10CFR2.390. In accordance with 10 CFR 50.91, a copy of this application, with attachments is being provided to the designated officials in New Hampshire. This letter contains no new or revised commitments.

NextEra requests NRC review and approval of the requested amendment by October 1, 2017 and implementation within 90 days.

Should you have any questions regarding this letter, please contact Kenneth Browne, Licensing Manager at 603-773-7932.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on August 1, 2016.

Sincerely,

Ralph A. Dodds III

Plant General Manager
NextEra Energy Seabrook, LLC

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|---|---|
| Enclosure 1 | NextEra Energy Seabrook's Evaluation of the Proposed Change Including Attachment 1 Markup of UFSAR Pages (Proprietary) |
| Enclosure 2 | MPR-4288, Revision 0, "Seabrook Station: Impact of Alkali-Silica Reaction on Structural Design Evaluations," July 2016. (Non-Proprietary) |
| Enclosure 3 | MPR-4273, Revision 0, "Seabrook Station - Implications of Large-Scale Test Program Results on Reinforced Concrete Affected by Alkali-Silica Reaction," July 2016. (Non-Proprietary) |
| Enclosure 4 | SG&H Report 160268-R-01 "Development of ASR Load Factors for Seismic Category I Structures (Including Containment) at Seabrook Station, Seabrook, NH," Revision 0 (Seabrook FP# 101039) |
| Enclosure 5 | MPR-4288, Revision 0, "Seabrook Station: Impact of Alkali-Silica Reaction on the Structural Design Evaluations," July 2016. (Seabrook FP# 101020) (Proprietary) |
| Enclosure 6 | MPR-4273, Revision 0, "Seabrook Station - Implications of Large-Scale Test Program Results on Reinforced Concrete Affected by Alkali-Silica Reaction," July 2016. (Seabrook FP# 101050) (Proprietary) |
| Enclosure 7 | NextEra Energy Seabrook's Evaluation of the Proposed Change (Non-Proprietary) |
| Enclosure 8 | Affidavit in Support of Application for Withholding Proprietary Information from Public Disclosure |

cc: NRC Region I Administrator
NRC Project Manager
NRC Resident Inspector

Mr. Perry Plummer, Director Homeland Security and Emergency Management
New Hampshire Department of Safety
Division of Homeland Security and Emergency Management
Bureau of Emergency Management
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NEXTera ENERGY SEABROOK

**NextEra Energy Seabrook, LLC**

## AFFIDAVIT IN SUPPORT OF APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION FROM PUBLIC DISCLOSURE

County of Rockingham )
)
State of New Hampshire )

I, Ralph A. Dodds III, being duly sworn according to law, depose and state the following:

(1) I am the Plant General Manager of NextEra Energy Seabrook, LLC (NextEra Energy Seabrook), and have been delegated the function of reviewing the information described in paragraph (3) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) I am making this Affidavit in conjunction with NextEra Energy Seabrook's "Application for Withholding Proprietary Information from Public Disclosure" accompanying this Affidavit and in conformance with the provisions of 10 CFR Section 2.390.

(3) The information sought to be withheld is contained in Enclosures 1, 5, and 6 to this letter, "NextEra Energy Seabrook's Evaluation of the Proposed Change" (Proprietary), MPR-4273, Revision 0, "Seabrook Station - Implications of Large-Scale Test Program Results on Reinforced Concrete Affected by Alkali-Silica Reaction," July 2016 (Seabrook FP# 101050) (Proprietary) and MPR-4288, Revision 0, "Seabrook Station: Impact of Alkali-Silica Reaction on the Structural Design Evaluations," July 2016 (Seabrook FP# 101020) (Proprietary). The NextEra Energy Seabrook proprietary information in Enclosure 1, 5 and 6 is identified by enclosing boxes ([__]).

(4) The information sought to be withheld is considered to be proprietary and confidential commercial information because alkali-silica reaction (ASR) is a newly-identified phenomenon at domestic nuclear plants. The information requested to be withheld is the result of several

years of intensive NextEra Energy Seabrook effort and the expenditure of a considerable sum of money. This information may be marketable in the event nuclear facilities or other regulated facilities identify the presence of ASR. In order for potential customers to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended. The extent to which this information is available to potential customers diminishes NextEra Energy Seabrook's ability to sell products and services involving the use of the information. Thus, public disclosure of the information sought to be withheld is likely to cause substantial harm to NextEra Energy Seabrook's competitive position and NextEra Energy Seabrook has a rational basis for considering this information to be confidential commercial information.

(5) The information sought to be withheld is being submitted to the NRC in confidence.

(6) The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by NextEra Energy Seabrook, has not been disclosed publicly, and not been made available in public sources.

(7) The information is of a sort customarily held in confidence by NextEra Energy Seabrook, and is in fact so held.

(8) All disclosures to third parties, including any required transmittals to the NRC, have been or will be pursuant to regulatory provisions and/or confidentiality agreements that provide for maintaining the information in confidence.

I declare that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information, and belief. Further, the affiant sayeth not.

R Dodds III

Ralph A. Dodds III

Plant General Manager
NextEra Energy Seabrook, LLC
626 Lafayette Road
Seabrook, New Hampshire 03874

Subscribed and sworn to before me
this 1st day of August, 2016

Victoria S. Brown
Notary Public
My commission expires 10/17/2017

VICTORIA S. BROWN
MY COMMISSION EXPIRES OCT. 17, 2017

# SBK-L-16071

# ENCLOSURE 7

# NextEra Energy Seabrook's Evaluation of the Proposed Change

(Non-Proprietary)

## Enclosure 1

## NextEra Energy Seabrook's Evaluation of the Proposed Change

Subject: License Amendment Request 16-03, Revise Current Licensing Basis to Adopt a Methodology for the Analysis of Seismic Category I Structures With Concrete Affected by Alkali-Silica Reaction

Portions to be redacted are contained within red boxes.

The information to be redacted includes details of test programs that MPR conducted and results from the test programs. Release of this information would concede intellectual property. Release of this information would also constitute a loss of competitive advantage relative to others engaged in similar test programs or engaged in assessment of structural impacts of alkali-silica reaction.

Attachments:

1. Markup of UFSAR Pages

## 1.0 SUMMARY DESCRIPTION

License Amendment Request (LAR) 16-03 proposes to revise the Seabrook Updated Final Safety Analysis Report (UFSAR) to include methods for analyzing seismic Category I structures with concrete affected by an alkali-silica reaction (ASR). ASR is a chemical reaction that occurs in susceptible concrete that causes the concrete to expand in volume and potentially reduces the capacity of concrete structures. ASR has been identified in concrete structures at Seabrook Station. In addition to ASR's potential effects on the capacity of concrete structures, the expansion effects from ASR have imposed an additional static load that was not accounted for in their original design.

Seismic Category I structures other than the containment building were designed to the requirements of American Concrete Institute (ACI) 318-71 (Reference 1). The containment building is a reinforced concrete structure that is designed in accordance with the requirements of Section III of the American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel Code (1975 Edition) (Reference 2). ACI 318-71 and the ASME Code do not include provisions for the analysis of structures affected by ASR. The proposed amendment incorporates the effects of ASR in the design of seismic Category I structures at Seabrook Station.

NRC approval of this LAR will allow NextEra Energy Seabrook, LLC (NextEra) to proceed in an optimum, safe, and effective manner toward a long-term solution for ASR effects at Seabrook Station. The proposed methodology changes are necessary to reconcile the design basis of the containment building and other seismic Category I structures that are affected by ASR.

# 2.0 DETAILED DESCRIPTION

## *2.1 Background on ASR at Seabrook Station*

NextEra Energy initially identified pattern cracking typical of ASR in the B Electrical Tunnel in 2009, and subsequently, several other seismic Category I structures. As a result, multiple campaigns were completed to remove concrete cores from the walls in several plant structures to confirm the presence of ASR. Petrographic examination of the cores concluded the concrete had ASR. ASR is a reaction that occurs over time in concrete between alkalis in the cement and reactive non-crystalline silica, which is found in many common aggregates. The presence of water promotes ASR. The reaction produces an alkali-silicate gel that expands as it absorbs moisture. The expansion exerts a stress on the surrounding concrete and results in cracking.

A root cause investigation into the ASR at Seabrook concluded that the original concrete mix designs used a coarse aggregate that was susceptible to ASR. The concrete used at Seabrook Station was not expected to be susceptible to ASR due to the combination of measures taken to prevent it: (1) the coarse aggregate is igneous rock that passed the ASR reactivity testing used during construction; (2) low-alkali cement (<0.6% total alkali) was used; and (3) the aggregate passed petrographic examination per ASTM C295-65. The American Society for Testing and Materials (ASTM) standard test procedure ASTM C289-71 was used to assess aggregate reactivity during construction (Reference 3). ASTM C289-71 was an appropriate test at the time of construction, but it is now known that the test may not accurately predict the reactivity of slow-reacting aggregates, such as the aggregate used at Seabrook Station.[1] A combination of aggregate being more susceptible to ASR than originally thought and groundwater intrusion during plant life appears to have resulted in the observed ASR in several structures.

The expansion of concrete and cracking from ASR can potentially impact both the capacity (i.e., material properties) of a concrete structure and the demand (i.e., loads) on a structure.

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[1] The ASTM testing standard has since been revised to caution that the specified aggregate test is not effective in identifying slow-reacting aggregate, and other ASTM testing standards have been issued to more reliably identify concrete mixtures to minimize the susceptibility to ASR.

- ASR may affect the material properties of concrete (compressive strength, elastic modulus, tensile strength). The property most notably affected is the elastic modulus (Reference 4). However, the change in material properties does not necessarily result in a corresponding decrease in capacity of a reinforced concrete structure. ASR-induced expansion in reinforced concrete has a prestressing effect that mitigates the loss of structural capacity that would be assumed based on the change in material properties.

- ASR expansion can lead to deformation of a structure, and can cause stresses where the expansion is resisted internally by reinforcement or externally by supports, other structures, or adjoining parts of the same structure that are outside the ASR-affected region. The deformation is important from the perspective of the increase in load or demand on the structure and on the consequences of the deformation in relation to seismic isolation of structures and the impact on equipment and components.

### 2.1.1 Evaluation of ASR at Seabrook

An interim structural assessment was completed in 2012 which evaluated the structural adequacy of reinforced concrete structures at Seabrook Station affected by ASR and system/component anchorages in ASR-affected concrete (Reference 4). The evaluation concluded that the reinforced structures at Seabrook Station remain suitable for continued service for an interim period given the extent of ASR identified at that time. The evaluation noted that additional testing was required to verify that some structures satisfy ACI 318-71 code requirements for shear and reinforcement anchorage. The test programs would produce the data necessary to fully assess design compliance for the concrete structures at Seabrook Station. NextEra has since completed large-scale test programs (see Reference 25) and used the test results and literature to define guidance for evaluating ASR-affected reinforced concrete structures at Seabrook Station (see Reference 24). The conclusions from the testing and guidance for structural evaluations establish a method for analyzing ASR in reinforced concrete structures at Seabrook Station.

In 2014, a walkdown of a water leak in the Mechanical Penetration area of the West Pipe Chase noted that a vertical seismic gap seal between the Containment Enclosure Building (CEB) and the containment building was torn. NextEra concluded that the condition of the seal and other local evidence indicated that the damage to the seal appeared to be caused by relative building movement and not seal degradation, such as shrinkage or material deterioration. A subsequent evaluation of the condition determined that the seal damage was caused by radial deformation of the CEB. The CEB deformation was caused primarily by the expansion of concrete in the CEB and the backfill concrete that abuts the CEB structure below grade.

NextEra Energy has assessed ASR-affected concrete on Seabrook structures to determine impact on operability of system, structures, and components. Prompt Operability Determinations have been performed on affected structures which concluded that the structures and concrete anchors are operable but degraded, and structures, systems and components housed within the structures are operable. NextEra is currently evaluating all seismic Category I structures at Seabrook with indications of ASR to verify that structures continue to satisfy the ACI 318-71 and ASME Code acceptance criteria, as appropriate, with the additional demand from ASR concrete expansion. The proposed amendment will adopt a method to incorporate the material effects and loads of

ASR into the Seabrook design basis to demonstrate that structures with ASR continue to meet the design codes for original construction.

## 2.2 Proposed Changes to UFSAR

ACI 318-71 and the ASME Boiler and Pressure Vessel Code Section III, Division 2, Subsection CC are the codes used to design seismic Category I structures and the containment structure, respectively, at Seabrook Station. These codes do not include methods to address the effects of ASR on the structural properties used in the design of concrete structures. NextEra evaluated ASR material effects and concluded that no adjustments to structural properties are necessary when the extent of ASR is less than the limits from NextEra's large-scale test program. The analyses and testing to assess ASR material effects established a method to incorporate ASR into the Seabrook design basis that is not described in either ACI 318-71 or the ASME Code. Incorporating the loads into the UFSAR and evaluating structures using the appropriate properties for ASR affected structural members is a change in methodology that requires NRC review and approval. Details of the analysis and tests to evaluate the impact of ASR on structural properties are included in Section 3.2.

As indicated above, ACI 318-71 and the ASME Code do not specify how loads that arise from ASR expansion and structure deformation are evaluated. For structures designed to these codes, load factors are proposed to combine these loads with other design basis loads. The approach used to establish ASR load factors was consistent with the methods used to determine structural load factors for other loads described in ACI 318-71 and the ASME Code. The proposed method to evaluate ASR loads includes calculating the loads currently imposed on the structure and adding margin for future deformation. A description of the process for defining load factors and the proposed method to evaluate ASR loads in structures is included in Section 3.3.

UFSAR Section 3.8 includes the requirements for the design of Category I structures at Seabrook. Section 3.8.1 applies to the concrete containment building, and Section 3.8.4 applies to other seismic Category I structures. Changes are proposed to each of these subsections to incorporate the changes related to ASR material effects and loads. Additional changes to other subsections of the UFSAR are necessary for limits on anchors in concrete walls and slabs affected by ASR, a change to the method for combining seismic loads using an alternate approach recommended by the NRC in Regulatory Guide 1.92, Revision 3, and a change to allow the use of ANSYS computer software. The proposed changes to the specific subsections of the Seabrook UFSAR are described below and presented in Attachment 1.

### Proposed Changes to Section 3.8.1 Concrete Containment

- Section 3.8.1.3 of the UFSAR includes the loads and load combinations that were considered in the design of containment. The section is revised to define the load associated with ASR as Normal Startup, Operational, and Shutdown Loads.

- Section 3.8.1.4.e identifies transient and localized loads in the containment design procedure. This section is revised to define the load from ASR as a localized load.

- Section 3.8.1.4.i is revised to state that a tensile strain is imposed on reinforcement in areas affected by ASR. Also, analyses of ASR-affected concrete use the structural properties and code equations from the original design analyses when ASR expansion levels are below the limits defined in Section 3.8.4.7.
- Table 3.8-1 is revised to include the specific load combinations and load factors for analyses of ASR loads.

## Proposed Changes to Section 3.8.3 Containment Internals Concrete

- Section 3.8.3.3 of the UFSAR identifies the design loads and load combinations that were considered in the design of containment internals. The section is revised to define the load associated with ASR as Normal Startup, Operational, and Shutdown Loads
- Section 3.8.3.6 is revised to describe the effects of ASR and the relationship between the expansion of concrete from ASR and the deformation of structures.
- Section 3.8.3.7 is revised to include a discussion on the Structural Monitoring Program requirements for inspection of ASR affected structures.
- Table 3.8-14 is revised to include the specific load combinations and load factors for analyses of ASR loads.

## Proposed Changes to Section 3.8.4 Other Seismic Category I Structures

- Section 3.8.4.3 of the UFSAR specifies the design loads that were evaluated in the design of Category I structures other than containment. Subsection 3.8.4.3a.1(a) is revised to identify creep, shrinkage and swelling as dead loads on structures when ASR loads are evaluated. Subsection 3.8.4.3a.1(e) is added to define ASR reaction loads as passive loads that occur in conjunction with other Normal Startup, Operational, and Shutdown Loads.
- Section 3.8.4.3.c defines the other load considerations for seismic Category I structures other than containment. Subsection 3.8.4.3.c.1 is revised to indicate that creep is included in the analysis of structures with ASR. Subsection 3.8.4.3.c.3 is added to define self-straining loads as those associated with ASR expansion, creep, shrinkage and swelling.
- Section 3.8.4.4 includes the design and analysis procedures for Category I structures. Section 3.8.4.4.a is revised to describe the analysis procedure for evaluating the self-straining loads associated with ASR expansion, creep, shrinkage and swelling. Section 3.8.4.4.b is revised to specify the use of material properties in their normal range of values for structures with ASR.
- Section 3.8.4.6 is revised to describe the effects of ASR and the relationship between the expansion of concrete from ASR and the deformation of structures.

- Section 3.8.4.7 is revised to define limits for ASR expansion to ensure structural properties of reinforced structures with ASR are consistent with properties and code equations used in the original design of structures. Limits for structure deformation are classified and included in the Structural Monitoring Program.
- Table 3.8-16 is revised to specify the load factors and load combinations used in analyzing the effects of ASR.
- Table 3.8-17 is revised to identify the structures that have undergone a detailed analysis of ASR deformation which used ANSYS as the computer code for the analysis.
- Table 3.8-18 is added to establish limits for concrete expansion in areas affected by ASR.

**Other Proposed Changes to the UFSAR**

- Sections 1.8 and 3.7(B).2.1 are revised to indicate that seismic analysis results may be combined using the 100-40-40 procedure from Regulatory Guide 1.92, Revision 3 for analyses of ASR expansion loads.
- Section 3.9(B).3.4 is revised to include the limit on the allowable ASR expansion for concrete with embedded plates, anchors, and inserts that are used for component supports.

# 3.0 TECHNICAL EVALUATION

## *3.1 Seabrook Station Design Requirements*

### 3.1.1 Seismic Category I Structures Other Than Containment

Safety-related structures other than containment were designed and constructed to comply with the 1971 edition of ACI 318, *Building Code Requirements for Reinforced Concrete* (Reference 1) per the Seabrook Station UFSAR Section 3.8.4. The loads determined in accordance with ACI 318 include normal loads (startup, operation and shutdown), environmental loads (severe and extreme), abnormal loads, and site-related (i.e., site-specific) loads. The load combinations in UFSAR Table 3.8-16 define the required strength during normal and unusual loading conditions. The load combinations are determined in accordance with ACI 318. While ACI 318-71 contains provisions for Working Strength Design (WSD) and Ultimate Strength Design (USD), the Seabrook design methodology for safety-related structures other than containment is USD.

The selection of material properties for design of concrete structures at Seabrook Station is based on the standard concrete mix specification (including Containment and other safety-related structures) from original plant construction. ACI 318-71 recognizes the concrete mix specification as the primary location to specify the design concrete compressive strength. Other material properties for concrete design (i.e., elastic modulus) are calculated based on the specified concrete compressive strength. The specified compressive strength of concrete used in design is a value below the actual compressive strength, which is established by the concrete mix. The margin between the specified compressive strength value and the value expected from the concrete mix ensures there is a low probability of measuring a compressive strength value after construction below the specified strength value.

### *3.1.2* Containment Structure

The containment structure was designed and constructed to the 1975 edition of the ASME Boiler and Pressure Vessel Code Section III, Division 2, Subsection CC (Reference 2) as described in the Seabrook Station UFSAR Section 3.8.1. The applicable loads determined in accordance with Article CC-3000 of the ASME Code include test pressure loads, normal loads (startup, operation and shutdown), environmental loads (severe and extreme), and abnormal loads. Several site-related loads were considered in the design, but none had a significant effect on containment design. The applicable load combinations define the required strength of containment at various locations. The load combinations are listed in UFSAR Table 3.8-1 and were determined per ASME Code Section III, Article CC-3000. The load combinations reflect a combination of working strength WSD and USD methodology. Using WSD, stresses are computed based on the assumption of an elastic strain profile. In USD, a non-linear strain profile can be used, which models the behavior of concrete much more accurately. Using either WSD or USD, the containment structure must behave elastically to the specified load combinations when thermal effects are not included and satisfy the acceptance criteria in UFSAR Section 3.8.1.5. These criteria were developed to comply with the requirements in Article CC-3000 of the ASME Code, Section III.

A secondary stress is defined as a normal or shear stress developed by the constraint of adjacent material or by self-constraint of the structure. Expansion from ASR produces a secondary stress in the affected structure that is relieved by cracking. The ASME Code allows for higher stresses for peak, localized and secondary stresses. Local yielding, minor distortions, and concrete cracking are permitted for these self-limiting conditions, per Reference 2, Article CC-3136.4.

The ASME code limits the average tensile stress in steel reinforcing bars to 50% of the yield stress in WSD for service loads (normal) and 90% of the yield stress in USD for factored loads (severe and abnormal load conditions). The design acceptance criteria for reinforcement are enforced on an average basis and are not applicable to peak or localized stresses. These limits are also not applicable to secondary stresses. Specifically, local yielding, minor distortions, and concrete cracking are permitted in self-limiting conditions per Article CC-3136.4 of Section III of the ASME Code.

### 3.1.3 Concrete Anchors

Seabrook Station uses cast-in-place anchorages and post-installed anchors. The strength of the concrete in which an anchor is embedded must be sufficient to ensure the anchor is capable of sustaining loads equal to the ultimate loads specified by the anchor manufacturer. Cast in place anchors (e.g., Nelson studs or embedded unistrut-type channels) are designed with embedment depths such that the limiting failure mode is ductile failure of the anchor steel. Post-installed anchors are designed in accordance with the requirements of NRC IE Bulletin 79-02 (Reference 5). This includes using a safety factor of four on the mean failure load for the design of post-installed anchors for pipe supports.

## *3.2 Impact of ASR on Seabrook Structures*

NextEra evaluated the effects of ASR on the load carrying capability of structural members and its impact on other design considerations. The limit states correspond to the capacity associated with a specific mode of loading for structural members. The design considerations are related to other requirements that are specified in the design codes. Table 1 identifies each of the limit states and design considerations that were evaluated for ASR.

**Table 1. Potential Structural Consequences of ASR**

| Structural Limit States | Design Considerations |
|---|---|
| Flexure & reinforcement anchorage development<br>Shear<br>Compression<br>Anchor bolts and structural attachments to concrete | Reinforcement steel strain<br>Reinforcement fracture<br>Seismic response<br>Applicability of design basis material properties<br>Effect of structural deformation |

Each of the items in Table 1 were evaluated using data from structural testing of ASR-affected specimens. The evaluation considered data from large-scale test programs conducted specifically for Seabrook Station by MPR Associates in collaboration with the Ferguson Structural Engineering Laboratory (FSEL) at The University of Texas at Austin. In addition, the MPR/FSEL structural test data were supplemented with publicly available literature in the evaluation.

The large-scale test program and evaluation of available literature to assess the effects of ASR is consistent with methods recommended in ACI 318-71. ACI 318-71 is a Construction Code written in the context of new design and construction. Chapter 20 of the code, "Strength Evaluation of Existing Structures," includes an approach to address strength deficiencies from construction. Chapter 20 is not part of the licensing basis of Seabrook structures and was not used during original construction. Also, this LAR does not propose to incorporate Chapter 20 of ACI 318-71 into the Seabrook licensing basis. However, Chapter 20 provides some guidance for structural assessments performed to address concerns regarding the safety of a structure.

Paragraph 20.1 of ACI 318-71 states that "a structural strength investigation by analysis or by means of load tests or by a combination of these methods" may be used if the strength of a structure is unclear. Load testing of the as-built structures is impractical for the Seabrook Station ASR issue. Therefore, an analysis is the best available means of evaluating the impact of ASR on strength. The objective of a strength evaluation by analysis is to demonstrate that the building will have strength close to or in excess of that envisaged in the original design or as required by the code.

The shear and reinforcement anchorage testing at FSEL[2] used methods that are consistent with those used for the original ACI code testing. Also, the specimens that were used in testing were structurally representative of concrete used in constructing Seabrook structures. The testing at FSEL, evaluation of the test results along with other published literature on ASR, and the analysis method discussed in Section 3.3 are intended to satisfy the objective stated in ACI 318-71 to demonstrate that Seabrook structures with ASR have a strength in excess of code requirements.

On several occasions during testing, NRC inspectors from Region I and representatives from NRR have audited the activities at FSEL related to the large-scale test programs for ASR. The inspectors witnessed testing, verified compliance with procedures, evaluated adherence to quality assurance/control requirements and examined the newly fabricated instrument beam and associated monitoring devices. These activities were performed in support of the NRC staff's ongoing review of the Seabrook license renewal application and in anticipation of NextEra submitting a license amendment request to address an ASR-related non-conforming condition with the current licensing basis (i.e., this LAR). References 7 - 14 include the NRC observations and findings from inspections and audits of the large-scale test programs at FSEL.

### 3.2.1 Structural Limit States

The need for Seabrook-specific testing was driven by limitations in the publicly available test data related to ASR effects on structures. Most research on ASR has focused on the science and kinetics of ASR, rather than engineering research on structural implications. Although structural testing of ASR-affected test specimens has been performed, the application of the conclusions to a specific structure can be challenged by lack of representativeness in the data (e.g., small-scale specimens; poor test methods; different reinforcement configuration). The large-scale test programs undertaken by NextEra provided data on the limit states that were essential for evaluating seismic Category I structures at Seabrook Station. The data produced from these programs were a significant improvement from the data in published literature sources, because test data across the range of ASR levels were obtained using a common methodology and identical test specimens. The results were used to assess the structural limit states and to inform the assessment of design considerations.

The large-scale test programs included testing of specimens that reflected the characteristics of ASR-affected structures at Seabrook Station. Tests were completed at various levels of ASR cracking to assess the impact on selected limit states. The extent of ASR cracking in the test specimens was quantified by measuring the expansion in the in-plane and through-thickness specimen dimensions. The in-plane dimension refers to measurements taken in a plane parallel to the underlying reinforcement bars. There was no reinforcement in the test specimen through-thickness direction (perpendicular to the in-plane direction). ASR expansion measurements were monitored throughout testing. The test programs assessed all relevant limit states except compression (i.e., flexure and reinforcement anchorage, shear, and anchor bolts and structural attachments to concrete). The results of the test program demonstrated that none of the assessed limit states are reduced by ASR when ASR expansion levels in plant structures are below those evaluated in the large-scale test programs.

[2] Anchor testing was performed consistent with the methods used to demonstrate anchor strength per NRC IE Bulletin 79-02 (Reference 5), which is consistent with the Seabrook licensing basis.

The effect of ASR on compressive strength was not assessed in the large-scale test program. Reference 24 includes an evaluation of compression using existing data from published literature sources. The evaluation concluded that ASR expansion in reinforced concrete results in compressive load that should be combined with other loads in design calculations. However, ASR does not reduce the structural capacity of compression elements.

The specimens used in the large-scale test programs experienced levels of ASR that bound ASR levels currently found in Seabrook structures (i.e., are more severe than at Seabrook), but the number of available test specimens and nature of the testing prohibited testing out to ASR levels where there was a clear change in limit state capacity. Because there is no testing data for these more advanced levels of ASR, periodic monitoring of ASR at Seabrook is necessary to ensure that the conclusions of the large-scale test program remain valid and that the level of ASR does not exceed that considered under the test programs. Proposed UFSAR Table 3.8-18 includes limits to maintain the validity of the test program results for Seabrook structures.

The overall conclusion from analyses of structural limit states is that limit state capacity is not degraded when small amounts of ASR expansion are present in structures. Presently, the ASR expansion levels in Seabrook structures are below the levels at which limit state capacities are reduced. Reference 25 documents the results of the large-scale test program and includes additional details on the assessment of structural limit states.

One of the objectives of the test program was to identify effective methods for monitoring ASR. The program concluded that monitoring the in-plane and through-thickness expansion is effective for characterizing the significance of ASR in structures. A Combined Cracking Index (CCI) methodology based on crack width summation was shown to be effective for in-plane expansion monitoring. Snap ring borehole extensometers (SRBEs) provided accurate and reliable measurements for monitoring through-thickness expansion. Section 3.5 provides additional discussion of ASR monitoring and includes the quantitative limits for applying the conclusions from the test programs to Seabrook structures.

### 3.2.2 Design Considerations

The evaluation of design considerations in Reference 24 concluded that Seabrook structures affected by ASR should be evaluated for reinforcement strain and deformation. The effects of ASR on other design considerations listed in Table 1 (i.e., reinforcement fracture, seismic response, and design properties) were not significant for Seabrook structures (see Reference 24). The following summarizes the impact of ASR on design considerations.

**Reinforcement Steel Strain**

The expansion of concrete from ASR-induced cracking imposes a tensile strain on steel reinforcement within the affected material. For structures designed to ACI 318-71, the design code allows for reinforcement strains beyond the yield point of the steel bars for flexural elements to prevent brittle compression failure of the concrete in bending. The added strain to the reinforcement should be evaluated in conjunction with the strains imposed by other loads on the structure.

For the containment structure, the stresses and strains introduced into the reinforcement by ASR should be evaluated using provisions in the ASME Code for reinforcement yielding due to secondary stresses as well as those for local yielding. The original design code for the Seabrook containment building includes these provisions.

### Reinforcement Fracture

The reinforcement steel at Seabrook Station is not susceptible to brittle fracture because design codes do not permit rebar bending to the extent that would be required for susceptibility to rebar fracture. The additional strain introduced from the expansion effects of ASR is insufficient to strain reinforcement to the extent that fracture could occur.

### Seismic Response

The seismic response is a function of the natural frequency of the structure and the seismic demands acting upon the structure. The seismic demand for safety-related structures is the ground motion response spectra provided in UFSAR Section 2.5. The natural frequency of the structure is a function of the structural stiffness and mass. ASR does not change the mass of the structure, but changes in stiffness can affect a structure's natural frequency.

In general, the response of a structure to a seismic event is affected by the stiffness of structural members in flexure and shear, and their stiffness in response to axial loads. Flexural stiffness is the most sensitive to cracking. Modern design codes such as the 2011 version of ACI 318 allow the flexural stiffness of cracked beams and walls to be represented as a fraction of the nominal flexural rigidity in a linear analysis. Also, this version of ACI 318 does not specify any reduction factor for axial rigidity or any reduction factor for shear rigidity if the shear loads are less than the shear capacity. Therefore, the effects of ASR on the seismic performance of Category I structures were evaluated based on the effects of ASR on flexural stiffness alone.

The cracking caused by ASR reduces the stiffness properties of structural members relative to uncracked concrete sections. Large-scale testing performed by MPR and FSEL (see Reference 25) to investigate the impact of ASR on the stiffness of reinforced concrete members concluded that there is a slight reduction in flexural stiffness at low load levels but at higher loads up to the onset of flexural cracking the stiffness is increased. The increase in flexural stiffness of structural members caused by ASR is small compared to other uncertainties in the seismic analysis and is covered by peak broadening of the seismic spectrum in the UFSAR. The potential change in stiffness is small and bounded by the current seismic analysis. Therefore, the seismic analysis results for Seabrook structures are unaffected by the small stiffness changes from ASR.

### Applicability of Design Basis Material Properties

Although ASR changes the compressive strength, elastic modulus, and tensile strength of unreinforced concrete, the MPR/FSEL large-scale test program results showed that the change in material properties does not have an adverse effect on structural performance when through-thickness expansion levels are low, as is the case at Seabrook. The results demonstrated that the performance of reinforced concrete structures should not be evaluated for ASR simply by adjusting the concrete material properties. Analyses of ASR-affected structures should use the structural properties from the original design analyses of Seabrook structures.

### Effect of Structural Deformation

Loads can be generated when ASR expansion occurs in a structural element with free expansion of the structure restrained. The loads must be addressed on a case-by-case basis because they are dependent on the geometry of the structure, the location(s) where expansion is restrained, and the extent of ASR in the affected structure. The approach for evaluating structure deformation using the provisions of the original design codes is described in Section 3.3.

### 3.2.3 Summary of ASR Implications for Seabrook Structures

The design codes used for Seabrook seismic Category I structures include methodologies to calculate structural capacities for the various limit states and loading conditions. The evaluation of each relevant limit state using published literature and the results of MPR/FSEL test programs concluded that structural capacity adjustments are unnecessary when ASR expansion levels are below the limits established in the assessment (see Reference 24). The effects of ASR on Seabrook Station structures can be evaluated by incorporating the load associated with ASR concrete expansion and analyzing structures using the properties specified in the original design with the equations of the construction code.

Reference 25 contains a detailed discussion of the test programs and the literature review that supported development of the test approach. Reference 24 incorporates the results of test programs and other studies to assess the effects of ASR on the structural design basis of affected concrete structures at Seabrook Station. These two reports provide the basis for the conclusions regarding the impact of ASR on structural limit states and design considerations for Seabrook structures. Table 2 and Table 3 summarize the results of these assessments. The limits for monitoring structures to ensure that the conclusions remain valid are discussed in Section 3.5

### Table 2. Effect of ASR on Structural Limit States

| Structural Design Issue | Conclusion | Basis | Recommendation |
|---|---|---|---|
| Flexure & reinforcement anchorage | There is no adverse impact on flexural capacity and reinforcement anchorage performance for through-thickness expansion levels up to [redacted]%. | Results from MPR/FSEL testing of specimens indicate no loss of flexural capacity. There was also no observed reduction in reinforcement anchorage for the levels of ASR in the MPR/FSEL test specimens. | Periodically verify that ASR expansion levels in the through-thickness direction are less than [redacted]%. |
| Shear | Shear capacity is not affected by ASR, provided that through-thickness expansion from ASR is at or below [redacted]% and expansion behavior is comparable to the test specimens (i.e., in-plane expansion has plateaued at a low level and through-thickness expansion dominates). | Results from the MPR/FSEL tests showed no loss in shear capacity due to the presence of ASR. The test specimens were more representative of Seabrook Station than published literature because of specimen scale effects in published data. | Periodically verify that ASR expansion levels in the through-thickness direction are less than [redacted]%. |
| Compression | Structural evaluations must account for the compression loading caused by ASR (i.e., "chemical pre-stressing") and combine this load with other external loads to assess compressive load capacity. This effect applies only to loads applied in reinforced directions. The compression zones of structural members in flexure also should be considered. | The expansion of concrete from ASR increases the compressive stress in the concrete. The additional compressive stresses reduce the capacity of compression elements to react to external loads. | Calculate the loads imposed on the structure from ASR concrete expansion and analyze the loads with other applied loads to the structure. |
| Anchor bolts and structural attachments | There is no adverse effect to anchor/embedment capacity when in-plane expansion (i.e., in reinforcement plane) from ASR is at or below [redacted]%. | Testing by MPR/FSEL to determine the tensile capacity of anchors in ASR-affected concrete showed no loss of tensile performance for anchors in concrete with up to [redacted]% in-plane expansion. | Periodically verify that ASR expansion of concrete with anchors is less than [redacted]% in the in-plane directions. |

### Table 3. Structural Design Considerations for ASR Effects

| Structural Design Issue | Conclusion | Basis | Recommendation |
|---|---|---|---|
| Reinforcement steel strain | Reinforcement strain from the effects of ASR expansion should be evaluated in accordance with the applicable design codes. | The expansion of concrete caused by ASR cracking results in tensile strain of the embedded steel reinforcement, while placing the concrete in compression. | The tensile strain should be calculated and evaluated with other applied loads to the structure. |
| Reinforcement fracture | The reinforcement steel at Seabrook Station is not susceptible to brittle fracture due to ASR-induced expansion. | Seabrook Station was designed in accordance with codes that do not permit rebar bending to the extent that would be required for susceptibility to rebar fracture. Additionally, quality requirements in effect during original construction at Seabrook would have prevented the poor construction practices that resulted in the observed rebar fractures elsewhere. | Monitoring and evaluation of reinforcement fracture is not necessary. |
| Seismic response | ASR affects the flexural stiffness of structural members, but the impact on Seabrook structures is bounded by the current seismic analysis. The current seismic analysis results for Seabrook structures are unaffected by the small stiffness changes from ASR. | The seismic response of a structure is affected by the stiffness of structural members in flexure and shear, and their stiffness in response to axial loads. The flexural stiffness is most sensitive to cracking. Large-scale testing demonstrated that the change in flexural stiffness of structural members affected by ASR cracking is small and does not affect the out-of-plane seismic response of structures. The structures at Seabrook Station primarily resist lateral loads using shear walls. The change in shear stiffness caused by ASR cracking is small relative to the impact of ASR on flexural properties. | Periodically verify that ASR expansion levels are less than [redacted]% to ensure conclusions on flexure properties are satisfied. |

**Table 3. Structural Design Considerations for ASR Effects**

| Structural Design Issue | Conclusion | Basis | Recommendation |
|---|---|---|---|
| Material properties | Using the material properties that were used in the original design of Seabrook structures is appropriate and conservative. | The MPR/FSEL test programs confirmed that the elastic modulus and strength of unreinforced concrete cores with ASR is reduced, but the strength of test specimens with ASR is consistent with that calculated using the original measured concrete compressive strength rather than the reduced strength measured from extracted cores with ASR. Hence, limited amounts of ASR did not have an adverse effect on the capacity of reinforced structural members. | Periodically verify that ASR expansion levels are less than [redacted]% to ensure structural limit state conclusions are valid. |
| Structural deformation | Loads caused by ASR expansion require evaluation on a case-by-case basis. | Structure deformation results in an additional load when the expansion of ASR-affected concrete is resisted by another structure or structural member or is restrained by concrete outside the ASR-affected region of a structure. Deformation loads should be included with other loads used in the design of a structure to verify that acceptance criteria are satisfied. Section 3.3 discusses the methods for analysis of structure deformation loads. | Quantify loads imposed by deformation of structures from ASR and evaluate with other applied loads to the structure. |

### *3.3 Building Deformation Assessment*

The evaluation of design considerations concluded that external loads can be imposed on structures when ASR expansion is restrained. Unlike the evaluation of the structural limit states and several of the design considerations given in Table 1, structure deformation loads must be analyzed on a case-by-case basis. Once the deformation is quantified and the loads calculated, the methods in the original design codes are used to evaluate whether acceptance criteria are satisfied. This section discusses the approach of evaluating structure deformation loads that arise from ASR expansion.

The original design calculations for Seabrook structures consider the factored load combinations listed in UFSAR Table 3.8-1 (containment) and Table 3.8-16 (other seismic Category I structures). These load combinations do not include self-straining loads. ASR expansion is one of the so-called "self-straining" behaviors that affect concrete; others are swelling, creep, and shrinkage. Inspections of structures at Seabrook have noted relative building movements, equipment misalignments, and concrete cracking which indicate the presence of self-straining mechanisms such as ASR. A Root Cause Evaluation of deformation measured for the Containment Enclosure Building (CEB) has concluded that ASR is the cause of localized structural deformations (Reference 6).

ASR expansion can lead to movement or deformation of a structure such as that observed for the CEB and affects the width of seismic gaps. In reinforced concrete sections, the concrete expansion is resisted by tension in the steel reinforcing bars, which leads to compression in concrete. A load arises when the expansion of ASR-affected concrete is resisted by another structure or the deformation is restrained by concrete outside the ASR-affected region of a structure. Building deformation caused by ASR results in additional stresses on the structure that were not considered in the original design analyses. The self-straining loads caused by ASR expansion are added to the other loads that are considered in the design of Seabrook structures.

The concrete fill at Seabrook is unreinforced and similarly susceptible to ASR as concrete structures at the site. Expansion of the concrete fill is resisted only by its boundary (i.e., bedrock and the adjacent structures). ASR expansion of concrete fill can potentially apply an external load on an adjacent structure. ASR expansion of the fill may cause the fill to come into contact with structure which imposes a pressure on the rigid buried structural walls. When the concrete fill is not confined by another structure vertically, the maximum pressure is limited by the overburden pressure on the concrete fill.

Swelling of concrete that is in contact with water for a long period of time results in a stress behavior in reinforced concrete similar to that for ASR expansion. Shrinkage and creep could decrease the tension of the reinforcement bars which could relieve some of the demands due to other design loads. Creep is a time-dependent strain in hardened concrete under sustained load. The mechanism occurs relatively early in the structure's life and does not change significantly over time. Shrinkage is caused by a reduction in concrete volume as water not consumed by cement hydration leaves the system. Analyses of ASR and these other effects (creep, shrinkage, and swelling) indicate that ASR expansion is the largest contributor of the self-straining behaviors active at Seabrook Station. However, all of these self-straining mechanisms can contribute to the observed deformations, so it is necessary to evaluate all simultaneously in the evaluation process. Self-straining behaviors were not included in the original design analyses either because they were deemed insignificant or because they were not known during the design process (i.e., ASR). Demands (forces and moments) caused by creep and shrinkage are conservatively neglected in cases where they reduce the overall demand from ASR. However, deformations due to creep and shrinkage are included in order to make comparisons with field measurements of deformation.

The deformation of structures changes the clearances between structures and equipment contained within the structure. Clearances in penetrations through structural members are also affected. Supports attached to a structure may also move with the structure and alter the loads on components. NextEra has completed walkdowns local to the Containment Enclosure Building to verify that structure-to-structure (Reference 6) and structure-to-component (Reference 16) clearances are adequate to ensure seismic isolation is achieved. The effects of structure deformation on plant equipment and seismic gaps will be managed through the Corrective Action Program based on input from the Structural Monitoring Program. The Structural Monitoring Program is discussed below.

The Corrective Action Program will require that changes in component clearances caused by deformation be evaluated for the impact on the equipment. Adverse effects caused by reduced clearances or the movement of supports and equipment will be corrected or evaluated to ensure the additional load on components is acceptable.

### 3.3.1 Design Material Properties

The structure deformation analyses will use the structural properties that were used in the original design analysis of the structures based on the results in Section 3.2 above.

### 3.3.2 Evaluation of Self-Straining Loads and Deformations for Seismic Category I Structures other than Containment

The license amendment proposes a method to evaluate each of the seismic Category I structures listed in UFSAR Section 3.8.4.1 to assess the impact of self-straining loads on the design of the structures other than containment. The original design loads listed in UFSAR Table 3.8-16 will be combined with the self-straining loads from ASR expansion, creep, shrinkage, and swelling. The impact of self-straining loads on seismic gaps will be evaluated at each stage of analysis.

A three-stage process would be used for analyzing structures. Each stage of the analysis applies more sophisticated methods and uses additional field data to improve the accuracy of the results.

- Stage One –Screening Evaluation: Each of the seismic Category I structures are screened for susceptibility to structural deformation caused by ASR using existing field data and conservative calculations.

- Stage Two – Analytical Evaluation: An analytical evaluation is performed for structures that the Stage One Screening Evaluation identifies as susceptible to deformation but do not satisfy ACI 318-71 acceptance criteria. A finite element model of the structure is used to estimate structural demands due to self-straining loads, while all other demands are taken from existing design calculations. Additional field data are obtained to use in the analysis. The evaluation verifies compliance with ACI 318-71 using the same criteria as the original design.

- Stage Three – Detailed Evaluation: A detailed design confirmation calculation is performed when the Stage Two Analytical Evaluation concludes that some area of a structure does not satisfy ACI 318-71 acceptance criteria or when the structure has sufficient deformation that may impact demands computed in the original design. The detailed evaluation uses the Stage Two finite element model to compute demands due to self-straining loads as well as all other design loads. In the Stage Three evaluation, consideration is given to cracked section properties, self-limiting secondary stresses, and the redistribution of structural demands when sufficient ductility is available.

All three stages of the evaluation process use the original design acceptance criteria given in the UFSAR including separation of structures by seismic gaps. Each analysis stage will determine threshold monitoring limits to define the criteria for re-evaluating structures with deformation. The threshold monitoring limits are specific to each structure and will be included in the Structural Monitoring Program. Section 3.5 discusses monitoring and acceptance criteria for ASR cracking and deformation of structures.

### Stage One: Screening Evaluation

NextEra has conducted walkdowns of structures and plant equipment to identify items of interest and evaluate the items through the Corrective Action Program for their impact on plant operations. Inspection data from these walkdowns and other measurements obtained for ASR-affected structures will be reviewed to identify potential locations and directions of movement or deformation. This existing data includes measurements of relative building movements, equipment misalignments, and concrete cracking indexes. ASR monitoring grids, which are used to measure the strain in reinforced concrete, were installed throughout the facility. The monitoring grids were installed at the most severe locations for ASR cracking, and therefore, provide a conservative estimate of the strain in the structure. After reviewing existing field data, a walkthrough inspection will be performed in the screening evaluation process to verify field conditions and determine if ASR expansion only affected localized regions of the structure or whether the structure has experienced global deformation of structural members.

In the Stage I screening process, conservative estimates of deformations and strains based on the field data are used to estimate demands caused by self-straining loads for critical locations in the structure. Self-straining loads include four components: ASR, creep, shrinkage, and swelling. Based on guidance in ACI 318-71, creep, shrinkage and swelling are included with the dead load. The ASR demands (identified as "$S_a$" herein) are factored as described in Section 3.3.4 and then combined with demands due to design loads for the load combinations in UFSAR Table

3.8-16. An evaluation is performed using strength acceptance criteria in ACI 318-71 for reinforced concrete consistent with UFSAR Section 3.8.4.5.

For screening evaluations that conclude a structure fully complies with the strength acceptance criteria, the critical locations of the structure are re-evaluated for a higher level of ASR demand to determine the maximum allowable, factored self-straining loads at which the structure meets the design acceptance criteria. A set of monitoring elements (consisting of strain measurements, deformation measurements, seismic gap measurements, and/or other quantifiable behaviors) is established along with threshold limits for each monitoring element. The threshold limits are defined as the maximum measurement for each monitoring element that results in a factored self-straining load equal to the factored self-straining load at the structural design limit (with factored design basis loads included). The threshold limit for the monitoring elements defined in Stage One is equal to the set of monitoring element measurements that produce a factored ASR demand that is 90% of the factored self-straining load at the acceptance limit. If a structure monitoring element measurement obtained from walkdowns and other monitoring activities exceeds the monitoring threshold limit, then a Stage Two Analytical Evaluation is required.

A structure is classified as Stage 1 if the Screening Evaluation concludes that the structure satisfies the strength acceptance criteria and the structure monitoring element measurements are less than the Stage One threshold limits. The Screening Evaluation for Stage 1 structures is summarized in a calculation package that supplements the original design calculation. The calculation package also documents the set of monitoring measurements and the threshold limits for the monitoring process. The monitoring measurements and the threshold limits are incorporated into the Seabrook Structural Monitoring Program to periodically assess the condition of structures and verify that the structure meets the design acceptance criteria.

### Stage Two: Analytical Evaluation

For structures that cannot be shown to meet the ACI 318-71 acceptance criteria using the conservative methods of the Screening Evaluation or monitoring measurements indicate high $S_a$ demands, an Analytical Evaluation is required. The Analytical Evaluation uses more accurate methods to quantify demands due to self-straining loads. Also, additional inspections are performed to measure structural strains and deformations at a broader range of critical locations on the structure. These measurements would be used to compute the self-straining loads with more accuracy than possible using the inputs from the Stage One Screening Evaluation process.

An ANSYS finite element model (FEM) of the structure is created based on design drawings and uncracked design section properties. The model is initially benchmarked to the original design analysis of the structure with only the current licensing basis loads. The FEM is then calibrated such that the deformations and strains due to unfactored sustained loads and self-straining loads are consistent with field measurements. The FEM is used to compute the structural demands due to ASR loads ($S_a$). The self-restraining demands from the finite element analysis are then factored as described in Section 3.3.4 and combined with demands due to factored design loads from the original design calculations for the load combinations in UFSAR Table 3.8-16. The structural demand in critical regions of the structure is evaluated using strength acceptance criteria in ACI 318-71 for reinforced concrete consistent with UFSAR Section 3.8.4.5. The methods used for the Stage Two analysis are unchanged from the original design analyses with the exception of accounting for the self-straining loads in the analysis and the use of the ANSYS software program for computing the sustained and self-straining loads.

Structures that satisfy the Analytical Evaluation acceptance criteria are re-evaluated for a higher level of $S_a$ to compute the maximum allowable self-straining loads on the structure. The maximum allowable loads correspond to the maximum, factored self-straining loads at which the structure meets the design acceptance criteria. A set of monitoring measurements are identified and threshold limits are set for each measurement based on the maximum allowable self-straining load. The threshold limits for each monitoring element defined in Stage Two are determined by scaling all measurements proportionally such that a factored self-restraining demand equal to 95% of the value at the design acceptance limit is achieved.

A structure is classified as Stage 2 if the Analytical Evaluation concludes that the structure satisfies the strength acceptance criteria and the structure monitoring element measurements are less than the Stage Two threshold limits. The Analytical Evaluation calculation for Stage 2 structures supplements the original design calculation. The monitoring measurements, measuring locations, and threshold limits for monitoring are also included in the supplement to the calculation. The monitoring measurements and the threshold limits are incorporated into the Seabrook Structural Monitoring Program to periodically assess the condition of structures and verify that the structure continues to satisfy the design acceptance criteria.

**Stage Three: Detailed Evaluation**

Structures that do not meet the acceptance criteria of the Stage Two Analytical Evaluation are analyzed by a Detailed Evaluation. In the Detailed Evaluation, $S_a$ demands and the loads from creep, shrinkage and swelling are recomputed using the Stage Two FEM. Structural demands due to design loads are recomputed by applying design demands (i.e. wind, seismic, hydrostatic pressure, etc.) to the FEM. A detailed structural evaluation is performed for all load combinations listed in UFSAR Table 3.8-16. The structure is evaluated using strength acceptance criteria in ACI 318-71 for reinforced concrete consistent with UFSAR Section 3.8.4.5. In the Stage Three evaluation, consideration is given to cracked section properties, self-limiting secondary stresses, and the redistribution of structural demands when sufficient ductility is available. The 100-40-40 percent rule in NRC Regulatory Guide 1.92, Revision 3, is used as an alternative to the SRSS method for combining three directional seismic loading in the analysis of structures that are deformed by the effects of ASR.

Structures that meet the acceptance criteria of the Detailed Evaluation are classified as Stage 3 and are re-evaluated for a higher level of self-straining load to establish the threshold limits for each monitoring element measurement. A similar process is used as described in the Stage Two Analytical Evaluation above. The threshold limit for each monitoring element defined in Stage 3 is equal to the limit for the monitoring element measurement that produces a factored $S_a$ load at the design acceptance limit.

The Detailed Evaluation is summarized in a design calculation package that will supersede the original design calculation. The calculation package documents the set of monitoring measurements and the threshold limits of each monitoring measurement. The monitoring elements and their threshold limits are included in the Structural monitoring program to periodically verify that the structure continues to meet the design acceptance criteria.

### 3.3.3 Evaluation of Self-Straining Loads and Deformations for Containment Building

The conditions and structural configuration of the containment building are unique relative to the other seismic Category I structures at Seabrook Station, and make it less susceptible to deleterious effects of ASR. Evaluation of Self Straining Loads and Deformation for Containment will be performed using the three stage process discussed in Section 3.3.2. The containment building will be evaluated at critical locations using the acceptance criteria in the ASME Boiler and Pressure Vessel Code as specified in UFSAR Section 3.8.1.5. Because of the unique design and for the reasons discussed below it is expected Containment will be screened as at a Stage 1 evaluation.

The containment building is located within the Containment Enclosure Building that protects the structure from loads due to outside weather (such as wind, snow, and rain), but also from potential loads due to ASR expansion of concrete fill on the containment cylinder. The containment structure consists of a mat and a cylinder that is topped by a spherical dome similar to the enclosure building. The containment building has two access hatchways and a number of piping penetrations; however, these penetrations are strengthened with robust reinforced concrete detailing. Finally, the reinforcement detailing for the containment building (heavily reinforced; regions with tri-axial reinforcement) limit ASR expansion and the structural implications of ASR.

Creep, shrinkage, and swelling have a negligible impact on the containment building, which is consistent with original design calculations. This is based on the robust reinforced concrete detailing used in the containment building that also has a continuous foundation and is protected from exterior weather. In addition, the containment building does not have large openings at the base, as is the case with the CEB, which would enhance the susceptibility to these time-dependent deformation mechanisms.

There are limited localized ASR locations on the exterior surface of the containment building cylinder with closely spaced pattern cracking and some regions of widely-spaced pattern cracks indicative of lower levels of ASR based on available field inspections and crack indexing measurements. A confirmatory visual walk-down inspection of the building exterior wall will be performed to further characterize the extent of ASR degradation. The inspection will be followed by a calculation to conservatively analyze the force and moment demands in the containment building wall due to the localized strain measurements from available expansion measurements. The force and moment demands due to ASR are added to the corresponding demands in the original design calculation for critical load combinations to estimate total demands.

The containment building will then be re-evaluated for a higher level of ASR strain to establish a threshold at which the structure still meets the design acceptance criteria. A set of monitoring measurement locations will be established along with threshold limits for each monitoring element. The monitoring requirements will be included in the Structural Monitoring Program to periodically verify that the containment building expansion behavior responses are within the limits of the ASR evaluation.

### 3.3.4 Factored Self-Straining Loads

The factored load combinations listed in UFSAR Table 3.8-16 are used for the design of seismic Category I structures at Seabrook other than the concrete containment building. The self-straining loads consist of four load types; shrinkage, creep, swelling, and ASR ($S_a$) which are not used in the original design calculations. The factored self-straining loads are combined with the original design load combination for the screening and analytical evaluations discussed above. The load factors for dead load are used for the shrinkage, creep, and swelling loads in accordance to ACI 318-71 Section 9.3.7. As discussed in Reference 23, the load factors applied to ASR loads ($S_a$) are developed to yield reliability index values similar to load factors specified in ACI 318-71 (Reference 17). The ASR load factors account for the uncertainty in ASR expansion by considering the variability in crack index measurements from all ASR monitoring grids in Seabrook Station structures. For unusual load combinations, such as SSE and tornado wind combinations, all load factors are taken as 1.0, including the factor for ASR loads, which is consistent with the method presently used in the UFSAR.

Reliability index is a parameter that accounts for uncertainties in demands and resistance. Load combinations in design codes generally use target reliability indices of 3.0, 2.5, and 1.75 for static, wind, and seismic (OBE) combinations, respectively (Reference 18).

The variability of ASR-related demands at Seabrook Station is based on 216 crack index measurements associated with the two axes of 108 plant-wide ASR monitoring grids. Expansion measurements from the large-scale test programs have shown that crack index provides a reasonable and conservative approximation of true engineering strain for reinforced concrete members undergoing ASR expansion. The dataset of the 216 crack index measurements is fit to probabilistic distributions for calculating ASR load factors.

### 3.3.5 Evaluation of Containment Enclosure Building

Analyses of Seabrook Station structures for ASR deformation are ongoing. The CEB was evaluated for deformation using the process described in Section 3.3.2 (reference 26). This evaluation is described as an example of a Stage 3 implementation of the methodology described above. The deformed shape of the CEB model, when subjected to sustained loads and self-straining loads, simulates field measurements of deformations. The CEB meets evaluation criteria of ACI 318-71 for all factored load combinations and analysis cases analyzed when ASR loads are amplified by a threshold factor of 1.2 to account for future ASR expansion. The as-deformed condition does not significantly impact the dynamic properties of the structure, and therefore the maximum seismic acceleration profiles for OBE and SSE excitation used in original design of the CEB remain valid.

### 3.4 Summary of ASR and Structure Deformation Methodology Changes

The analyses, evaluations, and acceptance criteria used in the screening and analyses of structure deformation are consistent with the methods described in the UFSAR except for the following:

- The effects of ASR can be evaluated by incorporating the load associated with ASR concrete expansion and analyzing structures using the properties specified in the original design with the equations of the construction code when ASR expansion is less than the limits established in Reference 24.

- ASR expansion loads were not considered in the UFSAR. The load factors associated with ASR loads for different load combinations are developed for the current evaluations. Incorporating the load from ASR expansion adds to the current design loads and reduces the original calculated design margin of each structure while meeting the intent of the codes of record.

- Creep, shrinkage, and swelling loads are considered to be insignificant in the UFSAR. These loads are considered in the evaluations of structures other than containment. Including these loads is necessary to accurately estimate the total load due to deformation based on the existing deformed shape of each structure.

- ANSYS Mechanical APDL Version 15.0 is used for the Analytical and Detailed Evaluations of seismic Category I structures with deformation. Although a different version of ANSYS was used in the dynamic and static analyses of seismic Category I code and non-code items, this computer software was not used in the original design calculations for Seabrook structures. ANSYS has been used for design analyses of seismic structures at other nuclear plants (e.g., Vogtle 3 and 4 and VC Summer 2 and 3).

- Detailed Evaluations of the loads caused by ASR may combine the orthogonal spatial components of seismic loads using the 100-40-40 procedure in accordance to Regulatory Guide 1.92 Revision 3. The current UFSAR specifies that only the square-root-of sum-of squares (SRSS) procedure is used to combine spatial components.

### 3.5 Monitoring

All seismic Category I structures at Seabrook Station are monitored under the Structural Monitoring Program (SMP). The SMP provides guidance for meeting the requirements of 10CFR50.65, the Maintenance Rule. The program provides a systematic approach for evaluating plant structures to provide assurance that structures are capable of fulfilling their intended function. NextEra has implemented a number of enhancements to the SMP to monitor the progression of ASR. The monitoring actions incorporated into the SMP are consistent with currently available industry practices (Reference 8). The SMP currently includes provisions for detection and monitoring of ASR degradation in plant structures. Monitoring of ASR is performed through periodic measurement of ASR expansion and periodic inspections of ASR-affected structures to identify and trend building deformation.

### 3.5.1 ASR Expansion

Expansion monitoring includes determination and trending of in-plane expansion and through-thickness (i.e., out-of-plane) expansion. These data track the progression of ASR in plant structures. Monitoring of building deformation includes measurement of seismic gaps and other key dimensions to identify and trend building deformation, and inspections to identify the impact of building deformation on plant components. The monitoring elements for deformation and the acceptance criteria are determined from the building deformation analyses described in Section 3.3 above and are specific to each structure. The structure-specific deformation criteria ensure code acceptance criteria are satisfied.

Although ASR-induced expansion can occur in all directions, expansion may not be equal in all directions depending on the confinement provided by steel reinforcement, loads (e.g., deadweight), and building configuration. NextEra has monitored in-plane expansion of ASR-affected structures using the Combined Cracking Index (CCI). CCI is measured by overlaying a grid onto areas with ASR and measuring the crack widths that intersect the horizontal and vertical lines of a grid. CCI is equal to the sum of the all crack widths divided by the cumulative length of the grid lines (millimeters/meter). CCI has been successfully used as an indicator of relative area expansions on Seabrook structures for several years. There are other methods for measuring in-plane expansion caused by ASR cracking, but CCI is method that provides the total in-plane expansion that has occurred since ASR cracking initiated. Viable alternate methods that were evaluated are relative in that they rely on calculating differences between repeated measurements.

NextEra is installing extensometers for measuring through-thickness expansion of plant structures. The extensometer is installed in a borehole that is perpendicular to the face of the wall (or slab). The instrument consists of two anchors and a rod. The rod is attached to the anchor installed deep in the borehole and slides through a hole in the anchor installed near the surface. Expansion is monitored by measuring the distance between the end of rod and the reference surface on the anchor near the surface. The extensometer being installed is a snap-ring borehole extensometer. It was selected because it was shown to be accurate and reliable in the MPR/FSEL testing.

Extensometers provide a relative measurement of the expansion because the readings show the increase in expansion relative to the time it was installed. The measured expansion needs to be combined with the expansion that occurred up to the time of instrument installation to yield the total through-thickness expansion to a given time. NextEra will use an empirical correlation developed in the large-scale test program to correlate concrete elastic modulus measurements with the through-thickness expansion to date (Reference 20).

The conclusions from NextEra's evaluation of the effects of ASR on structural limit states and other design considerations is predicated on maintaining ASR expansion levels below the limits described in Reference 24. The ASR expansion limits for structural limit states are summarized in Table 4. Maintaining these limits is assured by periodically measuring through-thickness expansion in areas affected by ASR. This LAR proposes to include the limits for ASR expansion in the Seabrook UFSAR as Table 3.8-18. UFSAR Section 3.8.4.7 is also revised to discuss the limits for ASR expansion and reference the SMP for periodic inspections of ASR and limits on structure deformation. Although the expansion limit for flexure and reinforcement anchorage from the large-scale test programs is [redacted]%, the lower value of [redacted]% for shear is included in the UFSAR and the SMP for these limit states.

**Table 4. ASR Expansion Limits For Structural Limit States**

| Structural Limit State | ASR Expansion Limit |
|---|---|
| Shear | [redacted]% through-thickness |
| Flexure | [redacted]% through-thickness |
| Reinforcement Anchorage | [redacted]% through-thickness |
| Anchors | [redacted]% in-plane |

ASR expansion limits for seismic design considerations discussed in Section 3.2.2 are maintained by satisfying the expansion limits in Table 4. The additional strain in reinforcement and axial compression in concrete are evaluated by analyzing ASR expansion loads with other design loads on ASR-affected structures. Additional discussion on limits for rebar strain and axial compression is included in Section 3.5.2.

The SMP also includes the monitoring frequencies for inspecting areas with ASR. Regions of structures with signs of ASR are classified based on the total ASR expansion to date. Structures with higher levels of ASR expansion are inspected more frequently than structures with minimal ASR expansion. The criteria for classifying structures based on ASR expansion are included in Table 5. The SMP requires installation of extensometers in the ASR affected locations that are classified as Tier 3.

**Table 5. ASR Expansion Acceptance Criteria and Condition Monitoring Frequencies**

| Tier | Recommendation from Inspection | In-Plane Expansion | Inspection Frequency |
|---|---|---|---|
| 1 | Routine inspection in accordance with SMP | NA* | As prescribed in the SMP |
| 2 | Qualitative monitoring | Areas with pattern cracking that cannot be accurately measured | 30 months |
|  | Quantitative monitoring and trending | 0.05% |  |
| 3 | Structural evaluation and implement enhanced ASR monitoring | 0.1% | 6 months |

* No indications of pattern cracking or water ingress.

The testing at FSEL demonstrated that anchor capacity is maintained for relatively high in-plane expansion levels that could only exist in structures classified as Tier 3 for ASR cracking. Tier 3 structures are inspected on a six month frequency which would ensure timely detection of any changes in ASR cracking that could potentially challenge anchor performance.

Current in-plane expansion levels in ASR-affected areas at Seabrook are well below the limits where anchor capacity may be reduced (Reference 21). Also, the expansion behavior observed in reinforced test specimens at FSEL suggests that in-plane expansion is unlikely to achieve levels where anchors are affected. Periodic monitoring of in-plane expansion in accordance with the frequencies in Table 5 will ensure that NextEra can take appropriate action before expansion reaches the ASR expansion criteria in Table 4.

### 3.5.2 Structure Deformation

The SMP also includes the requirements for monitoring Seabrook structures with measureable deformation. Structures with ASR are initially screened for deformation using the process described in Section 3.3. The process will classify affected structures into one of three categories: (1) structures with minimal amounts of deformation that do not affect the structural capacity as determined in the original design analysis; (2) structures with elevated levels of deformation that are shown to be acceptable using FEA and still meet the original design basis requirements when ASR effects are included; and (3) structures with significant deformation that are analyzed and shown to meet the requirements of the code of record using the methods described herein.

The deformation evaluation process described in Section 3.3.2 will establish threshold monitoring limits for ASR-affected structures. The process identifies the specific set of monitoring elements used to quantify deformation for each structure. Monitoring elements will include a combination of strain measurements, measurements of the relative deformation between structures, and other quantifiable behaviors. The threshold limits are defined as the maximum allowable measurement for each monitoring element that limits the self-straining loads to some fraction of the maximum allowable self-straining load.

The structure deformation evaluation process will classify affected structures into one of three categories, Stage 1, Stage 2, or Stage 3, based on the analysis necessary to demonstrate compliance with ACI 318-71 (or the ASME Code for containment). This approach is consistent with guidance in ACI 349.3R-1996 used to establish the inspection criteria for other degradation mechanisms in the SMP. The Stage 1, 2 and 3 deformation categories do not necessarily correspond to the criteria used to characterize local ASR expansion that are summarized in Table 5. The deformation monitoring frequencies for structures are summarized in Table 6.

**Table 6. Structure Deformation Monitoring Requirements**

| Stage | Deformation Evaluation Stage | Monitoring Interval |
|---|---|---|
| 1 | Screening Evaluation | 3 years |
| 2 | Analytical Evaluation | 18 months |
| 3 | Detailed Evaluation | 6 months |

Limits for rebar strain and axial compressive stress in concrete are evaluated in the process of evaluating structures for deformation. The magnitude of these parameters is directly related to the applied loads and the level of expansion that occurs locally in ASR-affected concrete, and each is calculated in the structure deformation analysis process. The threshold monitoring limits established in the deformation analysis process discussed in Section 3.3.2 and 3.3.3 limit the allowable levels of ASR expansion to ensure that rebar strain and axial compressive stresses are acceptable per the design codes for original construction.

There are no published standards that include inspection frequencies for monitoring ASR-affected structures. In addition, ACI 318-71 and the ASME Code, Section III, Division 2, do not have guidance for inspecting ASR-affected structures. Reference 22 includes guidance from the U. S. Department of Transportation Federal Highway Administration for inspecting transportation structures with ASR degradation. The guidance recommends inspections from six months to 5 years depending on the age of the damage to the structure and the rate of change in degradation. The monitoring frequencies in Table 6 are based on the recommendations in Reference 22 and the relative margin to design acceptance criteria from the structure deformation assessment process.

The process for evaluating deformation in ASR-affected structures is progressing in accordance with the Seabrook Station corrective action process. The inspection frequencies in Table 6 and the monitoring elements specific to each structure will be included in the SMP after all structures have been evaluated.

# 4.0 REGULATORY EVALUATION

## *4.1 Applicable Regulatory Requirements/Criteria*

### 4.1.1 10 CFR 50.59

10 CFR 50.59(c)(2)(viii) requires a licensee to obtain a license amendment pursuant to 10 CFR 50.90 prior to implementing a proposed change if the change would "result in a departure from a method of evaluation described in the FSAR (as updated) used in establishing the design bases or in the safety analyses".

### 4.1.2 Design Criterion

Seabrook Station was licensed for construction on July 7, 1976, and at that time committed to the General Design Criteria (GDC) reflected in Section 3 of the UFSAR. The GDC that are applicable to the proposed UFSAR changes are Criterion 1, 2, 4, 16, and 50.

- Appendix A to Part 50-General Design Criteria for Nuclear Power Plants
  - GDC Criterion 1 - Quality Standards and Records. Structures, systems, and components important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. 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 or modified as necessary to assure a quality product in keeping with the required safety function. A quality assurance program shall be established and implemented to provide adequate assurance that these structures, systems, and components will satisfactorily perform their safety functions. Appropriate records of the design, fabrication, erection, and testing of structures, systems, and components important to safety shall be maintained by or under the control of the nuclear power unit licensee throughout the life of the unit.
  - GDC Criterion 2 - Design Bases for Protection Against Natural Phenomena. Structures, systems, and components important to safety shall be designed to withstand the effects of 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 structures, systems, and components shall reflect: (1) appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, (2) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena and (3) the importance of the safety functions to be performed.

- Criterion 4 - Environmental and Missile Design Bases. Structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents. These structures, systems, and components shall 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. However, dynamic effects associated with postulated pipe ruptures in nuclear power units may be excluded from the design basis when analyses reviewed and approved by the Commission demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping.

- Criterion 16 - Containment Design. Reactor containment and associated systems shall be provided to establish an essentially leak-tight barrier against the uncontrolled release of radioactivity to the environment and to assure that the containment design conditions important to safety are not exceeded for as long as postulated accident conditions require.

- Criterion 50 - Containment Design Basis. The reactor containment structure, including access openings, penetrations, and the Containment Heat Removal System shall be designed so that the containment structure and its internal compartments can accommodate, without exceeding the design leakage rate and, with sufficient margin, the calculated pressure and temperature conditions resulting from any loss-of-coolant accident. This margin shall reflect consideration of (1) the effects of potential energy sources which have not been included in the determination of the peak conditions, such as energy in steam generators and energy from metal-water and other chemical reactions that may result from degradation but not total failure of emergency core cooling functioning, (2) the limited experience and experimental data available for defining accident phenomena and containment responses, and (3) the conservatism of the calculational model and input parameters.

- Codes and Standards

The design, materials, fabrication, construction, testing and inspection of the containment structure conform to the applicable sections of the following codes and specifications:

- ASME Boiler and Pressure Vessel Code, Section III, Division 2, Code for Concrete Reactor Vessels and Containments - 1975 Edition

The design, materials, fabrication, and inspection of seismic Category I structures other than containment and internal structures are covered by the following codes, standards, and guides that are either applicable in their entirety or in portions thereof:

- ACI 318-71 Building Code Requirements for Reinforced Concrete (with Commentary)

- Regulatory Guide 1.92, Revision 1, "Modes and Spatial Components in Seismic Response Analyses"

  Seismic analysis results for three orthogonal directions were combined using the grouping method in Regulatory Guide 1.92, Revision 1.

The proposed analysis method changes to the UFSAR are necessary to demonstrate that containment and other seismic Category I structures continue to meet the acceptance criteria in the ASME Code and ACI 318-71, as appropriate to the structure. With the implementation of the proposed change, Seabrook Station will continue to meet the applicable regulations and requirements listed above. Incorporating the ASR deformation loads into the design basis load combinations for Seabrook will ensure the ability to safely shutdown the plant and maintain it in a safe shutdown condition during the spectrum of design basis accidents specified in the Seabrook UFSAR.

### *4.2 No Significant Hazards Consideration*

The proposed change would revise the licensing basis as documented in the Updated Final Safety Analysis Report (UFSAR) to identify alkali-silica reaction (ASR) as a degradation mechanism for seismic Category I structures at Seabrook Station. The loads associated with the effects of ASR would be added to the original design loads of ASR-affected structures in accordance with the requirements of the Codes, Standards, and Specifications used for original design of the structures. Alternate analysis methods are used to demonstrate that the capability of structures to withstand design basis loads with the effects of ASR included. The methods would continue to use the acceptance criteria that were used in the original design of Seabrook Station structures. The proposed change would also establish limits for the allowable ASR expansion in structures and propose criteria for monitoring potential changes of ASR expansion and structure deformation to ensure structures and component supports continue to meet design requirements.

NextEra has evaluated whether or not a significant hazards consideration is involved with the proposed amendment by focusing on the three standards set forth in 10 CFR 50.92, "Issuance of amendment," as discussed below:

1. **Does the proposed amendment involve a significant increase in the probability or consequences of an accident previously evaluated?**

   **Response: No.**

   The proposed amendment is requesting approval of changes to the updated final safety analysis report (UFSAR) to allow a new method to analyze Alkali-Silica Reaction (ASR) related loads. The new methodology will verify that affected structures continue to have the capability to withstand all applied loads used in the original design of Seabrook

structures. The proposed changes do not impact the physical function of plant structures, systems, or components (SSCs) or the manner in which SSCs perform their design function. The proposed changes do not alter or prevent the ability of operable SSCs to perform their intended function to mitigate the consequences of an event within assumed acceptance limits.
The ASR-affected structures are not initiators of any accidents previously evaluated, and there are no accidents previously evaluated that involve a loss of structural integrity for seismic Category I structures. Approval of the UFSAR changes will demonstrate the structures affected by ASR will continue to maintain the capability to withstand all credible conditions of loading specified in the UFSAR.

Therefore, the proposed changes do not involve a significant increase in the probability or consequences of an accident previously evaluated.

2. **Does the proposed amendment create the possibility of a new or different kind of accident from any accident previously evaluated?**

**Response: No.**

The proposed amendment is requesting approval of changes to the UFSAR to allow the use of a new method to analyze ASR related loads to verify that affected structures continue to have the capability to withstand applied loads used in the original design of Seabrook structures, with the addition of ASR loads and loads previously considered negligible. Approving the use of the new methodology will not create the possibility of a new or different kind of accident previously evaluated. The new methodology will demonstrate that structures continue to satisfy the design requirements of the code of construction and other applicable requirements with the additional load from ASR. Structures will respond to applied loads consistent with their original design.

The proposed changes to the UFSAR do not challenge the integrity or performance of any safety-related systems. The changes do not alter the design, physical configuration, or method of operation of any plant SSC. No physical changes are made to the plant, other than as a result of the revised monitoring program, so no new causal mechanisms are introduced.

Therefore, the proposed change does not create the possibility of a new or different kind of accident from any previously evaluated.

3. **Does the proposed amendment involve a significant reduction in a margin of safety?**

**Response: No.**

The proposed amendment is requesting approval of changes to the UFSAR to allow the use of a new method to analyze ASR related loads to verify that affected structures continue to have the capability to withstand all applied loads used in the original design of Seabrook structures.

The proposed methods for re-evaluating seismic Category I structures will demonstrate that structures satisfy the acceptance criteria in the current licensing basis when the loads associated with ASR expansion are included with other design loads and load combinations. The safety margin provided by the design codes in the current licensing basis will not be reduced since the proposed change is not requesting any change to the codes of record.

The proposed changes to the UFSAR do not affect the margin of safety associated with confidence in the ability of the fission product barriers (i.e., fuel cladding, reactor coolant system pressure boundary, and containment structure) to limit the level of radiation dose to the public. The proposed changes do not alter any safety analyses assumptions, safety limits, limiting safety system settings, or methods of operating the plant. The changes do not adversely impact plant operating margins or the reliability of equipment credited in the safety analyses. The proposed changes do not adversely affect systems that respond to safely shutdown the plant and to maintain the plant in a safe shutdown condition.

Therefore, the proposed change does not involve a significant reduction in a margin of safety.

## 5.0 ENVIRONMENTAL CONSIDERATION

NextEra has evaluated the proposed amendment for environmental considerations. The review has determined that the proposed amendment would change a requirement with respect to installation or use of a facility component located within the restricted area, as defined in 10CFR20, or would change an inspection or surveillance requirement. However, the proposed amendment does not involve (i) a significant hazards consideration, (ii) a significant change in the types or significant increase in the amounts of any effluent that may be released offsite, or (iii) a significant increase in individual or cumulative occupational radiation exposure. Accordingly, the proposed amendment meets the eligibility criterion for categorical exclusion set forth in 10CFR51.22(c)(9). Therefore, pursuant to 10CFR51.22(b), no environmental impact statement or environmental assessment needs to be prepared in connection with the proposed amendment.

## 6.0 REFERENCES

1. American Concrete Institute (ACI) Standard 318-71, “Building Code Requirements for Reinforced Concrete.”

2. American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel Code (1975 Edition), Section III, Division 2.
3. ASTM C289-71, "Standard Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)," American Society for Testing and Materials, 1971.
4. MPR-3727, Revision 1, “Seabrook Station: Impact of Alkali-Silica Reaction on Concrete Structures and Attachments,” May 2012. (Seabrook FP# 100716)
5. IE Bulletin 79-02, “Pipe Support Base Plate Designs Using Concrete Expansion Anchors,” Revision 2.
6. Root Cause Report for Seabrook Station Containment Enclosure Building Local Deformation, CR Number 2014325.
7. Letter w/Attachment from Mr. C. Miller (NRC) to Mr. K. Walsh (NextEra), “Seabrook Station, Unit No. 1 - Confirmatory Action Letter Follow-Up Inspection - NRC Inspection Report 05000443/2012009,” dated December 3, 2012.
8. Letter w/Attachment from Mr. R. Lorson (NRC) to Mr. K. Walsh (NextEra), “Seabrook Station, Unit No. 1 - Confirmatory Action Letter Follow-Up Inspection - NRC Inspection Report 05000443/2012010,” dated August 9, 2013.
9. Letter w/Attachment from Mr. G. Dentel (NRC) to Mr. K. Walsh (NextEra), “Seabrook Station, Unit No. 1 - NRC Integrated Inspection Report 05000443/2013005,” January 30. 2014.
10. Letter w/Attachment from Mr. G. Dentel (NRC) to Mr. K. Walsh (NextEra), “Seabrook Station, Unit No. 1 - NRC Integrated Inspection Report 05000443/2014002,” May 6. 2014.
11. Letter w/Attachment from Mr. G. Dentel (NRC) to Mr. D. Curtland (NextEra), “Seabrook Station, Unit No. 1 - NRC Integrated Inspection Report 05000443/2014005,” February 6, 2015.
12. Letter w/Attachment from Mr. G. Dentel (NRC) to Mr. D. Curtland (NextEra), “Seabrook Station, Unit No. 1 – Integrated Inspection Report 05000443/2015002,” August 5, 2015.
13. Letter w/Attachment from Mr. T. Tran (NRC) to Mr. D. Curtland (NextEra), “Alkali Silica Reaction Monitoring Aging Management Program Audit Report Regarding The Seabrook Station, Unit 1, License Renewal (TAC No. ME4028),” December 17, 2015.
14. Letter w/Attachment from Mr. G. Dentel (NRC) to Mr. D. Curtland (NextEra), “Seabrook Station, Unit No. 1 – Integrated Inspection Report 05000443/2015004 and Independent Spent Fuel Storage Installation Report No. 07200063/2015001,” February 12, 2016.

15. Report No. 150252-SVR-01-R1, "Phase 1A Investigation of Apparent Movement of the Containment Enclosure Building at the NextEra Energy Seabrook Station, NH," June 25, 2015.

16. PEG-98, Revision 0, "CEB Extent of Condition Walkdown," July 29, 2015.

17. Simpson Gumpertz & Heger, Computation of Load Factors for ASR Demands, 160268-CA-01 Rev. 0, July 26, 2016.

18. Ellingwood, B. et al., Development of a Probability Based Load Criterion for American National Standard A58, NBS Special Publication 577, June 1980.

19. Not used.

20. MPR-4153, Revision 2, "Seabrook Station – Approach for Determining Through-Thickness Expansion from Alkali-Silica Reaction," July 2016. (Seabrook FP# 100918)

21. Report No. 120555-SVR-25-R0, "June 2015 – ASR Inspections and Crack Index Measurements on Concrete Structures, NextEra Energy Seabrook Station, NH," August 2015.

22. Fournier, B. et al, FHWA-HIF-09-004, "Report on the Diagnosis, Prognosis, and Mitigation of Alkali-Silica Reaction in Transportation Structures," January 2010.

23. SG&H Report 160268-R-01, " Development of ASR Load Factors for Seismic Category I Structures (Including Containment) at Seabrook Station, Seabrook, NH," Revision 0 (Seabrook FP# 101039)

24. MPR-4288, Revision 0, "Seabrook Station: Impact of Alkali-Silica Reaction on the Structural Design Evaluations," July 2016. (Seabrook FP# 101020) (Proprietary)

25. MPR-4273, Revision 0, "Seabrook Station - Implications of Large-Scale Test Program Results on Reinforced Concrete Affected by Alkali-Silica Reaction," July 2016. (Seabrook FP# 101050) (Proprietary)

26. Simpson Gumpertz & Heger Inc., "Evaluation and Design Confirmation of As-Deformed CEB, 150252-CA-02," Revision 0, July 2016.

SBK-L-16071

# ENCLOSURE 8

# Affidavit in Support of Application for Withholding Proprietary Information from Public Disclosure

## NextEra Energy Seabrook Application for

## Withholding Proprietary Information from Public Disclosure

| | |
|---|---|
| Subject: | MPR-4273, Revision 0, "Seabrook Station - Implications of Large-Scale Test Program Results on Reinforced Concrete Affected by Alkali-Silica Reaction," July 2016. (Seabrook FP# 101050) (Proprietary) |
| | MPR-4288, Revision 0, "Seabrook Station: Impact of Alkali-Silica Reaction on the Structural Design Evaluations," July 2016. (Seabrook FP# 101020) (Proprietary) |
| | Enclosure 1 to SBK-L-16071, "NextEra Energy Seabrook's Evaluation of the Proposed Change" (Proprietary) |

Enclosures 1, 5, and 6 to this letter, "NextEra Energy Seabrook's Evaluation of the Proposed Change" (Proprietary), MPR-4273, Revision 0, "Seabrook Station - Implications of Large-Scale Test Program Results on Reinforced Concrete Affected by Alkali-Silica Reaction," July 2016 (Seabrook FP# 101050) (Proprietary), and MPR-4288, Revision 0, "Seabrook Station: Impact of Alkali-Silica Reaction on the Structural Design Evaluations," July 2016 (Seabrook FP# 101020) (Proprietary) contain NextEra Energy Seabrook proprietary information. This letter is supported by an affidavit signed by NextEra Energy Seabrook, setting forth the basis on which the information may be withheld from public disclosure by the Commission and addressing the considerations listed in 10 CFR 2.390(b)(4). Accordingly, it is respectfully requested that the information which is proprietary be withheld from public disclosure in accordance 10 CFR 2.390.

Correspondence with respect to this application for withholding or the accompanying affidavit should be addressed to Mr. Kenneth Browne, Licensing Manager at (603) 773-7932.

# ATTACHMENT 1

## Markup of UFSAR Pages

(30 Pages)

Regulatory Guide 1.92 presents three other means of combining closely spaced modes. Justification for nonconformance is that the methods prescribed in the guide are not here applicable since the construction permit application docket date is before the date of issue of the guide. In addition, the method used is deemed more conservative. For further discussion, refer to Section 3.7(B) and Subsection 3.7(B).3.7.

(Rev. 3, 10/2012) Modes and Spatial Components in Seismic Response Analyses

A procedure for combining the three spatial components of an earthquake for seismic response analysis of nuclear power plant structures, systems, and components (SSCs) that are important to safety is presented in Subsection C.2.1. The Response Spectrum Method that uses the 100-40-40 percent combination rule, as described in Regulatory Position C.2.1 of this guide, is acceptable as an alternative to the SRSS method.

The 100-40-40 percent rule is used as an alternative to the SRSS method for combining three directional seismic loading in the analysis of seismic, Category I structures that are deformed by the effects of ASR. In general, the 100-40-40 combination method produces higher estimates of maximum response than the SRSS combination method by as much as 16 percent, while the maximum under-prediction is 1 percent.

Refer to Section 3.7(B).2.1 for further discussion of this subject.

Regulatory Guide 1.93

(Rev. 0, 12/74) Availability of Electric Power Sources

The Technical Specification (T/S) ac and dc power sources allowable out-of-service times (action statements) are based on RG 1.93. Where differences exist between the T/S and RG 1.93, the T/S are the governing document.

RG 1.93 does not allow out-of-service times to be used for preventative maintenance that incapacitates a power source. These activities are to be scheduled for refueling or shutdown periods. This is interpreted to also apply to surveillance activities. Preventative maintenance and surveillance activities are performed on-line when permitted by the T/S and with appropriate consideration of the effects on safety, reliability, and availability.

Regulatory Guide 1.95

(Rev. 1, 2/77) Protection of Nuclear Power Plant Control Room Operators Against Accidental Chlorine Release

The relevant portions of Regulatory Guide 1.95 are complied with based on the findings that the plant design does not include the storage of chlorine within 100 meters of the control room, excluding small laboratory quantities, nor is there chlorine stored in excess of the maximum allowable chlorine inventory, as given as a function of distance in Regulatory Guide 1.95 for Type I control rooms (refer to Subsection 2.2.3.1).

### 3.7(B).2 Seismic System Analysis

This subsection contains a discussion of the seismic analyses performed for seismic Category I structures and systems. Included in the discussion are the methods of seismic analysis used, the criteria used for mathematically modelling the structures and systems, the assumptions made in the analyses, and the effects considered.

### 3.7(B).2.1 Seismic Analysis Methods

The seismic response of Category I structures, systems and components has been determined from suitable elastic dynamic analyses. The results of these analyses are used for the design of seismic Category I structures, systems and components, and are input for subsequent dynamic analyses.

Two methods of seismic system analysis were used for seismic Category I structures: (1) the modal analysis response-spectrum method and (2) the mode-superposition time-history method. The time-history method was used to determine the dynamic response necessary to obtain amplified response spectra for component design. The input forcing functions (the time history of ground motion) are shown graphically in Figure 3.7(B)-1, Figure 3.7(B)-2 and Figure 3.7(B)-3. The time history shown on Figure 3.7(B)-1 is used in both horizontal directions. The peak acceleration is 0.25g for the SSE and 0.125g for the OBE. Design response spectra for the response-spectrum method are shown in Section 2.5.

The mathematical models used for the seismic Category I structures are typically lumped masses connected by linear elastic springs. Each structure, then, is described by a finite number of degrees-of-freedom chosen to represent the principal overall behavior of the system. The modelling is described in Subsection 3.7(B).2.3 in more detail. The number of masses or degrees-of-freedom included in the analysis is determined by requiring the total degrees-of-freedom to exceed twice the number of significant modes with frequencies less than 33 Hz. Up to four degrees-of-freedom were considered for each mass point, three translation and one torsion. The three orthogonal directions were run separately, and results were combined by the grouping method in accordance with Regulatory Guide 1.92. The orthogonal spatial components of seismic loads for response spectrum analyses of structures deformed by the effects of ASR are combined using the 100-40-40 procedure in Regulatory Guide 1.92 Revision 3.

All significant modes with frequencies up to 50 Hz were used in analyses for both local and overall effects.

The effects due to inertial characteristics of fluid contained within a structural component were considered in the analysis by techniques described in Reference 1. No soil-structure interaction effects were involved because of the rock siting.

(Section 3.8.1.3 continued…)

(f) Alkali Silica Reaction Loads ($S_a$)

These are structural effects caused by ASR expansion of concrete. ASR loads are passive and therefore occur during normal operation, shutdown conditions, and concurrently with all extreme environmental loads. The effects of ASR expansion occurring in reinforced concrete structural members are considered.

(Section 3.8.3.3 continued…)

a. Design Loads

The definitions of the loads used in the design of the internal structures include the following:

1. Normal Plant Startup, Operation and Shutdown Loads

Normal loads are those loads encountered during normal plant start-up, operation and shutdown. They include the following:

(a) Dead Loads (D)

Dead loads are all permanent gravity loads including the weight of concrete walls and slabs, structural framing, piping, cable and cable trays, permanent equipment, and static pressures of liquids. Concrete creep, shrinkage, and swelling are considered for structures affected by the expansion of concrete from alkali-silica reaction (ASR). See Subsection 3.8.4.6 for a description of the effects of ASR on concrete.

(b) Live Loads (L)

Live loads include any movable equipment loads and other loads which vary in intensity and/or occurrence. Live loads are present only during shutdown conditions, and do not govern the design of any components.

(c) Operational Thermal Loads ($T_o$)

The temperature gradient through the walls under normal operating conditions is considered in the design. For a discussion of minimum and maximum operating temperatures, see Subsection 6.2.1.

(d) Operational Pipe Reactions ($R_o$)

These are pipe reactions due to thermal conditions existing in the piping during normal operation or shutdown. They are based on the most critical transient or steady-state condition.

(e) Alkali-Silica Reaction Loads

These are structural effects caused by ASR. ASR loads are passive and therefore occur during normal operation, shutdown conditions, and concurrently with all extreme environmental loads. The effects of ASR expansion occurring in reinforced concrete structural members as well as concrete backfill are considered.

2. Severe Environmental Loads

   Severe environmental loads are those loads that result from events that could infrequently be encountered during the plant life. The only load included in this category is the following:

   (a) Operating Basis Earthquake ($E_o$)

   These are the loads generated by the Operating Basis Earthquake, which is the earthquake that could reasonably be expected to affect the site during the operating life of the plant. Only the actual dead load and weights of fixed equipment are considered in evaluating the seismic response forces.

   The horizontal and vertical design response spectra for the OBE are derived by applying a factor of 0.5 to the response spectra given for the Safe Shutdown Earthquake (SSE) which is described below. The effects of two (2) orthogonal horizontal components and one (1) vertical component of earthquake are considered and combined by the square-root-of-the-sum-of-the-squares rule.

3. Extreme Environmental Loads

   Extreme environmental loads are those loads which result from events which are credible but highly improbable. The only load included in this category is the following:

   (a) Safe Shutdown Earthquake ($E_{ss}$)

   These are the loads generated by the Safe Shutdown Earthquake, which is the earthquake based upon an evaluation of the maximum earthquake potential in the vicinity of the plant. Dead and fixed equipment loads are described under the Operating Basis Earthquake, above. The horizontal and vertical forces on the internals are developed from the response spectra given in Figure 2.5-38 and Figure 2.5-39 the development of which is described in Subsection 2.5.2.6.

   The effects of two (2) orthogonal horizontal earthquakes and one (1) vertical earthquake are considered and combined by the square-root-of-the-sum-of-the-squares rule.

(Section 3.8.3.3 continued…)

(2) The containment structure functions as an independent structure with complete physical separation from the internal structures, and therefore there are no loading interactions between the two.

(3) Compartmentalization is considered in the design of the internal structures by using the peak subcompartment differential pressures, plus a safety margin. This is further discussed in Subsection 6.2.1.2.

(4) Self-Straining Loads

The containment internals concrete is analyzed for deformation caused by ASR and is designed to withstand the effects of ASR expansion, creep, shrinkage, and swelling

b. Load Combinations

Various load combinations are considered in design to determine the greatest strength requirements of the structure. Where varying loads occur, the combinations producing the most critical loading are used. Basic combinations in the design of the containment internal structures are given in Table 3.8-14. These load combinations are in agreement with Subsections II.3 and II.5 of the Standard Review Plan for Subsection 3.8.3 of the UFSAR. The factors which are to be applied to allowable stresses have been transposed and applied as load factors instead, resulting in acceptance criteria as indicated in the table. Two categories of loading conditions and criteria are used in the design of the containment internal structures as described below.

1. Normal Load Conditions

Normal load conditions e those encountered during testing and normal operation. They include dead load, live load, Alkali Silica Reaction (ASR) loads, and anticipated transients or test conditions during normal and emergency startup and shutdown of the Nuclear Steam Supply, Safety and Auxiliary Systems. Normal loading also includes the effect of an Operating Basis Earthquake. Normal load conditions are referred to in Division 2 as service load conditions.

4. STAAD III Structural Analysis and Design Software: A proprietary computer program of Research Engineers, Inc. (REI), California, for the analysis and design of structures. The code has been placed under configuration control by Westinghouse and specific features of this software utilized in the simplified head assembly calculations have been independently verified by Westinghouse. (Westinghouse Letter Number EDRE-CSE-134(97), Software Release of STAAD III (22.0W) on Windows NT System, 9/25/97, and Westinghouse Calculation #CSE-06-98-0001, Rev. 0, titled: "STAAD Verification Problem-Response Spectra Analysis.")

5. GOTHIC Generation of Thermal-Hydraulic Information for Containments: GOTHIC is a general purpose thermal-hydraulic computer program for design, licensing, safety and operating analysis of nuclear power plant containments and other confinement buildings. GOTHIC has been developed for the Electric Power Research Institute (EPRI) by Numerical Applications Inc, Richland, Washington. The code has been placed under configuration control by Westinghouse. (GOTHIC Qualification Report for Version 5.0e (NAI 8907-09, Rev. 3, Dec. 1995.)

### 3.8.3.5 Structural Acceptance Criteria

The bases for the development of the following stress-strain criteria are the ACI 318-71 and AISC codes.

a. Normal Load Conditions

Internal structures are proportioned to remain within the elastic limits under all normal loading conditions described in Subsection 3.8.3.3.

Reinforced Concrete - designed in accordance with ACI 318-71 Strength Method, which insures flexural ductility by control of reinforcing steel percentages and stresses.

Structural and Miscellaneous Steel - designed in accordance with AISC Specification for the Design, Fabrication and Erection of Structural Steel for Buildings, Part I.

b. Unusual Load Conditions

Internal structures are designed to maintain elastic behavior under all unusual load conditions shown in Subsection 3.8.3.3. The upper bound of elastic behavior is taken as the yield strength capacity of the load carrying components. The yield strength of structural and reinforcing steel is taken as the minimum guaranteed yield stress as given in the appropriate ASTM Specification.

(Section 3.8.3.6 continued…)

a. Concrete

Concrete work is in accordance with ACI 318-71 and ACI 301 codes, except as noted in Subsection 1.8 (Regulatory Guide 1.55). The concrete is a dense, durable mixture of sound, coarse aggregate, cement and water. Admixtures were added, where required, to improve the quality and workability during placement and to retard the set of the concrete. Engineering approval was required prior to the use of admixtures.

Aggregate conforms to ASTM C33. It consists of inert materials that are clean, hard and durable, free from organic material and uncoated with clay or dirt. Fine aggregate consists of natural sand and the coarse aggregate consists of crushed stone.

Portland cement conforms to ASTM C150, Type II (moderate heat of hydration requirements).

Water is clean and free from any deleterious amounts of acid, alkali, salts, oil, sediment, organic matter or other substances which may be harmful to the concrete or steel.

The reinforced concrete has a nominal density of 150 $lb/ft^3$, which is used for determination of dead load. Shielding calculations for the primary shield wall are based on a dry concrete density of 139 $lb/ft^3$; other shielding calculations are based on a dry concrete density of 147 $lb/ft^3$. The 28-day standard compressive strength of the concrete is 4000 psi.

Refer to Subsection 3.8.4.6 for a discussion on the material effects of Alkali Silica Reaction (ASR) on concrete

To assure that adequate means of control were used in the manufacture and that the properties described above were realized, the following were required:

1. Suppliers, fabricators and contractors were required to have written quality assurance procedures, which were reviewed and approved by United Engineers. Material certifications were required in accordance with the applicable portions of the quality assurance plan described in Chapter 17 of the UFSAR and in the material specifications.

d. Steel and Concrete Coating System

Materials used for coating the internal structures are the same as those described in Subsection 3.8.1.6. These materials meet the requirements of ANSI Standard N101.2.

### 3.8.3.7 Testing and In-Service Surveillance Requirements

Quality control testing as discussed in Subsection 3.8.3.6 will be employed. No additional testing or in-service surveillance is required.

Refer to Subsection 3.8.4.7 for a discussion on the Structural Monitoring Program requirements for inspection of ASR affected structures

(Section 3.8.1.3.b continued)…

Long-term conditions, such as operating thermal loads, creep and shrinkage, which produce compression in the reinforcing steel, do not have a significant effect on the structural integrity of the containment structure, since the accident loads, which are the most significant loads, are generally resisted in tension by the reinforcing steel. In addition, the accident loads are short once-occurring loads which will have negligible creep effects. The self-straining loads associated with ASR expansion are considered for localized areas affected by ASR in combination with other loads as indicated in Table 3.8-1.

For the design of the liner, the load combinations in Table 3.8-1 are applicable with the exception that coefficients for all load cases are taken equal to 1.0.

Steel components of the containment shell that are pressure-resisting but unbacked by concrete are designed in accordance with the ASME Code, Section III, Division 1, using loads described in Subsection 3.8.2.

Earthquake effects are not assumed to occur simultaneously with flooding effects since the maximum flood is not associated with an earthquake.

Effects of a thermal gradient through the concrete section are not considered where the effects of the gradient reduce the effects caused by an abnormal loading condition.

Maximum values of time-dependent loads such as accident pressure, temperature and pipe break loads are considered.

The load combinations in Table 3.8-1 are applicable to the computations of factors of safety against overturning, sliding and flotation, with the exception that the coefficient for live load is zero. Buoyant forces are conservatively considered to decrease the dead loads for determination of overturning and sliding.

### 3.8.1.4 Design and Analysis Procedures

The containment structure is designed as a reinforced concrete thin shell structure in accordance with the requirements of Article CC-3000 of Division 2, as described in this Subsection and in other subsections of Subsection 3.8.1, and in accordance with the other applicable codes, standards and specifications defined in Subsection 3.8.1.2. The containment structure is designed to safely withstand the load combinations as defined in Subsection 3.8.1.3, and to

(Section 3.8.1.4)

e. Transient and Localized Loads

A "hot liner" transient load was analyzed and accounted for in the design of the reinforced concrete wall. A temperature spike was placed on the liner for two cases: (a) "hot liner" with no temperature gradient on concrete wall, and (b) "hot liner" with a temperature gradient through the wall (see Table 3.8-4). When combined with mechanical loads, the effect of thermal loadings is a redistribution of stresses and strains on the cross section. The stresses and strains in the liner are discussed in Subsection 3.8.1.4k, "Steel Liner Plate and Anchors."

The aircraft impact analysis is described in detail in Appendix 2P. Three analyses were performed: two of the overall structural behavior and one localized elasto-plastic dynamic analysis. The analyses of overall behavior considered the conditions of impact on the dome (axisymmetric structure with axisymmetric loading) and impact on the springline (axisymmetric structure with unsymmetric loading). Both analyses assumed linear behavior and used the Wilson II finite element code. The asymmetric loading of the second analysis was represented by a Fourier series. Both analyses showed that yielding would occur local to the point of impact. Accordingly, a localized, nonlinear analysis was used to determine the extent of damage to the containment shell. The details of this analysis are also found in Appendix 2P. In brief, effective mass and stiffness properties were determined for an assumed mode of collapse consisting of a circular fan yield-line configuration.

An equivalent single-degree-of-freedom nonlinear model was then subjected to an idealized force-time loading function and the maximum deformations determined. It was shown that the "as designed" containment structure with Enclosure Building can withstand impact of an FB-111 aircraft at 200 -mph impact speed without collapse or impairment of the leak-tight integrity of the liner.

The localized strain from ASR expansion is determined from measurements of the structure in ASR-affected locations. Closed form analytical equations for cylindrical shells subjected to local loadings were used to calculate the forces and moments to localized ASR expansions. The ASR loads are combined with other loads for the structure to analyze critical areas affected by ASR.

The forces and moments due to seismic loading are discussed in Subsection 3.7.2. Three components of the seismic motion were assumed to exist simultaneously, and the resulting component forces and moments were combined by the square-root-of-the-sum-of-the squares (SRSS) method. The maximum tangential shear from the SRSS combination is assumed to act simultaneously at all points on the containment circumference at the given elevation. All forces and moments were combined per the specified load combinations. The LESCAL program, described in Subsection 3.8.1.4g, was used to calculate rebar stresses for all sections and elevations combining the stresses due to in-plane forces and moments. Duchon's equations (Reference 3) are incorporated into LESCAL for calculating rebar stresses (including inclined rebar) for the combined membrane forces.

(Section 3.8.1.4.i)

i. Variation in Physical Material Properties

The effects of variations in material properties were considered in the design and analysis. Material properties which can strongly influence both analysis and design due to variability or uncertainty include: (1) dynamic modulus of soils, (2) the modulus of elasticity of concrete and, (3) material strengths.

As this containment is founded on rock, the first of these sources of variability is removed from consideration. The modulus of elasticity of concrete is a function of concrete compressive strength which in turn is typically substantially higher in the "as-built" structure than assumed for analysis and design. While variability in concrete modulus has no significant effect on structural design, it influences structural stiffness and natural frequency, and, subsequently, the amplified response spectra of the seismic analysis. This impacts equipment design as discussed in Subsection 3.7.3. The variability was accounted for by peak spreading when generating envelopes of the response spectra. Variability in material strength is taken into account in Division 2, Subarticle CC-3400, design allowables.

Analyses and tests were completed to assess the effects of ASR on structural properties of reinforced concrete. The results indicate that using the structural properties and code equations from the original design analysis is conservative when ASR expansion levels are below the limits defined in Subsection 3.8.4.7. Concrete expansion from ASR imposes a localized tensile strain in the reinforcement.

(Section 3.8.4.3a.1 continued…)

(a) Dead Loads (D)

Dead loads are all permanent gravity loads including, but not limited to, concrete walls and slabs, structural framing, piping, cable and cable trays, permanent equipment and miscellaneous building items. Hydrostatic pressures of liquids are also included in this category. Concrete creep, shrinkage, and swelling are considered for structures affected by the expansion of concrete from alkali-silica reaction (ASR). See Subsection 3.8.4.6 for a description of the effects of ASR on concrete.

(b) Live Loads (L)

Live loads are all temporary gravity loads including but not limited to normal snow loads, conventionally distributed and concentrated floor loads, and movable equipment loads, such as cranes and hoists.

Equipment operating loads and impact factors are the greater of those recommended by the manufacturer or the applicable building codes.

Unusual snow load ($L_S$), which is greater in magnitude than normal snow load, was also used where applicable. Lateral earth pressures due to soil backfill (H) were used where applicable. Three types of lateral earth pressure loading, active, at rest and passive, were considered, with pressures determined by acceptable theories of soil mechanics.

(c) Operational Thermal Loads ($T_o$)

These are the thermal effects and loads occurring during normal operating or shutdown conditions, based on the most critical transient or steady-state condition.

(d) Operational Pipe Reactions ($R_o$)

These are the pipe reactions occurring during normal operating or shutdown conditions, based on the most critical transient or steady-state condition.

(e) Alkali-Silica Reaction Loads

These are structural effects caused by ASR. ASR loads are passive and therefore occur during normal operation, shutdown conditions, and concurrently with all extreme environmental loads. The effects of ASR expansion occurring in reinforced concrete structural members as well as concrete backfill are considered.

1. Normal Load Conditions

Normal load conditions are those encountered during testing and normal operation and are referred to in the standard review plan as service load conditions. They include dead load, live load and anticipated transients, loads occurring during normal startup and shutdown, and loads occurring during emergency shutdown of the nuclear steam supply, safety and auxiliary systems. Normal loading also includes the effect of an operating basis earthquake and normal wind load. Under each of these loading combinations the structures were designed so that stresses are within the elastic limits. Design and analysis procedures are presented in Subsection 3.8.4.4 and stress limitations are presented in Subsection 3.8.4.5.

2. Unusual Load Conditions

Unusual load conditions are those resulting from combinations of accident, wind, tornado, earthquake, live and dead loads and are referred to in the standard review plan as factored load conditions.

For these loading combinations, the structures were designed to remain below their ultimate yield capacity such that deformations will be small and structural components will respond elastically. Design and analysis procedures are presented in Subsection 3.8.4.4 and stress limitations are presented in Subsection 3.8.4.5.

(Section 3.8.4.3 continued…)

c Other Load Considerations

1. Creep

Effects of concrete creep are negligible due to the low sustained concrete stresses associated with conventionally reinforced concrete structures and, therefore, were not a governing factor in design. Concrete creep is included with other self-straining loads in the design of structures with deformation caused by the effects of ASR expansion.

2. Stability

The other seismic Category I structures were checked for overturning, sliding, and flotation using the load combinations of Table 3.8-16 with the exception that the coefficient for live load is zero. Buoyant forces were considered to decrease the dead load in computing both overturning and sliding.

3. Self-Straining Loads

Structures that are analyzed for deformation caused by ASR are designed to withstand the effects of ASR expansion, creep, shrinkage, and swelling.

### 3.8.4.4 Design and Analysis Procedures

a Design and Analysis

Category I structures other than the containment are constructed of reinforced concrete with structural steel framing used to support vertical loading on floor slabs. Structural steel is also used to provide enclosure for some areas, as described in Subsection 3.8.4.1, and for other miscellaneous purposes. Reinforced concrete structures consist of a system of walls and slabs generally to provide a continuous, integral framing system. Vertical forces are transferred to the foundation mats through the walls and structural steel and reinforced concrete columns. Lateral forces are transferred to the foundation mats primarily by the action of shear walls; some load is also transferred by means of flexural action of the walls, all of which are rigidly attached at the mat.

The Containment Enclosure Building, due to its cylindrical and hemispherical shape and relative dimensions, was analyzed as a three-dimensional, thin-shell structure. Boundary conditions were consistent with the support on rock and the lateral restraint provided by backfill concrete placed against the structure. Internal resultant forces and moments were determined by integration of the appropriate shell stresses through the thickness. Critical transverse shear force was derived by considering the variations in bending moments across the surface, in conjunction with the applied hydrostatic load (which produces additional local shear not reflected in the finite element analysis). Reinforcing was subsequently designed for these internal forces.

Columns are designed to resist other lateral loads, such as pipe loads or building displacements, in addition to those forces transmitted to the columns at floor levels. Steel columns are generally pin-connected at the foundation mat, and reinforced concrete columns are rigidly attached. Structural steel framing for floor systems primarily consists of pin-connected framing with some members being continuous. Rigidity is provided by the box-like concrete walls and slabs.

Structures with deformation were analyzed by calculating the self-straining load associated with the combined effects of ASR-expansion, creep, shrinkage, and swelling as determined from measurements of the structure. ASR expansion loads were combined with other loads and the appropriate load factors from Table 3.8-16 were applied.

Several computer programs were used for static analysis and are described in Appendix 3F.

Table 3.8-17 contains a list of these programs and the respective structures for which they were used. The load combinations are given in Subsection 3.8.4.3.

In the Waste Processing Building only those areas housing radioactive gaseous waste equipment were designed for tornado loads; the other areas do not contain safety-related equipment. Procedures by which the structures were checked for missile loads, tornado-generated as well as internally generated, are described in Section 3.5. Determination of pressures on structures due to tornado is described in Subsection 3.3.2. Pressure loadings from wind are described in Subsection 3.3.1.

The seismic analysis of seismic Category I structures is described in Subsection 3.7.2. All cranes in these structures are furnished with hold-down devices to ensure that they are not dislodged by earthquake forces. Monorails, by nature of their support mechanisms, cannot be dislodged by earthquake forces.

Using methods outlined in TID-7024, "Nuclear Reactors and Earthquakes," the effects of hydrodynamic forces were included in the seismic analyses of the Service Water Cooling Tower. Also using methods outlined in TID-7024, the weight of constrained water and sloshing effects of water in motion were included as equivalent static loads in the final design of the Service Water Cooling Tower, Service Water Pumphouse and Fuel Storage Building.

Reinforced concrete design of Category I structures was in accordance with the strength design procedures of the ACI 318-71 code, except as indicated in Subsection 3.8.4.5. Structural steel design was in accordance with the provisions of the AISC Specification for the Design, Fabrication and Erection of Structural Steel for Buildings (1969 Edition). Refer to Subsection 1.8 (Regulatory Guide 1.142) for a statement concerning compliance with ACI-349.

(Section 3.8.4.4 continued…)

b. <u>Material Properties</u>

Material properties were selected from the normal range of values to produce a conservative design. See Subsection 3.8.1.4 for a detailed discussion of the influence of material properties on design and analysis.

Analyses and test of ASR-affected concrete concluded that the capacity of structural members and embedded concrete anchors in ASR-affected structures is not reduced when ASR expansion levels are below the limits included in Subsection 3.8.4.7.

c. <u>Computer Programs</u>

The computer programs used in analysis and design of other Category I structures

In June 2010, concrete cores were removed for examination and testing from the walls of the lower electrical tunnel in the Control Building, as part of preparations for license renewal inspections. The purpose was to evaluate potential concrete aging effects in below grade areas of the plant that had been subjected to historical groundwater wetting of the concrete. In general the removed cores showed the expected quality materials and placements from original construction. There were no obvious visual signs of aging distress or concrete degradation. Petrographic examinations were performed which involved sectioning and polishing the core samples and analysis under magnification by a qualified professional petrographer. This analysis revealed micro cracks and other features indicative of Alkali Silica Reaction (ASR). Materials testing of the removed cores also resulted in lower than expected mechanical properties consistent with low levels of ASR. The impact of ASR in the material strength testing of removed cores is not indicative of actual in situ performance and cannot be directly correlated to actual structural impact. Once removed from the structural context (e.g., reinforcement or confining loads) the behavior of the cores no longer reflects that of the confined structure.

(Section 3.8.4.6 continued...)

The expansion of concrete from silica gel formation and cracking results in a small, but measurable, change in the dimensions of ASR-affected concrete. In 2014, Engineering determined that damage to a vertical seismic gap seal between the Containment Enclosure Building and the Containment Building was caused by relative building movement and not seal degradation. A subsequent evaluation of the condition determined that the seal damage was caused by radial deformation of the Containment Enclosure Building. The building deformation was caused by the expansion of ASR-affected concrete in the building and the backfill concrete that abuts the structure below grade.

Engineering evaluations of the extent of deformation in each structure determined the impact of the ASR on affected structures. Subsection 3.8.4.7 and the Structural Monitoring Program includes criteria for monitoring the effects of ASR.~~Additional concrete core sampling has been performed to determine the extent of condition both from the perspective of additional areas that might be affected by ASR and also the extent of ASR degradation within a given area and control areas (non-wetted adjacent areas). Subject Matter Experts from around the country were consulted and a specific monitoring and action plan for ASR was added to the Structural Monitoring Program. Engineering evaluations that were performed and documented in foreign print 100716, (Subsection 3.8.6, Ref. 6) established that although the concrete can be considered degraded, the structures and embedded concrete anchors are capable of performing all required design basis functions. ASR is considered to be a degraded nonconforming condition pursuant to Regulatory Issue Summary (RIS) 2005-20. An operability determination was performed which established reasonable assurances that the structures and embedded/drilled-in concrete anchors are capable of performing all required design basis functions. Design basis calculations will be reconciled to account for ASR following completion of the actions delineated in the ASR corrective action plan.~~

### 3.8.4.7 Testing and In-Service Surveillance Requirements

Normal quality control testing is discussed in Subsection 3.8.3.6. A general visual inspection of the exposed accessible interior and exterior surfaces of the Containment Enclosure Building will be periodically conducted as discussed in Subsection 6.2.6.1.

The Structural Monitoring Program includes requirements for inspecting structures affected by ASR. The total expansion of ASR-affected areas is limited to less than the amounts specified in Table 3.8-18. Periodically verifying that ASR expansion levels are below the limits is necessary to ensure structural properties of ASR-affected areas are similar to areas with no evidence of ASR.

The Structural Monitoring Program also has limits on structure deformation from ASR concrete expansion. Structures with increasing levels of deformation, as determined by an analysis of the self-straining loads, are classified as Stage 1, 2, or 3. Monitoring criteria for each structure are included in the Structural Monitoring Program and inspection requirements are defined based on the analysis and classification of each structure.

#### 3.8.4.7.1 STRUCTURES MONITORING PROGRAM

The Structures Monitoring Program is implemented through the plant Maintenance Rule Program, which is based on the guidance provided in NRC Regulatory Guide 1.160 "*Monitoring the Effectiveness of Maintenance at Nuclear power Plants*" and NUMARC 93-01 "*Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants*", and with guidance from ACI 349.3R, "Evaluation of Existing Nuclear Safety-Related Concrete Structures". The Structures Monitoring Program was developed using the guidance of these three documents. The Program is implemented to monitor the condition of structures and structural components within the scope of the Maintenance Rule, such that there is no loss of structure or structural component intended function.

#### 3.8.4.7.2 ALKALI-SILICA REACTION (ASR) MONITORING

The ASR Monitoring Program manages cracking due to expansion and reaction with aggregates of concrete structures. The potential impact of ASR on the structural strength and anchorage capacity of concrete is a consequence of strains resulting from the expansive gel.

The Structures Monitoring Program performs visual inspections of the concrete structures at Seabrook for indications of the presence of alkali-silica reaction (ASR). ASR involves the formation of an alkali-silica gel which expands when it absorbs water. This expansion is volumetric in nature but is most readily detected by visual observation of cracking on the surface of the concrete. This cracking is the result of expansion that is occurring in the in-plane directions. Expansion is also occurring perpendicular (through the thickness of the wall) to the surface of the wall, but cracking will not be visible in this direction from the accessible surface. Cracking on the surface of the concrete is typically accompanied by the presence of moisture and efflorescence. Concrete affected by expansive ASR is typically characterized by a network or "pattern" of cracks. Micro-cracking due to ASR is generated through forces applied by the expanding aggregate particles and/or swelling of the alkali-silica gel within and around the boundaries of reacting aggregate particles. The ASR gel may exude from the crack forming white secondary deposits at the concrete surface. The gel also often causes a dark discoloration of the cement paste surrounding the crack at the concrete surface. If "pattern" or "map" cracking typical of concrete affected by ASR is identified, an evaluation will be performed to determine further actions.

Monitoring of crack growth is used to assess the in-plane expansion associated with ASR and to specify monitoring intervals. In selected locations, cores will be removed for modulus testing to establish the level of through-thickness expansion to date. Instruments (extensometers) will be placed in the resulting bore holes to monitor expansion in this direction going forward.

ASR is primarily detected by non-intrusive visual observation of cracking on the surface of the concrete. The cracking is typically accompanied by the presence of moisture and efflorescence. ASR may also be detected or confirmed by removal of concrete cores and subsequent petrographic analysis.

A Combined Cracking Index (CCI) is established at thresholds at which structural evaluation is necessary (see table below). The Cracking Index (CI) is the summation of the crack widths on the horizontal or vertical sides of 20-inch by 30-inch grid on the ASR-affected concrete surface. The horizontal and vertical Cracking Indices are averaged to obtain a Combined Cracking Index (CCI) for each area of interest. A CCI of less than the 1.0 mm/m can be deemed acceptable with deficiencies (Tier 2). Deficiencies determined to be acceptable with further review are trended for evidence of further degradation. The change from qualitative monitoring to quantitative monitoring occurs when the Cracking Index (CI) of the pattern cracking equals or is greater than 0.5 mm/m in the vertical and horizontal directions. Concrete crack widths less than 0.05 mm cannot be accurately measured and reliably repeated with standard, visual inspection equipment. A CCI of 1.0 mm/m or greater requires structural evaluation (Tier 3). All locations meeting Tier 3 criteria will be monitored via CCI on a ½ year (6-month) inspection frequency and added to the through-thickness expansion monitoring via extensometers. All locations meeting the Tier 2 structures monitoring criteria will be monitored on a 2.5 year (30-month) frequency. CCI correlates well with strain in the in-plane directions and the ability to visually detect cracking in exposed surfaces making it an effective initial detection parameter.

| **Tier** | **Structural Monitoring Program Category** | **Recommendation for Individual Concrete Components** | **Criteria** |
|---|---|---|---|
| 3 | Unacceptable (requires further evaluation) | • Structural Evaluation<br>• Implement enhanced ASR monitoring, such as through-wall expansion monitoring using Extensometers. | 1.0 mm/m or greater Combined Cracking Index (CCI) |

| | | | |
|---|---|---|---|
| 2 | Acceptable with Deficiencies | Quantitative Monitoring and Trending | ▪ 0.5 mm/m or greater CCI<br>▪ CI of greater than 0.5 mm/m in the vertical and horizontal directions. |
| | | Qualitative Monitoring | Any area with visual presence of ASR (as defined in FHWA-HIF-12-022) accompanied by a CI of less than 0.5 mm/m in the vertical and horizontal directions. |
| 1 | Acceptable | Routine inspection as prescribed by the Structural Monitoring Program | Area has no indications of pattern cracking or water ingress- No visual symptoms of ASR |

The Alkali-Silica Reaction Monitoring Program was initially based on published studies describing screening methods to determine when structural evaluations of ASR affected concrete are appropriate. Large scale destructive testing of concrete beams with accelerated ASR has confirmed that parameters being monitored are appropriate to manage the effects of ASR and that acceptance criterion of 1 mm/m a used provides sufficient margin.

CCI's limitation for heavily reinforced structures is that in-plane expansion, and therefore CCI, has been observed in the large scale test programs to plateau at a relatively low level of accumulated strain (approximately 1 mm/m). No structural impacts from ASR have been seen at these plateau levels in the large scale testing program at the University of Texas at Austin, Ferguson Structural Engineering Laboratory. While CCI remains useful for the detection and monitoring of ASR at the initial stages, an additional monitoring parameter in the out-of-plane direction is required to monitor more advanced ASR progression. ASR expansion in the out-of-plane direction will be monitored by borehole extensometers installed in drilled core bore holes.

Although the observed strains due to ASR are of very small magnitude and adequately monitored by CCI and extensometers, over large distances and with the right building geometry, they can result in discernable dimension changes in a structure. Additional monitoring of this relative displacement potential and its impact to plant systems and components is included in the ASR Monitoring Program. Specifically, monitoring includes identifying signs of relative displacement or building deformation (e.g., fire seal displacement, seismic gap width changes, pipe/conduit misalignments at penetrations or between adjacent structures, bent or displaced pipe/conduit and supports, doorway misalignments). Critical building geometry locations where the potential for deformation is likely will be monitored for displacement via location-specific techniques.

### 3.8.4.7.3 BUILDING DEFORMATION MONITORING PROGRAM

The Building Deformation Monitoring Program is a plant specific program implemented under the existing Maintenance Rule Structures Monitoring Program. Building

Deformation is an aging mechanism that may occur as a result of other aging effects of concrete. Building Deformation at Seabrook is primarily a result of the alkali silica reaction (ASR) but can also result from swelling, creep, and shrinkage. Building deformation can cause components within the structures to move such that their intended functions may be impacted.

The Building Deformation Monitoring Program uses visual inspections associated with the Structures Monitoring Program and cracking measurements associated with the Alkali-Silica Reaction program to identify buildings that are experiencing deformation. The first inspection is a baseline to identify areas that are exhibiting surface cracking. The surface cracking will be characterized and analytically documented. This inspection will also identify any local areas that are exhibiting deformation. The amount of components experiencing deformation and the extent of surface cracking will be input into an analytical model. This model will determine the extent of building deformation and the frequency of required visual inspections.

For building deformation, location-specific measurements (e.g. via laser target and gap measurements) will be compared against location-specific criteria to evaluate acceptability of the condition.

Structural evaluations will be performed on buildings and components affected by deformation as necessary to ensure that the structural function is maintained. Evaluations of structures will validate structural performance against the design basis, and may use results from the large-scale test programs, as appropriate.

Evaluations for structural deformation will also consider the impact to functionality of affected systems and components (e.g., conduit expansion joints). NextEra will evaluate the specific circumstances against the design basis of the affected system or component. Structural evaluations will be used to determine whether additional corrective actions (e.g., repairs) to the concrete or components are required. Specific criteria for selecting effective corrective actions will be evaluated on a location-specific basis.

### 3.8.6 References

1. Wilson, E.L., "Structural Analysis of Axisymmetric Solids," AIAAJ. Vol. 3, No. 12 (1965) pp. 163-182.
2. Wilson, E.L., "A Digital Computer Program for the Finite Element Analysis of Axisymmetric Solids with Orthotropic, Nonlinear Material Properties," November 1969.
3. Duchon, N.B., "Analysis of Reinforced Concrete Membrane Subject to Tension and Shear," ACI Journal, September, 1972, pp. 578-583.
4. Wilson, E.L. and Nicholl, R.E., "Application of the Finite Element Method to Heat Conduction Analysis," Journal of Nuclear Engineering and Design, Vol. 4, 1966.
5. Alexandria, S. C., Effects of Irradiation of Concrete, Final Results, Research Reactor Division UKAEA, Harwell, AERE-R-4490, December 1963.
6. Foreign Print 100716, Impact of ASR on Structures.
7. MPR-4288, Revision 0, "Seabrook Station: Impact of Alkali-Silicia Reaction on the Structural Design Evaluations," July 2016. FP#101020

(3) The stiffness values used for support design were:

| Pipe size (OD, in.) | Stiffness (lb./in.) |
|---|---|
| Up to 2½ | $1\text{x}10^4$ |
| 2½ to 6 | $1\text{x}10^5$ |
| Above 6 | $1\text{x}10^6$ |

In those cases where the support stiffness was less than that specified above, the piping analysis was reviewed to determine the impact on the component.

(4) Component supports are designed to be in the rigid range (natural frequency fn≥33 Hz). In cases where the frequency is less than 33 Hz, the analysis of the piping system was reviewed to assure that the piping analysis remained valid.

(5) The thermal movement of the component at the support was accommodated through clearance included in the component support design.

(6) Component supports are connected to concrete walls and slabs by either welding to embedded plates, or by bolting to the concrete with either concrete expansion anchors (wedge type) or concrete inserts. The response to the NRC's IE Bulletin No. 79-02, (Reference 2), was used as a guide for the design of the concrete expansion anchors. The maximum allowable design loads for the concrete expansion anchors for ASME Class 1, 2, and 3 supports were developed using the manufacturer's ultimate loads and a safety factor of 4 for worst case loading (normal and upset or faulted loads). Embedded plates, expansion anchors, and concrete inserts installed in concrete degraded by ASR provide full structural capacity up to the ASR expansion level defined in Table 3.8-18.

Baseplate flexibility and shear-tension interaction were accounted for in the design of the concrete expansion anchors.

**TABLE 3.8-1** CONTAINMENT LOAD COMBINATIONS AND LOAD FACTORS(5)

| | | | | LOADING$^{(6)}$ | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | $R_r$ (DBA Local Effects) | | | | | |
| Design Conditions | Category | Load Combination Number | Dead Load | Live Load | ASR Load | Test Pressure | Accident Pressure | Test Temperature | Normal Temperature | DBA Temperature | Operating Basis Earthquake | Safe Shutdown Earthquake | Wind Load | Tornado | Normal Pipe Reaction | DBA Thermal Pipe Reaction | Reaction of Ruptured High Energy Pipe | Jet Impingement Loads | Impact of Ruptured High Energy Pipe | Pressure Variations | Design Basis Flood |
| | Loading Notation | | D | L | $S_a$ | $P_t$ | $P_a$ | $T_t$ | $T_o$ | T$^{(1)}$ | $E_o$ | $E_{ss}$ | W | $W_t$ | $R_o$ | $R_a$ | $R_{rr}$ | $R_{rj}$ | $R_{rm}$ | P$^{(2)}$ | F$^{(3)}$ |
| Service Load | Test | 1 | 1.0 | 1.0 | 1.0 | 1.0 | - | 1.0 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Normal | 2 | 1.0 | 1.0 | 1.0 | - | - | - | 1.0 | - | - | - | - | - | 1.0 | - | - | - | - | 1.0 | - |
| | Severe Environmental | 3 | 1.0 | 1.0 | 1,0 | - | - | - | 1.0 | - | 1.0 | - | - | - | 1.0 | - | - | - | - | 1.0 | - |
| Factored Load | Severe Environmental | 4 | 1.0 | 1.3 | 1.0 | - | - | - | 1.0 | - | 1.5 | - | - | - | 1.0 | - | - | - | - | 1.0 | - |
| | Extreme Environmental | 5a | 1.0 | 1.0 | 1.0 | - | - | - | 1.0 | - | - | - | - | 1.0$^{(7)}$ | 1.0 | - | - | - | - | 1.0 | 1.0 |
| | | 5b | 1.0 | 1.0 | 1.0 | - | - | - | 1.0 | - | - | 1.0 | - | 1.0$^{(7,8)}$ | 1.0 | - | - | - | - | 1.0 | - |
| | Abnormal | 6a | 1.0 | 1.0 | 1.0 | - | 1.5$^{(4)}$ | - | - | 1.0$^{(4)}$ | - | - | - | - | - | 1.0 | - | - | - | - | - |
| | | 6b | 1.0 | 1.0 | 1.0 | - | 1.0$^{(4)}$ | - | - | 1.0$^{(4)}$ | - | - | - | - | - | 1.25 | - | - | - | - | - |
| | Abnormal/Severe Environmental | 7 | 1.0 | 1.0 | 1.0 | - | 1.25$^{(4)}$ | - | - | 1.0$^{(4)}$ | 1.25 | - | - | - | - | 1.0 | 1.0 | 1.0 | 1.0 | - | - |
| | Abnormal/Extreme Environmental | 8 | 1.0 | 1.0 | 1.0 | - | 1.0$^{(4)}$ | - | - | 1.0$^{(4)}$ | - | 1.0 | - | - | | 1.0 | 1.0 | 1.0 | 1.0 | - | - |

**TABLE 3.8-14** INTERIOR CONTAINMENT STRUCTURES BASIC LOAD COMBINATIONS AND LOAD FACTORS

| Design Conditions | Material<br>Loading Notations | | Load Case Number | LOADING(1)<br>Dead Load and Hydrostatic Load | Live Load | ASR Loads | Accident Pressure | Operational Temperature | Accident Temperature | Operating Basis Earthquake | Safe Shutdown Earthquake | Operational Piping Loads | Accident Piping Loads | Jet Force Reaction | Jet Impingement Loads | Missile Impact Loads | Internal Missile Loads | Stress Limit or Design Criteria |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | D | L | $S_a$ | $P_a$ | $T_o$ | $T_a$ | $E_o$ | $E_{ss}$ | $R_o$ | $R_a$ | $R_{rr}$ | $R_{rj}$ | $R_{rm}$ | M | |
| Normal Load | Structural Steel | | 1S | 1.0 | 1.0 | - | - | - | - | - | - | - | - | - | - | - | - | ≤$F_s$ Per AISC |
| | | | 2S | 1.0 | 1.0 | - | - | - | - | 1.0 | - | - | - | - | - | - | - | |
| | | | 3S | 0.67 | 0.67 | - | - | 0.67 | - | - | - | 0.67 | - | - | - | - | - | |
| | | | 4S | 0.67 | 0.67 | - | - | 0.67 | - | 0.67 | - | 0.67 | - | - | - | - | - | |
| | Concrete | | 1C | 1.4 | 1.7 | 2.0 | - | - | - | - | - | - | - | - | - | - | - | ACI 318-71 |
| | | | 2C | 1.4 | 1.7 | 1.3 | - | - | - | 1.9 | - | - | - | - | - | - | - | |
| | | | 3C | - | - | | - | - | - | - | - | - | - | - | - | - | - | |
| | | | 4C | 1.05 | 1.28 | 1.0 | - | 1.28 | - | 1.43 | - | 1.28 | - | - | - | - | - | |
| Unusual Load | (3) (4) | Elastic | 5S | 0.63 | 0.63 | - | - | 0.63 | - | - | 0.63 | 0.63 | - | - | - | - | - | ≤$F_s$ Per AISC |
| | | | 6S | 0.63 | 0.63 | - | 0.63 | - | 0.63 | - | - | - | 0.63 | - | - | - | - | |
| | | | 7S | 0.63 | 0.63 | - | 0.63 | - | 0.63 | 0.63 | - | - | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | |
| | | | 8S | 0.59 | 0.59 | - | 0.59 | - | 0.59 | - | 0.59 | - | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | |
| | Structural Steel | Plastic | 5S | 1.1 | 1.1 | - | - | 1.1 | - | - | 1.1 | 1.1 | - | - | - | - | - | AISC, Part II |
| | | | 6S | 1.1 | 1.1 | - | 1.7 | - | 1.1 | - | - | - | 1.1 | - | - | - | - | |
| | | | 7S | 1.1 | 1.1 | - | 1.4 | - | 1.1 | 1.4 | - | - | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | |
| | (3) (4) | | 8S | 1.1 | 1.1 | - | 1.1 | - | 1.1 | - | 1.1 | - | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | |
| | Concrete | | 5C | 1.0 | 1.0 | 1.0 | - | 1.0 | - | - | 1.0 | 1.0 | - | - | - | - | - | ACI 318-71 |
| | | | 6C | 1.0 | 1.0 | 1.0 | 1.5 | - | 1.0 | - | - | - | 1.0 | - | - | - | - | |
| | | | 7C | 1.0 | 1.0 | 1.0 | 1.25 | - | 1.0 | 1.25 | - | - | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 | |
| | (4) | | 8C | 1.0 | 1.0 | 1.0 | 1.0 | - | 1.0 | - | 1.0 | - | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | |

($F_s$ = Allowable Stress)

(1) See Subsection 3.8.3.3 for discussion of loadings.

(2) In above load combinations, the peak values of $P_a$, $T_a$, $R_a$, $R_{rj}$, $R_{rr}$, $R_{rm}$ and M shall be combined (when they act concurrently) unless time history analysis is performed to justify otherwise.

(3) For these load combinations either elastic or plastic design may be used.

(4) Load combinations 7S, 8S, 7C and 8C are also checked without $R_{rr}$, $R_{rj}$, $R_{rm}$.

(5) Where ASR strains are greater than 0.05% (0.5 mm/m), ASR load factors may be reduced by 20% but shall not be taken as less than 1.0.

**TABLE 3.8-16** CATEGORY I, STRUCTURES OTHER THAN REACTOR CONTAINMENT STRUCTURE OR ITS INTERNALS BASIC LOAD COMBINATIONS AND LOAD FACTORS

| | | | | Loading(1), (4) | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | All Structures | | | | | | | Concrete Only | | | Certain Structures, Where Appropriate | | | | | | | | | | | |
| | Material | | | | | | | | | | | | | | | | | Pipe Break Loads (Rr) | | | | | | | |
| Design Conditions | | | Required Strength | Dead Load and Hydrostatic Load | Live Load | Operational Temperature | Operating Basis Earthquake | Safe Shutdown Earthquake | Wind | Tornado Wind | Lateral Earth Pressuress | Earth Pressure due to OBE | Earth Pressure due to SSE | ASR Load (6) | Operational Piping Loads | Accident Pressure | Accident Piping Loads | Jet Impingement Loads | Missile Impact Loads | Jet Force Reaction | Internal Missile Loads | Accident Temperature | Design basis Flood | Unusual Snow Load | Stress Limit (5) or Design Criteria |
| | Loading Notations | | | D | L | $T_o$ | $E_o$ | $E_s$ | W | $W_t$ | E | $H_e$ | $H_s$ | $S_a$ | $R_o$ | $P_a$ | $R_a$ | $R_{rj}$ | $R_{rm}$ | $R_{rr}$ | M | $T_a$ | F | Ls | |
| Normal Load | Structural Steel | | S | 1.0 | 1.0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | $\le F_s$ Per AISC |
| | | | | 1.0 | 1.0 | - | 1.0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | | |
| | | | | 1.0 | 1.0 | - | - | - | 1.0 | - | - | - | - | - | - | - | - | - | - | - | - | - | | | |
| | | | | 0.67 | 0.67 | 0.67 | - | - | - | - | - | - | - | - | 0.67 | - | - | - | - | - | - | - | | | |
| | | | | 0.67 | 0.67 | 0.67 | 0.67 | - | - | - | - | - | - | - | 0.67 | - | - | - | - | - | - | - | | | |
| | | | | 0.67 | 0.67 | 0.67 | - | - | 0.67 | - | - | - | - | - | 0.67 | - | - | - | - | - | - | - | | | |
| | Concrete | | U | 1.4 | 1.7 | - | - | - | - | - | 1.7 | - | - | 2.0 | - | - | - | - | - | - | - | - | | | ACI 318-71 |
| | | | | 1.4 | 1.7 | - | 1.9 | - | - | - | 1.7 | 1.9 | - | 1.3 | - | - | - | - | - | - | - | - | | | |
| | | | | 1.4 | 1.7 | - | - | - | 1.7 | - | 1.7 | - | - | 1.7 | - | - | - | - | - | - | - | - | | | |
| | | | | 1.05 | 1.28 | 1.28 | - | - | - | - | 1.28 | - | - | 1.5 | 1.28 | - | - | - | - | - | - | - | | | |
| | | | | 1.05 | 1.28 | 1.28 | 1.43 | - | - | - | 1.28 | 1.43 | - | 1.0 | 1.28 | - | - | - | - | - | - | - | | | |
| | | | | 1.05 | 1.28 | 1.28 | - | - | 1.3 | - | 1.28 | - | - | 1.28 | 1.28 | - | - | - | - | - | - | - | | | |
| | | | | 1.2 | - | - | - | - | 1.7 | - | 1.7 | - | | 1.7 | - | - | - | - | - | - | - | - | | | |
| | | | | 1.2 | - | - | 1.9 | - | - | - | 1.7 | 1.9 | | 1.3 | - | - | - | - | - | - | - | - | | | |
| Unusual Load | Structural Steel | Elastic | | 0.63 | 0.63 | 0.63 | - | 0.63 | - | - | - | - | - | - | 0.63 | - | - | - | - | - | - | - | | | $\le F_s$ Per AISC |
| | | | S | 0.63 | 0.63 | 0.63 | - | - | - | 0.63 | - | - | - | - | 0.63 | - | - | - | - | - | - | - | | | |
| | | | (2) | 0.63 | 0.63 | - | - | - | - | - | - | - | - | - | - | 0.63 | 0.63 | - | - | - | - | 0.63 | | | |
| | | | (2) | 0.63 | 0.63 | - | 0.63 | - | - | - | - | - | - | - | - | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 | | | |
| | | | | 0.59 | 0.59 | - | - | 0.59 | - | - | - | - | - | - | - | 0.59 | 0.59 | 0.59 | 0.29 | 0.29 | 0.29 | 0.59 | | | |
| | | Plastic | | 1.1 | 1.1 | 1.1 | - | 1.1 | -- | - | - | - | - | - | 1.1 | - | - | - | - | - | - | - | | | AISC, Part II |
| | | | Y | 1.1 | 1.1 | 1.1 | - | - | - | 1.1 | - | - | - | - | 1.1 | - | - | - | - | - | - | - | | | |
| | | | | 1.1 | 1.1 | - | - | - | - | - | - | - | - | - | - | 1.7 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | | | |
| | | | (*) | 1.1 | 1.1 | - | 1.4 | - | - | - | - | - | - | - | - | 1.4 | 1.1 | - | - | - | - | 1.1 | | | |
| | | | (*) | 1.1 | 1.1 | - | - | 1.1 | - | - | - | - | - | - | - | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | | | |
| | Concrete | | U | 1.0 | 1.0 | 1.0 | - | 1.0 | - | - | 1.0 | - | 1.0 | 1.0 | 1.0 | - | - | - | - | - | - | - | | | ACI 318-71 |
| | | | | 1.0 | 1.0 | 1.0 | - | - | - | 1.0 | 1.0 | - | - | 1.0 | 1.0 | - | - | - | - | - | - | - | | | |
| | | | | 1.0 | 1.0 | - | - | - | - | - | 1.0 | - | - | 1.0 | - | 1.5 | 1.0 | - | - | - | 1.1 | 1.0 | | | |
| | | | | 1.0 | 1.0 | - | 1.25 | - | - | - | 1.0 | 1.25 | - | 1.0 | - | 1.25 | 1.0 | 1.0 | 1.0 | 1.0 | - | 1.0 | | | |
| | | | | 1.0 | 1.0 | - | - | 1.0 | - | - | 1.0 | - | 1.0 | 1.0 | - | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | | | |
| | | | | 1.0 | 1.0 | 1.0 | - | - | 1.0 | - | - | - | - | 1.0 | 1.0 | - | - | - | - | - | - | - | (3) | 1.0 | |
| | | | | 1.0 | 1.0 | 1.0 | - | - | 1.0 | - | - | - | - | 1.0 | 1.0 | - | - | - | - | - | - | - | 1.0 | 1.0 | |

(1) In above load combinations, the peak values of $P_a$, $T_a$, $R_a$, $R_{rj}$, $R_{rr}$, $R_{rm}$ and M shall be combined (when acting concurrently) unless time history analysis is performed to justify otherwise.

(2) Elastic cases to be checked for overall stability by the plastic load combination cases as indicated by (*).

(3) For design bases flood load case, elevation shall be the effective maximum ground water elevation i.e., El. + 20'-0".

(4) See Subsection 3.8.4.3 for discussion of loadings.

(5) ($F_s$ = Allowable Stress)

~~(5)~~(6) Where ASR strains are greater than 0.05% (0.5 mm/m), ASR load factors may be reduced by 20% but not be taken as less than 1.0.

## **TABLE 3.8-17** **COMPUTER PROGRAMS USED IN THE ANALYSIS AND DESIGN OF OTHER SEISMIC CATEGORY I STRUCTURES**

| Computer Program | Structures On Which Used |
|---|---|
| 1. MRI/STARDYNE (Static Analysis) | Control & Diesel Generator Building |
| | Fuel Storage Building |
| | Main Steam and Feedwater Pipe Chase (East) |
| | Main Steam and Feedwater Pipe Chase (West) |
| | Pre-Action Valve Area |
| | Primary Auxiliary Building Including Residual Heat Removal Equipment Vault |
| | Service Water Cooling Towers Including Switchgear Room |
| | Service Water Pumphouse |
| 2. MARC-CDC (Static Analysis) | Containment Enclosure Building |
| 3. LESCAL (Design of Reinforcing Steel) | Containment Enclosure Building |
| | Main Steam and Feedwater Pipe Chase (East) |
| 4. GENSAP (Static Analysis) | Containment Enclosure Ventilation Area |
| | Emergency Feedwater Pump Building Including Electrical Cable Tunnels and Penetration Areas |
| | Piping Tunnels |
| 5. MULTISPAN (Static Analysis) | Service Water Cooling Towers |
| | |
| 6. ANSYS (ASR Deformation) | Containment Enclosure Building |

**TABLE 3.8-18 ASR EXPANSION LIMITS FOR STRUCTURAL LIMIT STATES**

| Structural Limit State | ASR Expansion Limit |
|---|---|
| Shear | See FP#101020 - Section 2.1 (Ref 7) |
| Flexure | See FP#101020 - Section 2.1 (Ref 7) |
| Reinforcement Anchorage | See FP#101020 - Section 2.1 (Ref 7) |
| Anchors | See FP#101020 - Section 2.1 (Ref 7) |
| Compression | Note 1 |

(1) Compressive load from ASR in the direction of reinforcement is combined and evaluated with other applied compressive loads.