UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

In the Matter of NEXTERA ENERGY SEABROOK, LLC (Seabrook Station, Unit 1)	Docket No. 50-443-LA-2 ASLBP No. 17-953-02-LA-BD01

Hearing Exhibit

Exhibit Number: INT017

Exhibit Title: Revised Seabrook Station License Renewal Application Appendix B Sections B.2.1.31 for Structures Monitoring, B.2.1.31A for Alkali-Silica Reaction and B.2.1.3b for Building Deformation (Enclosure 2 to Letter SBK-18072)

Enclosure 2 to SBK-L- 18072

Revised Seabrook Station License Renewal Application Section B.2.1.31 for Structures Monitoring, Section B.2.1.31A for Alkali-Silica Reaction (ASR) and Section B.2.1.31B for Building Deformation Aging Management Programs

B.2.1.31 STRUCTURES MONITORING PROGRAM

Program Description

The Seabrook Station Structures Monitoring Program (SMP) is an existing program that will be enhanced to ensure provision of aging management for structures and structural components including bolting within the scope of this program. The Structures Monitoring Program is implemented through the Seabrook Station Maintenance Rule Program, which is based on the guidance provided in NRC Regulatory Guide 1.160, Revision 2, *"Monitoring the Effectiveness of Maintenance at Nuclear Power Plants"* and NUMARC 93-01, Revision 2," *Industry Guidance 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 Seabrook Station Structures Monitoring Program was developed using the guidance of these three documents 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.

The Seabrook Station Structures Monitoring Program includes periodic visual inspection of structures and structural components for the detection of aging effects specific for that structure. These inspections are completed by qualified individuals at a frequency determined by the characteristics of the environment in which the structure is found. A structure found in a harsh environment is defined as one that is in an area that is subject to outside ambient conditions, very high temperature, high moisture or humidity, frequent large cycling of temperatures, frequent exposure to caustic materials, or extremely high radiation levels. For structures in these harsh environments, the inspection is conducted on a five year basis (plus or minus one year due to outage schedule and two inspections within ten years). Structures not found in areas qualifying as a harsh environment are classified as being in a mild environment, and are inspected on a ten year basis (plus or minus one year due to outage schedule and two inspections within twenty years).

Individuals conducting the inspection and reviewing the results are qualified per the Seabrook Station Structures Monitoring Program, which is in accordance with the requirements specified in ACI 349.3R-96, *"Evaluation of Existing Nuclear Safety related Concrete Structures"*. Individuals conducting the inspection and reviewing the results are to possess expertise in the design and inspection of steel, concrete and masonry structures. These individuals must either be a licensed Professional Engineer experienced in this area, or will work under the direction of a licensed Professional Engineer experienced in this area.

The station SMP identifies plant equipment impacted or potentially impacted by building deformation through baseline and periodic walkdowns of the structures. The as-found conditions of the items of interest are evaluated and recommendations for repair or periodic monitoring are established in accordance with the Corrective Action Program.

Detection of aggressive subsurface environments will be completed through the sampling of groundwater. This procedure monitors groundwater for chloride concentration, sulfate concentration and pH on a 5 year basis

The Structures Monitoring Program will include an external surface inspection of the aboveground steel tanks 1-FP-TK-35-A, 1-FP-TK-35-B, 1-FP-TK-36-A, 1-FP-TK-36-B, and 1-AB-TK-29. This inspection will inspect the paint or coating for cracking, flaking, or peeling.

Examination of inaccessible areas, such as buried concrete foundations, will be completed during inspections of opportunity or during focused inspections. An evaluation of these opportunistic or focused inspections for buried concrete will be performed under the Maintenance Rule Program every 5 years (if no opportunistic inspection was performed during a 5-year period, a focused 5 year inspection is required) to ensure that the condition of buried concrete foundations on site is characterized sufficiently to provide reasonable assurance that the foundations on site will perform their intended function through the period of extended operation. To date Seabrook Station has performed numerous opportunistic inspections of buried concrete structures to confirm the characterization of ASR affected structures (e.g. switchyard generator step up transformer pit inspections in 2014, and Unit 2 Circulating Water Vault in 2015). Additional inspections may be performed in the event that an opportunistic or focused inspection or visible portions of the concrete foundation reveal degradation and will be entered into the Corrective Action Program (CAP).

Concrete structures were constructed equivalent to recommendations in ACI 201.2R, *"Guide for Making a Condition Survey of Concrete in Service"*. Loss of material due to leaching of calcium hydroxide is considered to be an aging effect requiring management for Seabrook Station. There have been indications of leaching in below grade concrete in Seabrook Station structures. Leaching of calcium hydroxide from reinforced concrete becomes significant only if the concrete is exposed to flowing water. Resistance to leaching is enhanced by using a dense, well-cured concrete with low permeability. These structures are designed in accordance with ACI 318 and constructed in accordance with ACI 301 and ASTM standards. Nevertheless, Seabrook Station manages loss of material due to leaching of calcium hydroxide with visual inspection through the Structures Monitoring Program.
Seabrook Station has scheduled specific actions to determine the effects of aggressive chemical attack due to high chloride levels in the groundwater. Seabrook Station has scheduled concrete testing during the second and third quarter of 2010. An evaluation will be performed based on the results of the testing and a determination of the concrete condition which may lead to additional testing or increased inspection frequency. Testing of concrete may consist of the following:

a. concrete core samples
b. penetration resistance tests
c. petrographic analysis of the concrete core samples
d. visual inspection of rebar as they are exposed during the concrete coring

NextEra Energy Seabrook will evaluate the results of the testing and, if required, undertake additional corrective actions in accordance with the Structures Monitoring Program CAP.

The Seabrook Station Structures Monitoring Program does not credit protective coatings for management of aging effects on structures and structural components within the scope of this program.

There are no preventative actions specified in the Seabrook Station Structures Monitoring Program, which includes implementation of NUREG-1801 XI.S5, XI.S6, and XI.S7. These are monitoring programs only.

The parameters monitored in the Seabrook Station Structures Monitoring Program are in agreement with ACI 349.3R-96 and ASCE 11-90, "*Structural Condition Assessment of Buildings*".

Concrete deficiencies are classified using the criteria specified in the Seabrook Station Structures Monitoring Program, which is based on the guidance provided in ACI 201.1R-2, "*Guide for Making a Condition Survey of Concrete in Service*".

As noted in the Seabrook Station response to NRC IN 98-26, *"Settlement Monitoring and Inspection of Plant Structures Affected by Degradation of Porous Concrete Subfoundations"*, porous concrete was not used in the construction of building sub-foundations at Seabrook Station.

Monitoring of structures and structural components in the scope of the Seabrook Station Structures Monitoring Program is performed in compliance with Regulatory Position 1.5 of NRC Regulatory Guide 1.160. The condition of all structures within the scope of this program is assessed on a periodic basis as specified by 10 CFR 50.65. Structures that do not meet their design basis at the time of inspection due to the extent of degradation, or that may not meet their design basis at the next normally scheduled inspection due to further degradation without intervention are entered into the Corrective Action Program and evaluated for corrective action and/or additional inspections as delineated in 10 CFR 50.65(a)(1). In addition, structures may also be scheduled for follow-up inspections following the completion of any corrective actions to that structure.

The condition of any structure subject to additional inspections or corrective actions is recorded through Seabrook Station Structures Monitoring Program reports to provide a basis for scheduling additional inspections and any required corrective actions in the future, as specified the Seabrook Station Structures Monitoring Program.

Structures that are determined to be acceptable under the Maintenance Rule structural inspections are monitored as specified in 10 CFR 50.65(a)(2).

Evaluations of a structure's condition assess the extent of any degradation of the structural member in accordance with industry standards and the judgment of the qualified individuals performing the inspections.

The acceptance guidelines in the Seabrook Station Structures Monitoring Program are a three-tier hierarchy similar to that described in ACI 349.3R-96, which provides quantitative degradation limits. Under this system, structures are evaluated as being acceptable, acceptable with deficiencies, or unacceptable. Evaluations of a structure's condition are completed according to the guidelines set forth in the Seabrook Station Structures Monitoring Program.

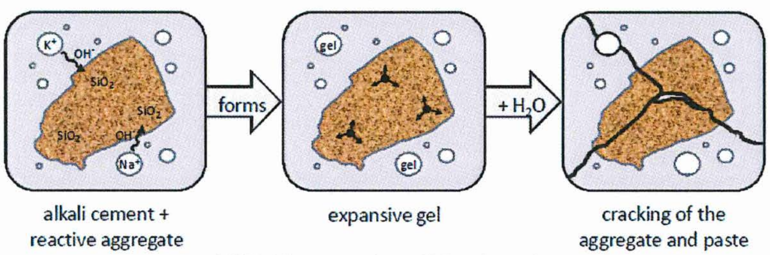
B.2.1.31A ALKALI-SILICA REACTION

PROGRAM DESCRIPTION

The Alkali-Silica Reaction (ASR) Aging Management Program (AMP) is a new plant specific program being implemented under the existing Maintenance Rule Structures Monitoring Program that will manage the aging effects related to Alkali-Silica Reaction of each structure and component subject to an Aging Management Review, so that the intended function(s) will be maintained consistent with the current licensing basis for the period of extended operation.

Alkali-Silica Reaction

Alkali-Silica Reaction is an aging mechanism that may occur in concrete under certain circumstances. It is a reaction between the alkaline cement and reactive forms of silicate material (if present) in the aggregate. The reaction, which requires moisture to proceed, produces an expansive gel material. This expansion results in strains in the material that can produce micro-cracking in the aggregate and in the cement paste. The potential impact of ASR on the structural strength and anchorage capacity of concrete is a consequence of strains resulting from the expansive gel. These strains produce the associated cracking. Because the ASR mechanism requires the presence of moisture in the concrete, ASR has been predominantly detected in groundwater impacted portions of below grade structures, with limited impact to exterior surfaces of above grade structures.



ASR Expansion Mechanism

Impact of Confinement

Reinforcing steel, loads on the concrete structure (i.e., deadweight of the structure itself), and the configuration of the structure provide confinement that restrains in-situ expansion of the gel and limits the resulting cracking in concrete.

Since the impact of ASR on mechanical properties relates to the extent of cracking, restraint of the expansion limits the reduction of in-situ mechanical properties and overall degradation of structural performance. There is a prestressing effect that occurs when reinforcement restrains the expansion caused by ASR. This effect is similar to concrete prestressing or analogous to pre-loading a bolted joint.

The concrete prestressing effect is only present when the concrete is confined. If the concrete is removed from the stress field, the concrete prestressing effect is lost. For example, a core taken from a reinforced concrete structure that has been affected by ASR will lose the confinement provided by the reinforcement and concrete surrounding the sample, and therefore is no longer representative of the concrete within its structural context.

Seabrook Station Concrete

The concrete mix designs used in original construction at Seabrook Station utilized an aggregate that was susceptible to ASR, which was not known at the time. Although testing was conducted in accordance with the ASTM C289 standards, the test method was subsequently identified as limited in its ability to predict long term ASR for moderate to low reactive aggregates. ASTM C289 has since been withdrawn.

In 2009, Seabrook Station tested seasonal groundwater samples to support the development of a License Renewal Application. The results showed that the groundwater had become aggressive and NextEra Energy Seabrook initiated a comprehensive review of possible effects to in-scope structures.

A qualitative walkdown of plant structures was performed and the "B" Electrical Tunnel was identified as showing the most severe indications of groundwater infiltration. Concrete core samples from this area were removed, tested for compressive strength and modulus of elasticity, and subjected to petrographic examinations. While the results showed that both compressive strength and modulus of elasticity had declined, the structure was determined to be within its design basis and therefore remained able to perform its design function. The results of petrographic examinations on the core samples identified Alkali-Silica Reaction (ASR). This discovery prompted an Extent of Condition evaluation. Because the ASR mechanism requires the presence of moisture or very high humidity in the concrete, ASR has been predominantly detected in portions of below-grade structures, with limited impact to exterior surfaces of above grade structures.

Large-Scale Testing Program

The structural assessment of ASR-affected structures at Seabrook Station considered the various limit states for reinforced concrete and applied available literature data to evaluate structural capacity. This evaluation identified gaps in the publicly available test data and the applicability to the reinforcement concrete at Seabrook Station. The limited available data for shear capacity and reinforcement anchorage for ASR-affected reinforced concrete with two-dimensional reinforcement mats were not representative of Seabrook Station. This conclusion was driven largely by the facts that the literature data for reinforcement anchorage were from a test method that ACI indicates is unrealistic and the literature data for shear capacity were from test specimens only inches in size. Additionally, no data were available on anchor bolt capacity on reinforced concrete with two dimensional reinforcement mats like Seabrook Station.

The need for Seabrook Station 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 Energy Seabrook 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 impact of ASR on structural limit states and on selected design considerations[2]. This assessment supports use of the test results in structural calculations.

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 dimensions. The in-plane dimension refers to measurements taken in a plane parallel to the underlying reinforcement bars. There was no reinforcement in the through-thickness direction (perpendicular to the in-plane direction). ASR expansion measurements were taken throughout the test programs. The test programs assessed flexural capacity and reinforcement anchorage, shear capacity, and capacity of anchor bolts and structural attachments to concrete). The results of the shear and reinforcement anchorage test programs demonstrated that there was no adverse effect; on structural performance in these limit states when ASR expansion levels were below those in the test specimens. The results of the anchor test program demonstrated that there was no adverse effect on anchor capacity except at high levels of ASR expansion.

The effect of ASR on compressive strength was not assessed in the large-scale test program. An evaluation of compression using existing data from published literature sources was performed. 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 Station structures (i.e., are more severe than at Seabrook Station), 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 are not testing data for these more advanced levels of ASR, periodic monitoring of ASR at Seabrook is necessary to ensure that the level of ASR does not exceed that observed in the test programs, which ensures that the conclusions of the large-scale test program remain applicable.

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 Station structures are below the levels at which limit state capacities are reduced.

---

[2] FP #101020 MPR-4288, Revision 0, "Seabrook Station: Impact of Alkali-Silica Reaction on the Structural Design Evaluations," July 2016

One of the objectives of the large-scale 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.

In-plane expansion can be monitored using embedded pins or the Combined Cracking Index (CCI). Embedded pin measurements determine changes in ASR expansion more precisely than CCI measurements over the duration of a monitoring period, since the embedded pin measurements are performed using a calibrated mechanical device capable of measuring changes in length as small as 0.0001 inch. However, embedded in-plane expansion measurements are only able to capture strains that occur after the gage points are installed in the concrete surface after initial (baseline) measurements are made. For use at Seabrook Station, CCI provides a reasonable value for expansion to date. Once the CCI is calculated and the expansion level is quantified, reference pin measurements can be used to monitor future expansion.

Snap ring borehole extensometers (SRBEs) provided accurate and reliable measurements for monitoring through-thickness expansion.

Results from the large-scale test program are used to support evaluations of structures subjected to deformation. These evaluations are discussed in the Building Deformation Aging Management Program in LRA Section B.2.1.31B.

PROGRAM ELEMENTS

The following provides the results of the evaluation of each program element against the 10 elements described in Appendix A of NUREG-1800 Rev. 1, *"Standard Review Plan for Review of License Renewal Applications for Nuclear Power Plants"*.

ELEMENT 1 - SCOPE OF PROGRAM

The Alkali-Silica Reaction (ASR) Aging Management Program (AMP) provides for management of aging effects due to the presence of ASR. The program scope includes concrete structures within the scope of the License Renewal Structures Monitoring Program and License Renewal ASME Section XI Subsection IWL Program. License Renewal concrete structures within the scope of this program include:

Category I Structures

- Containment Building (including equipment hatch missile shield)
- Containment Enclosure Building
- Containment Enclosure Ventilation Area
- Service Water Cooling Tower including Switchgear Rooms
- Control Building
- Control Building Make-up Air Intake Structures
- Diesel Generator Building
- Piping (RCA) Tunnels
- Main Steam and Feed Water East and West Pipe Chase
- Waste Processing Building

- Tank Farm
- Condensate Storage Tank Enclosure
- Emergency Feed Water Pump House Building, including Electrical Cable Tunnels and Penetration Areas (Control Building to Containment)
- Fuel Storage Building
- Primary Auxiliary Building including RHR Vaults
- Service Water Pump House
- Service Water Access (Inspection) Vault
- Circulating Water Pump House Building (below elevation 21'-0)
- Safety Related Electrical Manholes and Duct Banks
- Pre-Action Valve Building

Miscellaneous Non-Category I Yard Structures

- SBO Structure – Transformers and Switch Yard foundations
- Non-Safety-Related Electrical Cable Manhole, Duct Bank Yard Structures foundations
- Switchyard and 345 KV Power Transmission foundations

Non-Category I Structures

- Turbine Generator Building
- Fire Pump House
- Aboveground Exterior Tanks 1-FP-TK-35-A, 1-FP-TK-35-B, 1-FP-TK-36-A, 1-FP-TK-36-B and 1-FP-TK-29 foundations
- Fire Pump House Boiler Building
- Non-Essential Switchgear Building
- Steam Generator Blowdown Recovery Building
- Intake & Discharge Transition Structures

ELEMENT 2 - PREVENTIVE ACTIONS

There are no preventive actions specified in the Seabrook Station Structures Monitoring Program, which includes implementation of NUREG-1801 XI.S5, XI.S6, and XI.S7. These are monitoring programs only. Similarly, the ASR AMP does not rely on preventive actions.

ELEMENT 3 - PARAMETERS MONITORED/INSPECTED

The Alkali-Silica Reaction (ASR) AMP manages the effects of cracking due to expansion and reaction with aggregates. The potential impact of ASR on the structural performance and anchorage capacity of concrete is a consequence of strains resulting from the expansive gel. The strains consequently produce the associated cracking.

The program focuses on identifying evidence of ASR, which could lead to expansion due to the reaction with aggregates. The program reflects published guidance for condition assessment of structures and incorporates practices consistent with those used as part of the large-scale testing programs.

Initial screening of ASR

Walkdowns of the station are performed on a periodic basis (SMP walkdowns, Systems Walkdowns, etc.). Visual symptoms of deterioration are noted and compared to those commonly observed on structures affected by ASR. Common visual symptoms of ASR include, but are not limited to, "map" or "pattern" cracking and surface discoloration of the cement paste surrounding the cracks. The cracking is typically accompanied by the presence of moisture and efflorescence. The lists of symptoms associated with the initial screening of ASR is consistent with many published documents, including but not limited to the Federal Highway Administration (FHWA) document FHWA-HIF-09-004, "Report on the Diagnosis, Prognosis, and Mitigation of Alkali-Silica Reaction (ASR) in Transportation Structures", and the Institution of Structural Engineering document "Structural Effects of Alkali-Silica Reaction: Technical Guidance on the Appraisal of Existing Structures."

Inspection of inaccessible areas of concrete will be performed during opportunistic or focused inspections for buried concrete performed under the Maintenance Rule every 5 years. The concrete materials used to produce the concrete placed in inaccessible areas were the same as the concrete materials used to produce the concrete placed in accessible areas. Thus, the performance and aging of inaccessible concrete would be the same as the performance and aging of accessible concrete.

Since the concrete mix and aggregates used at Seabrook Station are consistent between structures, it is assumed unless demonstrated otherwise that pattern cracking observed during walkdowns is from ASR. Petrographic examination can be performed on a concrete specimen to aid in confirming the proposed diagnosis arrived upon from visual inspection of the concrete surface. Typical petrographic features of ASR generally consist of the following:

- Micro-cracking in the aggregates and/or cement paste
- Reaction rims around the aggregates.
- Silica gel filling cracks or voids in the sample.
- Loss of cement paste-aggregate bond.

Expansion

For ASR-affected surfaces at Seabrook Station, NextEra Energy Seabrook monitors the effects of ASR expansion by obtaining measurements in both the in-plane (X&Y directions) and through-thickness directions (Z-direction). Specifically, NextEra Energy Seabrook monitors the Combined Cracking Index (CCI) and/or embedded pin measurements (the distance between the embedded reference pins) for in-plane expansion and extensometer measurements for through-thickness expansion. In addition, NextEra Energy Seabrook uses the in-plane and through-thickness expansion measurements to determine volumetric expansion. Expansion from ASR results in cracking and a change to the material properties of the concrete, and eventually requires an evaluation to ensure adequate structural performance.

Expansion is a readily quantifiable parameter and an effective method for determining ASR progression. Expansion measurements at Seabrook Station can be easily obtained in the in-plane directions. The Cracking Index (CI) is a quantitative assessment of cracking present in the cover concrete of affected structures. A CI measurement is taken on accessible surfaces exhibiting the typical ASR symptoms. The CI is the summation of the crack widths on the horizontal or vertical sides of a section of the ASR-affected concrete surface of predefined dimensions. Seabrook Station uses a grid size of 20 inches by 30 inches. The CI in a given direction is converted and reported in units of mm/m. Embedded pins are also installed to measure strain and monitor in-plane expansion.

The CIs are used to establish the Combined Cracking Index (CCI). The CCI estimates expansion on a concrete surface using measurements of crack widths along a predetermined length or grid. The CCI is calculated by summing the crack widths crossing all reference grid lines and dividing the result by the sum of all gridline lengths.

Criteria used in assessment of expansion is expressed in terms of in-plane expansion based on the screening approach described in MPR-3727, "Seabrook Station: Impact of Alkali-Silica Reaction on Concrete Structures and Attachments."

Initial screening for ASR is performed by using in-plane expansion measurements. In-plane strain values exceeding 1 mm/m (0.1%) will trigger additional actions. CCI is a relatively simple, non-destructive method for monitoring cracking that appropriately characterizes expansion until expansion reorients in the direction of least restraint (i.e., the through-thickness direction at Seabrook Station).

Results from the large-scale test programs indicated that direction of expansion is not significantly affected by the reinforcement when expansion is low. At higher levels of expansion, the two-dimensional reinforcement mats provide confinement in the in-plane directions, and through-thickness expansion dominates (MPR-4273, Revision 1).

Data analysis from the large-scale test program has been completed and thresholds have been established based on the test reports. The thresholds are based on the structure as a whole so if localized extensive ASR or macro cracking is experienced in particular areas of the structure, then the entire structure is assumed to be susceptible to similar degradation. The overall methodology for using in-plane expansion, through-thickness expansion, and volumetric expansion values for various aspects of the monitoring program is discussed below.

Anchor Performance Monitoring Parameter

For anchor performance, the large-scale test programs show that ASR does not have an effect until in-plane expansion reaches a sufficiently high level. Therefore, if the CCI exceeds a specified threshold, additional evaluation must be performed to justify continued acceptability of the anchors.

This approach is based on the fact that anchor performance is sensitive to in-plane expansion, but not through-thickness expansion. In-plane expansion creates micro-cracks parallel to the axis of an anchor, mainly in the concrete cover. These micro-cracks perpendicular to the concrete surface have the potential to provide a preferential failure path within a potential breakout cone, leading to degraded anchor performance.

Through-thickness expansion has the potential to create micro-cracks perpendicular to the axis of an anchor. These potential micro-cracks that open parallel to the concrete surface do not provide a preferential failure path to result in degraded anchor performance. An anchor loaded in tension would compress the through-thickness expansion and close any potential micro-cracks within the area of influence of that anchor. Without a 'short-circuit' of the breakout cone, through-thickness expansion is a non-factor in anchor performance.

Crack Width Summation

Crack width summation is a simple methodology for initial assessment of ASR-affected components and is recommended by publicly available resources.

ASR produces a gel that expands as it absorbs moisture. This expansion exerts a tensile stress on the surrounding concrete which strains the concrete and eventually results in cracking.

The engineering strain in a structural member at the time of crack initiation (ε_{cr}) is equivalent to the tensile strength of the concrete divided by the elastic modulus ($\varepsilon_{cr} = \sigma_t / E$). The Cracking Index quantifies the extent of the surface cracking. The total strain in the concrete can be approximated as the sum of the strain at crack initiation plus the cracking index ($\varepsilon \approx \varepsilon_{cr} + CI$). Figure 1 depicts a concrete specimen with rebar being put in tension resulting in cracking.

Concrete has little strain capacity; therefore, in ASR-affected concrete, the crack widths comprise most of the expansion (ΔL). As a result, the Cracking Index provides a reasonable approximation of the total strain applied to the concrete after crack initiation, because strain in the un-cracked concrete between cracks is minimal.

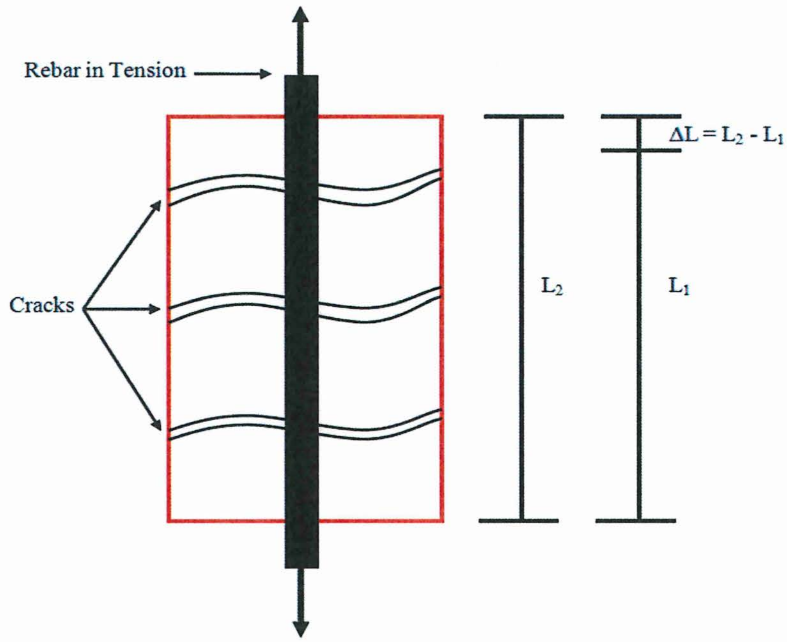


Figure 1 - Concrete Specimen put in Tension

For surfaces where horizontal and vertical cracking indices are similar (e.g., where there is equivalent reinforcement in both directions), a Combined Cracking Index (CCI) that averages the horizontal and vertical Cracking Indices can consolidate the expansion assessment to a single parameter.

Change in Elastic Modulus and Extensometer Measurements

The large-scale test program showed that through-thickness expansion dominates for structures with two-dimensional reinforcement mats in the in-plane directions (like structures at Seabrook Station).

Data from the structural testing programs showed that expansion in the in-plane direction plateaued at low expansion levels, while expansion in the through-thickness direction continues to increase. Based on this observation, Seabrook Station has and will continue to install the extensometers in Tier 3 and other selected locations to measure expansion in the through-thickness direction. This approach enables expansion to be measured for a given concrete structural member from the time the extensometer is installed and going forward. To calculate the total expansion, NextEra Energy Seabrook has and will determine expansion from original construction until the time the extensometers are installed and then add the extensometer measurement.

The method to determine the total ASR induced through-thickness expansion at each instrument location at Seabrook Station is to determine expansion at the time the extensometer is installed based on the reduction in modulus of elasticity.

The foundation of the approach for determining expansion in the through-thickness direction prior to installing an extensometer is the universal agreement among published sources that elastic modulus decreases with ASR progression. NextEra Energy Seabrook could have used the literature data to produce a generic correlation between reduction of elastic modulus and expansion, but instead elected to pursue a more precise relationship that was more representative of Seabrook Station. The correlation relating through-thickness expansion to elastic modulus is based exclusively on data from the large-scale test programs, which has several important advantages:

- All data are from cores removed from reinforced concrete that has a reinforcement configuration that is comparable to Seabrook Station. Accordingly, the test data reflect ASR development is a stress field that was more representative of an actual plant structure than literature data, which are typically based on unconfined cylinders.

- The cores were obtained from test specimens that have a concrete mixture design that is as representative of Seabrook Station as practical.

- The test programs were conducted under a Nuclear Quality Assurance program that satisfies the requirements of 10 CFR 50, Appendix B.

The extensometer measurements will provide direct measurements of through-thickness expansion going ~~forwards~~ forward. The measurements are the parameter to be monitored. The elastic modulus will not be monitored going forward. Pre-instrument expansion is calculated initially to establish expansion to date and is not repeated (except for the purpose of studies to corroborate applicability of the correlation, which are discussed in the license renewal commitments).

Volumetric Expansion

To support that concrete at Seabrook Station is appropriately represented by the specimens from the large-scale test programs, NextEra Energy Seabrook will also monitor volumetric expansion using the CCI data and extensometer data.

Volumetric expansion is the sum of expansion in each of the principal directions, as shown in the equation below.

$$\varepsilon_v = \varepsilon_1 + \varepsilon_2 + \varepsilon_3$$

Where:

ε_v = volumetric expansion
ε_1 = principal strain (e.g., in the length direction)
ε_2 = principal strain (e.g., in the height direction)
ε_3 = principal strain (e.g., in the depth direction)

Because Seabrook Station uses combined cracking index (CCI) to characterize in-plane expansion, this equation is re-written as follows:

$$\varepsilon_v = 2 \times (0.1 \times CCI) + \varepsilon_{TT}$$

Where:

ε_v = volumetric strain, %
CCI = combined cracking index, mm/m
ε_{TT} = through-thickness expansion, %

Structural Limit States
The applicable design codes provide methodologies to calculate structural capacities for the various limit states and loading conditions applicable to Seabrook Station. Each relevant limit state was evaluated using published literature and the results of the large-scale test programs that used specimens designed and fabricated to represent reinforced concrete at Seabrook Station. The following guidance applies for structural evaluations of ASR-affected concrete structures at Seabrook Station:

- Flexure/Reinforcement Anchorage - Based on the MPR/FSEL large-scale test program results, structural evaluations should consider that there has been no adverse impact on flexural capacity and reinforcement anchorage (development length) performance, provided that through-thickness expansion is at or below bounding conditions of the large-scale testing and expansion behavior is comparable to the test specimens, including through-thickness and volumetric expansion.

- Shear – Based on the MPR/FSEL large-scale test program results, structural evaluations should consider that there has been no adverse impact on shear capacity, provided that through-thickness expansion is at or below bounding conditions of the large-scale testing and expansion behavior is comparable to the test specimens, including through-thickness and volumetric expansion.

- Anchors and Embedments – Based on the MPR/FSEL large-scale test program results, structural evaluations should consider that there is no adverse effect to post-installed or cast in place anchor/embedment capacity, provided that in-plane expansions remain at or below limits established by large-scale testing. Through-thickness expansion is not relevant for anchor/embedment capacity.

The interim structural assessment used available literature to identify the impact of ASR on the various limit states. The literature review identified three limit states of interest: shear in members without transverse reinforcement, reinforcement anchorage in specimens without transverse reinforcement and embedments. For shear, the literature showed up to a 25% reduction in capacity but the results varied significantly within the literature. For reinforcement anchorage, the available test data were based on an unreliable test method. For embedments, there was no relevant data. The large-scale test programs addressed these limits using test specimens representative of reinforced concrete structures at Seabrook Station.

ELEMENT 4 - DETECTION OF AGING EFFECTS

Monitoring walkdowns are performed on a periodic basis. The Structures Monitoring Program (SMP) walkdowns identify areas that show symptoms of ASR being present. The SMP includes periodic visual inspection of structures and components for the detection of aging effects specific for that structure. The inspections are completed by qualified individuals at a frequency determined by the characteristics of the environment in which the structure is found. A structure found in a harsh environment is defined as one that is in an area that is subject to outside ambient conditions, very high temperature, high moisture or humidity, frequently large cycling of temperatures, frequent exposure to caustic materials, or extremely high radiation levels. For structures in these harsh environments, the inspection is conducted on a five (5) year basis (plus or minus one year due to outage schedule and two inspections within ten years. Structures not located in an area qualifying as a harsh environment are classified as being in a mild environment, and are inspected on a ten (10) year basis (plus or minus one year due to outage schedule and two inspections within twenty years).

In-Plane Expansion

As previously discussed in Element 3, Seabrook Station uses the CCI methodology or embedded pin measurements to monitor the expansion of ASR affected areas in the in-plane direction. An in-plane strain measurement of less than 1.0 mm/m (0.1%) can be deemed acceptable with deficiencies (Tier 2). Deficiencies determined to be acceptable with further review are trended for evidence of further degradation. An in-plane strain measurement of1.0 mm/m (0.1%) or greater requires structural evaluation (Tier 3). All locations meeting Tier 3 will be monitored on a ½ year (6-month) inspection frequency. All locations meeting Tier 2 will be monitored on a 2.5 year (30-month) frequency. In the event ASR monitoring results indicate a need to-amend either the monitoring program acceptance criteria or the frequency of monitoring, NextEra Energy Seabrook will take such action under the Operating Experience element of the Alkali-Silica Reaction Aging Management Program. (Structural calculations that support the Building Deformation AMP may indicate that more frequent CCI monitoring (e.g., semiannually) may be appropriate for locations that have an in-plane strain measurement of less than 1.0 mm/m (0.1%) (Tier 1 or 2). NextEra Energy Seabrook will perform in-plane expansion monitoring at whichever interval is more frequent.)

Seabrook Station has established reference grids that track the CCI of ASR affected areas. These grids are 20" x 30" and consist of three parallel vertical lines and two parallel horizontal lines. Measurement points (gage points) are installed at the intersections of horizontal and vertical lines of the reference grid to allow for long-term monitoring of potential ongoing expansion. The CI is obtained from measurements of crack widths along a set of lines drawn on the surface of a concrete member. Expansion is documented by measuring the increase in the length of the lines used to determine the CI (distance between gage points). A pocket-size crack comparator card and an optical comparator are used to take the measurements.

The location of the CCI reference grid is established in the area that appears to exhibit the most-severe deterioration due to ASR (accessibility and structure geometry also factor into the decision making progress on where to establish a grid). At Seabrook Station the axes of the reference grid/grids are parallel and perpendicular to the main reinforcement of the associated reinforced concrete member.

CI 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. However, embedded pin measurements determine changes in ASR expansion more precisely than CI measurements over the duration of a monitoring period, since the embedded pin measurements are performed using a calibrated mechanical device. In addition, the embedded pin measurements avoid the potential increase due to human or environmental factors that do not relate to true expansion (i.e. the inadvertent widening of the face of a crack due to cleaning of the surface).
Embedded pin measurements are only able to capture strains that occur after the gage points are installed in the concrete surface after initial (baseline) measurements are made. For use at Seabrook Station, CI provides a reasonable value for expansion to date. Once the CI is calculated and the expansion level to-date is quantified, CI or embedded pin measurements can be used to monitor future expansion.

While in-plane expansion measurements via CI or embedded pins is useful for the detection and monitoring of ASR at the initial stages, an additional monitoring parameter in the through-thickness direction is required to monitor more advanced ASR progression. The difference between the in-plane expansion and the through-thickness expansion is due to the reinforcement detailing and the resulting difference in confinement between the in-plane and through-thickness direction. Through thickness expansion is less confined due to the fact that there is no reinforcement in that direction, therefore, expansion occurs preferentially in the through-thickness direction. Similarly, for unreinforced concrete backfill, expansion occurs in all directions.

Through-Thickness Expansion

The need for through-thickness expansion monitoring is triggered by a CCI exceeding 1 mm/m. The expansions of the test specimens in the MPR/FSEL large-scale test programs were significantly more pronounced in the through-thickness direction (i.e. perpendicular to the reinforcement mats) than the in-plane directions (i.e. on the faces of the specimens parallel to the reinforcement mats).

Pre-Instrument Expansion

To determine expansion to date at a location selected for instrument installation, Seabrook Station removes concrete cores at the location in which the instruments are installed and tests them for compressive strength and elastic modulus. Using the methodology from MPR-4153, the elastic modulus values are used to determine pre-instrument expansion in the through-thickness direction.

Cores removed for material property testing have the approximate dimensions of 4” diameter × 8” length and are tested in accordance with ASTM C39 for

Compressive Strength and C469 for Elastic Modulus. The cores are taken perpendicular to the reinforcement mat.

The cores are visually examined to confirm there is no mid-plane crack or edge-effect cracking.

Snap-Ring Borehole Extensometer

Seabrook Station installs Snap-Ring Borehole Extensometers (SRBEs) at the station to monitor through-thickness expansion. The MPR/FSEL program evaluated performance of the SRBEs, along with two other instrument types, in a test specimen representative of the concrete at Seabrook Station over a one-year period. The SRBE provided accurate measurements of through-thickness expansion throughout the test program and did not exhibit any problems related to reliability. The test program involved cycles of extended exposure to high temperature and humidity, which bounds the conditions expected at Seabrook Station.

The SRBE consists of a graphite rod that is held in place by an anchor placed in the borehole. Measurements are performed by using a depth micrometer to measure the distance from a reference anchor at the surface of the concrete to the end of the graphite rod. The SRBE design contains no electronics and does not require calibration. Failure of the SRBE is unlikely. In the event that an SRBE did fail (e.g., an anchor broke loose), Seabrook Station could install another SRBE nearby to the failed location and continue expansion monitoring. This will not result in significant loss of data.

A SRBE is installed in a core bore at each Tier 3 location. The elastic modulus is only determined at the time of core removal to determine pre-instrument expansion to date. Additionally, mid-plane or edge-effect cracking visually observed at the time of core removal. SRBE monitoring is conducted on a six month frequency.

Volumetric Expansion

Although the test programs identified through-thickness expansion as the most sensitive correlating parameter, ASR expansion can also be characterized in terms of volumetric expansion. To support that concrete at Seabrook Station is appropriately represented by the specimens from the large-scale test programs, NextEra Energy Seabrook also monitors volumetric expansion by using the CCI and extensometer measurements to calculate volumetric expansion at each monitoring location where an extensometer is installed. Volumetric expansion is determined at each monitoring interval (i.e., every six months for Tier 3 locations). An advantage of the volumetric expansion parameter is that it accounts for expansion in all three principal directions, which will address slight variation among in-plane expansion values at different locations throughout Seabrook Station.

ELEMENT 5 - MONITORING AND TRENDING

The progression of ASR degradation of the concrete is an important consideration for assessing the long term implications of ASR and specifying monitoring intervals. The most reliable means for establishing the progression of ASR degradation is to monitor expansion of the in situ concrete. Results of walkdowns are initially reviewed by a licensed Professional Engineer (PE) to determine whether the symptoms shown have potential to be ASR and if CCI measurements are needed.

In-Plane and Through-Thickness Expansion

For anchor capacity, NextEra Energy Seabrook uses in-plane expansion (CCI or embedded pins) to apply the results from the MPR/FSEL large-scale test program. For shear capacity, and reinforcement anchorage, NextEra Energy Seabrook uses in-plane expansion (CCI or embedded pins) and through-thickness expansion (modulus + SRBE measurements) to apply the results from the MPR/FSEL large-scale test program.

ASR is a slow progressing phenomenon. NextEra Energy Seabrook will consider the rate at which a location is approaching the established limits and take appropriate action if the limit is anticipated to be exceeded prior to the next scheduled inspection.

Volumetric Expansion

For shear capacity and reinforcement anchorage, NextEra Energy Seabrook uses volumetric expansion to compare observed ASR progression at the plant with the test specimens from the MPR/FSEL large-scale testing programs.

ASR is a slow progressing phenomenon. NextEra Energy Seabrook will consider the rate at which a location is approaching the established limits and take appropriate action if the limit is projected to be exceeded prior to the next scheduled inspection.

ELEMENT 6 - ACCEPTANCE CRITERIA

Identification of the typical symptoms indicative of ASR generates the need to initially start monitoring the area using CCI. For the structures subject to ASR monitoring, rebar strain as a result of ASR induced stresses and ASR induced stresses in combination with design bases loads will be verified to be within code allowable limits.

In-Plane Expansion for Initial Screening

A Combined Cracking Index (CCI) and corresponding in-plane expansion values are 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 (0.05% expansion) in the vertical and horizontal directions. Concrete crack widths less than 0.05 mm (0.05% expansion) cannot be accurately measured and reliably repeated with standard, visual inspection equipment. A CCI of 1.0 mm/m (0.1%) or greater requires structural evaluation (Tier 3). All locations meeting Tier 3 criteria will be monitored via CCI (in-plane expansion) and borehole extensometers (through-thickness expansion) on a ½ year (6-month) inspection. 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 1 structures do not display signs of ASR and are monitored consistent with the Structures Monitoring Program. In the event ASR monitoring results indicate a need to amend either the monitoring program acceptance criteria or the frequency of monitoring, NextEra Energy Seabrook will take such action under the Operating Experience element of the Alkali-Silica Reaction Aging Management Program.

Tier	Structures Monitoring Program Category	Recommendation for Individual Concrete Components	Criteria
3	Unacceptable (requires further evaluation)	• Structural Evaluation • Implement enhanced ASR monitoring, such as through-wall expansion monitoring using Extensometers.	1.0 mm/m (0.1%) or greater strain measurement (CCI or pin-pin)
2	Acceptable with Deficiencies	Quantitative Monitoring and Trending	• 0.5 mm/m (0.05%) or greater strain measurement (CCI or pin-pin) • CI or pin-pin measurement of greater than 0.5 mm/m (0.05%) 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 (0.05%) 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.

Criterion of 1mm/m (0.1%) distinguishes between Tier 2 and Tier 3 locations in relation to in-plane expansion. The large-scale test program shows agreement between embedded pins and CCI, therefore ensuring CCI is acceptable. A structural evaluation is needed when the CCI reaches what is classified as Tier 3 (CCI > 1 mm/m, in-plane expansion > 0.1%). The structural evaluation should reflect the current expansion levels of the structure.

For ASR-affected structures within the scope of the Building Deformation AMP, the structural evaluation for building deformation fulfills the requirement in the ASR AMP for structural evaluation of Tier 3 structures. For ASR-affected structures that are within the scope of the ASR AMP but not within the scope of the Building Deformation AMP, a structural evaluation that considers the effects of ASR may not exist at the time it reaches Tier 3. In such cases, it will be necessary to perform the evaluation.

If a structural evaluation has already been performed to evaluate building deformation, plant personnel will verify that the in-plane expansion included in the structural evaluation bounds the as-found condition. If necessary, the existing evaluation will be updated to bound the as-found condition and provide margin for future expansion.

It is noted that the Tiers are intended for (1) initial screening of structures, (2) determination of when to install extensometers, and (3) determination of the base monitoring frequency.

Once a structural evaluation is performed for building deformation, the monitoring frequency will be established based on the most stringent criteria. For example a Stage Two Building Deformation Evaluation that is monitored on a 18 month frequency may have Tier 3 location monitored on a six month frequency and a Stage Three Building Evaluation that is monitored on a 6 month frequency may have Tier 2 locations that will also be monitored on a 6 month frequency.

In-Plane Expansion for Anchor Bolts and Structural Attachments
A specific in-plane expansion acceptance criterion[3] was established for anchor capacity by the large-scale test program test reports, and is presented in FP#101020, Section 2.1. Maintaining this limit is assured by periodically measuring in-plane expansion in areas affected by ASR.

Through-Thickness Expansion
In areas in which the CCI is classified as Tier 3, the expansion due to ASR will be monitored in the through-thickness direction as well. Specific acceptance criteria have been established by the large-scale test program test reports, and are presented in FP#101020, Section 2.1. Maintaining these limits is assured by periodically measuring through-thickness expansion in areas affected by ASR.

Volumetric Expansion
In areas in which the in-plane expansion measurement is classified as Tier 3, the expansion due to ASR will be monitored in the through-thickness direction as well. Specific acceptance criteria have been established by the large-scale test program test reports, and are summarized in FP#101050, Appendix B. Maintaining these limits is assured by periodically measuring through-thickness expansion in areas affected by ASR.

ELEMENT 7 - Corrective Actions
Evaluations will be performed under the NextEra Energy Seabrook Corrective Action Program (CAP) and an appropriate analysis will be performed to evaluate against the design basis of that structure. The NextEra Energy Quality Assurance Program and Nuclear Fleet procedures will be utilized to meet Element 7 Corrective Actions.

ELEMENT 8 - CONFIRMATION PROCESS

The FPL/NextEra Energy Quality Assurance Program and Nuclear Fleet procedures will be utilized to meet Element 8 Confirmation Process.

ELEMENT 9 - ADMINISTRATIVE CONTROLS

The FPL/NextEra Energy Quality Assurance Program and Nuclear Fleet procedures will be utilized to meet Element 9 Administrative Controls.

ELEMENT 10 - OPERATING EXPERIENCE

The primary source of OE, both industry and plant specific, was the NextEra Energy Seabrook Corrective Action Program documentation. The NextEra Energy Seabrook Corrective Action Program is used to document review of relevant external OE including INPO documents, NRC communications and Westinghouse documents, and plant specific OE including corrective actions, maintenance work, orders generated in response

---

[3] Expansion Limit Criteria are considered proprietary to NextEra Energy Seabrook. FP #101020 MPR-4288, Revision 0, "Seabrook Station: Impact of Alkali-Silica Reaction on the Structural Design Evaluations," July 2016; 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," August 1, 2016

to a structure, system or component deficiencies, system and program health reports, self-assessment reports and NRC and INPO inspection reports.

Newly Identified Operating Experience (OE)
NextEra Energy Seabrook will update the Aging Management Program for any new plant-specific or industry OE. This includes ongoing industry studies performed both nationally and internationally. Research data taken from these studies will be used to enhance the ASR program, if applicable. In addition NextEra Energy Seabrook has submitted a License Amendment Request to the Commission in accordance with 10CFR50.90 to incorporate a revised methodology related to ASR material properties and building deformation analysis for review and approval. NextEra Energy Seabrook will incorporate changes related to this LAR submittal as necessary to maintain alignment of the aging management program to the current license basis.

Groundwater Operating Experience
Historically, NextEra Energy Seabrook has experienced groundwater infiltration through cracks, capillaries, pore spaces, seismic isolation joints, and construction joints in the below grade walls of concrete structures. Some of these areas have shown signs of leaching, cracking, and efflorescence on the concrete due to the infiltration. During the early 1990's an evaluation was conducted to assess the effect of the groundwater infiltration on the serviceability of the concrete walls. That evaluation concluded that there would be no deleterious effect, based on the design and placement of the concrete and on the non-aggressive nature of the groundwater.

In 2009, NextEra Energy Seabrook tested seasonal groundwater samples to support the development of a License Renewal Application. The results showed some of the groundwater to be aggressive. Ground water testing performed in November 2008 and September 2009 found pH values between 6.01 and 7.51, chloride values between 19 ppm and 3900 ppm, and sulfate values between 10 ppm and 100 ppm. Aggressive chemical attack becomes a concern when environmental conditions exceed threshold values (Chlorides > 500 ppm, Sulfates >1500 ppm, or pH < 5.5). Based on determination of aggressive ground water and observed efflorescence on the concrete surface, NextEra Energy Seabrook initiated a comprehensive review of possible effects to concrete of in-scope structures.

ASR Identification OE
In 2009, NextEra Energy Seabrook performed a qualitative walkdown of plant structures and the "B" Electrical Tunnel (Control Building portion) was identified as showing the most severe indications of groundwater infiltration. Concrete core samples from this area were removed, tested for compressive strength and modulus of elasticity, and subjected to petrographic examinations. The results showed that both compressive strength and modulus of elasticity were less than the expected values, which is symptomatic of ASR. The results of the petrographic examinations also showed that the samples had experienced Alkali-Silica Reaction (ASR).

NextEra Energy Seabrook initiated an extent of condition evaluation and concrete core samples were taken from five additional areas of the plant that showed characteristics with the greatest similarity to the "B" Electrical Tunnel. Additional concrete core samples were also taken from an expanded area around the original concrete core samples in the "B" Electrical Tunnel.

Tests on these core samples confirmed that the original "B" Electrical Tunnel core samples show the most significant ASR. For the five additional areas under investigation, final results of compressive strength and modulus testing indicate that the compressive strength in all areas is greater than the strength required by the design of the structures. Modulus of elasticity was in the range of the expected value except for the Diesel Generator, Containment Enclosure Buildings, Emergency Feedwater Pumphouse, and the Equipment Vaults, which were less than the expected value in localized areas.

Evaluation of the affected structures concluded that they are fully capable of performing their safety function but margin had been reduced. Material property results from cores removed from a reinforced concrete structure do not properly represent the actual structural performance because the structural context is lost. However, the areas are potentially subject to further degradation of material properties due to the effects of ASR.

Examination of Inaccessible Areas OE

To date, NextEra has not observed ASR in in-accessible areas greater than that observed in accessible areas and does not expect to observe such expansion in the future. In general these areas are not accessible because they are buried and have no accessible interior spaces. The environmental conditions that affect ASR development are those related to alkali transport and silica solubility.

Temperature and humidity (in this case ground water) are the most significant.
The buried concrete is subject to ground water on all sides. Most accessible areas have groundwater on one side with an adjacent interior space. This arrangement allows for flow through the concrete with an alternating wet dry surface on one side. This tends to facilitate alkali transfer and higher ASR progression has been seen in these conditions as opposed to fully or constantly wetted conditions. With respect to ambient temperature, in general the higher the temperature the more soluble the silica and the faster ASR will progress. The below grade accessible areas generally have a heated interior space that means the concrete is warmer than the surrounding backfill material. The inaccessible below grade concrete will essentially be at the constant cool temperature of the surrounding backfill material. The ambient temperature and humidity conditions are no harsher for ASR than the observable concrete and so the rates of ASR progression are bounded.

Several inaccessible areas have been inspected and results to date have confirmed instances where ASR is present. However, the levels of ASR observed were consistent with that observed in accessible areas of the plant. Typical inaccessible areas inspected include underground electrical manholes, GSU transformer foundations, GSU transformer containment structures, underground SW pipe access vault, and below grade backfill concrete.

An opportunistic Structures Monitoring inspection was conducted on the underground Unit 2 Circulating Water Pipe Access Vault on June 3, 2015. The vault was found to have been flooded to approximately 15 foot elevation. Overall the condition of the concrete was found to be in good condition and deemed acceptable. Minor cracking was present (mostly on the top surface concrete) but did not exceed 0.025 inches in width and appeared to be shallow in depth for all notable instances. No visible map cracking, dark staining or gel exudation indicative of ASR was noted.

An opportunistic Structures Monitoring inspection was conducted on concrete structures associated with the Generator Step-up Transformer Units (GSU) on March 19, 2014 and June 26, 2014 for "A" and "C", respectively. The inspections encompassed both the GSU foundation and its respective containment structure. Both pit areas that were inspected showed characteristics that are suggestive of ASR (pattern cracking, and dark staining). The indications were noted on the inside face and top of the oil containment structure only. No indications were noted on the foundations. The nominal width of the pattern cracking appeared to be less than 2 mils (0.002 inches), the minimum measurable crack width that can be reliably and accurately measured. Therefore, the ASR cracking on top of the oil containment walls are classified as ASR Tier 2 -Qualitative and being monitored on a 30-month basis. The top of the south wall at 1-ED-X-JA (GSU) has a modified CCI grid (due to size restrictions) and will be classified as ASR Tier 2- Quantitative and will be monitored on a 30-month basis as well. In addition, areas of spalled concrete were found on the GSU foundations and were promptly remediated.

Confirmation of Overall Expansion Behavior

NextEra Energy Seabrook will perform several actions to confirm that expansion behavior at the plant is consistent with the specimens from the MPR/FSEL Large-scale Test Programs. These actions assess similarity of expansion behavior in terms of trends between directions and expansion levels. The actions also include corroborating the correlation of normalized modulus versus through-thickness expansion derived from the MPR/FSEL testing against plant data. This AMP may be updated as necessary to account for any findings from these checks, which are described in the table below.

Objective	Approach	When
Ongoing Monitoring (See AMP Elements 3 through 6)		
Expansion within limits from test programs	Compare measured in-plane expansion (εxy), and through-thickness expansion (εz), and volumetric expansion (εv) at the plant to limits from test programs	Intervals as specified in AMP
Lack of mid-plane crack	Inspect cores removed from ASR-affected structures (and boreholes) for evidence of mid-plane cracks	When cores are removed to install extensometers or for other reasons.
Periodic Confirmation of Expansion Behavior		

Lack of mid-plane crack	Review of records for cores removed to date or since last assessment	Periodic assessments: • At least 5 years prior to the Period of Extended Operations (PEO) • Every 10 years thereafter
Expansion initially similar in all directions but becomes preferential in z-direction	Compare ε_{xy} to ε_z using a plot of ε_z versus Combined Cracking Index (CCI)	
Expansions within range observed in test programs	Compare measured ε_{xy}, ε_z and ε_v at the plant to limits from test programs to check margin for future expansion	
Corroborate modulus-expansion correlation with plant data (A secondary objective of these studies is to provide additional data to confirm that expansion behavior at the plant is comparable to the test specimens.)	For 20% of the extensometer locations: • Remove cores for modulus Compare ε_z determined from the modulus-expansion correlation with ε_z determined from the extensometer and the original modulus result	At least 5 years prior to PEO (initial study) and 10 years thereafter (follow-up study). A detailed explanation of this approach is provided in MPR-4273, Revision 1, "Seabrook Station - Implications of Large-Scale Test Program Results on Reinforced Concrete Affected by Alkali-Silica Reaction" (Seabrook FP# 101050).

EXCEPTIONS TO NUREG-1800

None

ENHANCEMENTS

- The Alkali-Silica Reaction (ASR) Monitoring is being implemented
- The NextEra Energy Seabrook Structures Monitoring Program, SMPM has been revised to include Alkali-silica reaction description, aging effects, inspection criteria, acceptance criteria.
- The NextEra Energy Seabrook ASME Section XI, Subsection IWL Program ES1807.031 has been revised to include Alkali-silica reaction aging effects.

CONCLUSION

To manage the aging effects of cracking due to expansion and reaction with aggregates in concrete structures, the existing Structures Monitoring Program, B.2.1.31, and ASME Section XI, Subsection IWL Program, B.2.1.28 have been augmented by this plant specific Alkali-Silica Reaction (ASR) Aging Management Program (AMP), B.2.1.31A.

Routine inspections are performed by the Structures Monitoring and the ASME Section XI, Subsection IWL Program. Areas that have no visual presence of ASR are considered "acceptable" (Tier 1). An area with an in-plane expansion of less than 0.1% (Combined Cracking Index (CCI) of less than 1.0 mm/m) is deemed "acceptable with deficiencies" (Tier 2). An area with an in-plane expansion of greater than 0.1% (CCI of 1.0 mm/m 0.1%) is deemed "unacceptable" and requires further evaluation (Tier 3). In addition, an area that meets Tier 3 requirements will be monitored for through-thickness expansion in addition to in-plane expansion. In such areas, the through-thickness expansion and in-plane expansion values will be used to determine volumetric expansion.

Evaluations will be performed under the NextEra Energy Seabrook Corrective Action Program (CAP) and an appropriate analysis will be performed to evaluate against the design basis of that structure.

The NextEra Energy Seabrook ASR AMP provides reasonable assurance that the effects of aging of in-scope concrete structures due to the presence of ASR will be managed to ensure the structures continue to perform their intended function consistent with the current licensing basis for the period of extended operation.

B.2.1.31B BUILDING DEFORMATION

PROGRAM DESCRIPTION

The Building Deformation Aging Management Program (AMP) is a new plant specific program being 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 Station is primarily a result of ASR, described in LRA section B.2.1.31A, 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 Aging Management 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 is characterized and documented. The first inspection identifies any local areas that are exhibiting deformation. The extent of surface cracking serves as input into an analytical model. This model determines 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) are compared against location-specific criteria to evaluate acceptability of the condition.

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

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

PROGRAM ELEMENTS

The following provides the results of the evaluation of each program element against the 10 elements described in Appendix A of NUREG-1800 Rev. 1, *"Standard Review Plan for Review of License Renewal Applications for Nuclear Power Plants"*.

ELEMENT 1 - SCOPE OF PROGRAM

The NextEra Energy Seabrook Building Deformation Aging Management Program provides for management of the effect of building deformation on concrete structures and associated components within the scope of license renewal. Program scope includes components within the scope of license renewal contained in concrete structures within the scope of the Structures Monitoring Program and License Renewal ASME Section XI Subsection IWL Program. Concrete structures within the scope of this program include:

Category I Structures

- Containment Building (including equipment hatch missile shield)
- Containment Enclosure Building
- Containment Enclosure Ventilation Area
- Service Water Cooling Tower including Switchgear Rooms
- Control Building
- Control Building Make-up Air Intake Structures
- Diesel Generator Building
- Piping (RCA) Tunnels
- Main Steam and Feed Water East and West Pipe Chase
- Waste Processing Building
- Tank Farm
- Condensate Storage Tank Enclosure
- Emergency Feed Water Pump House Building, including Electrical Cable Tunnels and Penetration Areas (Control Building to Containment)
- Fuel Storage Building
- Primary Auxiliary Building including RHR Vaults
- Service Water Pump House
- Service Water Access (Inspection) Vault
- Circulating Water Pump House Building (below elevation 21'-0)
- Safety Related Electrical Manholes and Duct Banks
- Pre-Action Valve Building

Non-Category I Structures

- Intake & Discharge Transition Structure

ELEMENT 2 - PREVENTIVE ACTIONS

There are no preventive actions specified in the NextEra Energy Seabrook Structures Monitoring Program, which includes implementation of NUREG-1801 XI.S5, XI.S6, and XI.S7. These are monitoring programs only. Similarly, the Building Deformation Aging Management Program does not rely on preventive actions.

ELEMENT 3 – PARAMETERS MONITORED/INSPECTED

The Methodology Document (FP# 101196) describes a process in which ASR-affected structures[4] are initially screened for deformation and analyzed to assess the effects on structures for the self-straining loads from ASR expansion, creep, shrinkage, and swelling. Each stage of the process (i.e., Stage One, Stage Two, and Stage Three) has

---

[4] The Methodology Document applies to all ASR-affected structures; it is not limited to Seismic Category I structures. Thus the methodology can be used to analyze all structures within the scope of this program.

increasing levels of rigor. The analysis and evaluation of each structure may begin at any of the three stages.

The following criteria should be considered when selecting the starting stage for analysis.

1. Structures with simple geometry that permits structural analysis using closed-form solutions and/or simple finite element models

2. Structures with localized ASR expansion, or ASR expansion affecting the structure as a whole but with only minor indications of distress

3. Structures with an apparent robust original design leading to a reasonable amount of margin to accommodate ASR demands

4. Structures that do not exhibit significant signs of distress

Structures should start at Stage One if they meet all four criteria listed above. Structures should start at Stage Two if they meet two or three of the listed criteria. Structures should start at Stage Three if they meet one or none of the listed criteria.

Establish Parameters Monitored and Threshold Limits
As detailed in the Methodology Document, the specific locations where ASR exists in each structure and the critical areas where the margin to Licensing Basis structural design code and design basis acceptance criteria are most limiting influence the locations and types of measurements that are used to monitor each structure. Results from the structural analysis are used to identify the critical areas for meeting the acceptance criteria. Monitoring parameters, locations, frequencies, administrative limits, and threshold limits associated with the ASR-affected structure of interested are documented in the associated structural calculation.

Field inspections shall be performed to obtain observations and measurements that can be used to quantify ASR loads applied to each structure. A list of observations and measurements that may be recorded during field inspection is provided in the table below.

Parameter	Description
Cracking suspect of ASR (visual observations)	Qualitative visual observations made of cracking that exhibits visual indications of ASR and ASR-related features, using industry guidelines.
Cracking not suspect of ASR (visual observations)	Qualitative visual observations made of cracking that do not exhibit indications of ASR. These cracks may be structural (i.e. caused by stresses acting on the structure) or caused by shrinkage or other mechanisms aside from ASR.
Other structural or material distress (visual observations)	Qualitative visual observations made of structural distress, such as buckled plates, broken welds, spalled concrete, delaminated concrete, displacement at embedded plates, damage to coatings, and chemical staining.
Crack index	Quantitative measurement of in-plane cracking on a concrete structural component using the cracking index measurement

	procedure
In-plane strain rate	Quantitative measurement of length between two points installed on a concrete component using a removable strain gage. In-plane expansion is computed as the change in length between measurements recorded at different times.
Through-thickness expansion	Quantitative measurement of the thickness of a concrete component using an extensometer device. Through-thickness expansion is computed as the change in thickness between measurements recorded at different times.
Through-thickness strain rate	Calculated value based on measurements of through-thickness expansion over a period of time.
Individual crack widths/lengths	Quantitative measurement of individual crack widths using either a crack card, an optical comparator, or any other instrument of sufficient resolution. Such measurements shall be accompanied by notes, sketches, or photographs that indicate the pattern of the cracks and their length. Also included in this category are tools that quantify the change in crack widths, such as mountable crack gages, extensometers, and invar wires
Seismic isolation joints	Quantitative measurement of the width of seismic joints that separate two adjacent structures. Also included in this category are qualitative observations of distress in seals covering or filling isolation joints, such as tears, wrinkles, and bubbles.
Structure dimensions	Quantitative measurement of a structure's dimensions or the distance between two adjacent structures. Included in this category are measurements of plumbness of walls, levelness of slabs, and bowing/bending of members.
Equipment/conduit offsets	Quantitative measurement or visual observation of building deformation through the misalignment of equipment and/or the deformation of flexible conduit joints.

A document review shall be performed for each structure. Documents that are necessary to review include design drawings and design criteria. Other additional documents shall also be reviewed as needed in order to perform susceptibility evaluations. All documents reviewed shall be the latest available revision. A list of documents that may be reviewed is provided in the table below.

	Documents	Description
Review Necessary	Structural design drawings and specifications	Structural design drawings, including excavation drawings, backfill drawings, and adjacent structure drawings as needed
	Original structural design criteria	Structural design criteria, including the Updated Final Safety Analysis Report (UFSAR), documenting loads, load combinations, and strength acceptance criteria for which the structure was originally designed
	Structural design calculations	Structural design calculations documenting the underlying assumptions of the original structural design and original design demands and capacities.
Review As Needed	Construction documentation	Construction documents, drawings, and photos documenting construction stages, concrete placement, etc. This category also includes as-built drawings and survey data following construction.
	Documentation of structural and material tests	Existing documentation of testing, including petrography that has been performed on the structure or the materials of the structure.

The number of monitoring locations and the types of measurements taken will be influenced by the sensitivity of the results to the level of expansion or deformation in these regions as well as the size and shape of ASR-affected areas in the structure.

Stage One – Susceptibility Screening Evaluation:
Threshold monitoring measurements should be performed at a frequency of 36 months. Since the Stage One analyses are performed using a conservative approach based on several CI and/or pin-to-pin in-plane expansion locations and other structural deformation parameters, there will be a limited number of threshold monitoring quantitative measurements and several qualitative observation parameters. The quantitative measurements shall be compared to the corresponding specified limits from Stage One analysis evaluation. Similarly, the qualitative threshold measurements should be within the specified description and/or limits for these observations. When the observed variables are below the specified limits, the next threshold monitoring shall be performed within the monitoring frequency of 36 months. If a quantitative or qualitative observation variable approaches the corresponding specified limits, then further evaluations or structural modifications may be considered, as described in the Methodology Document and in Element 6 of this program.

Stage Two – Analytical Evaluation:
Threshold monitoring measurements should be performed at a frequency of 18 months. Quantitative measurements include in-plane expansion measurements and measurement of additional structural deformations. The quantitative threshold

variable could be from one location or from an average of several locations with similar behavior. The quantitative measurement or average of several measurements as defined by the monitoring program shall be compared to the corresponding specified limits from Stage Two analysis evaluation. Similarly, the qualitative threshold measurements should be within the specified description and/or limits for these observations. When the observed variables are below the specified limits, then the next threshold monitoring shall be performed within the monitoring frequency of 18 months. If a quantitative or qualitative observation variable approaches the corresponding specified limits, then further evaluations or structural modifications may be considered, as described in the Methodology Document and in Element 6 of this program.

Stage Three – Detailed Evaluation:
Threshold monitoring measurements should be performed at a frequency of 6 months. Quantitative measurements include CI in-plane expansion measurements, pin-to-pin in-plane expansion measurements, crack width measurements, and measurement of other structural deformation variables. The quantitative threshold variable for each region could be from one location or from an average of several locations with similar behavior. The quantitative and qualitative measurements specified for each building shall be performed within the required frequency of inspection. The quantitative measurement or average of several measurements, as defined by the structural monitoring program, shall be compared to the corresponding specified limits from Stage Three analysis evaluation. Similarly, the qualitative threshold measurements should be within the specified description and/or limits for these observations. When the observed variables are below the specified limits, then the next threshold monitoring shall be performed within the monitoring frequency of 6 months. If a quantitative or qualitative observation variable approaches the corresponding administrative limits, then further evaluations or structural modifications may be considered, as described in the Methodology Document and in Element 6 of this program.

Summary

In summary, the structural analysis process, as described in the Methodology Document, classifies ASR-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 (i.e. Stage One); (2) structures with elevated levels of deformation that are shown to be acceptable using Finite Element Analysis (FEA) to calculate ASR loads but still meeting the original design basis requirements when ASR effects are included (i.e., Stage Two); and (3) structures with significant deformation that are analyzed and shown to meet the requirements of the code of record using the methods described in the Methodology Document (i.e., Stage Three).

This approach is consistent with guidance in ACI 349.3R-1996 used to establish the inspection criteria for the Structures Monitoring Program. The ASR deformation categories do not necessarily correspond to the criteria used to characterize ASR cracking in structures that is discussed in LRA section B.2.1.31A. That is, a Stage

Two structure does not necessarily have ASR cracking that is classified as Tier 2. Structures will be monitored based on the most limiting parameter for monitoring from either the ASR Aging Management Program or the Building Deformation Aging Management Program. The building deformation monitoring frequency for structures for each stage is summarized in the table below.

Stage	Deformation Evaluation Stage	Monitoring Interval[5]
1	Screening assessment	3 years
2	Analytical Evaluation	18 months
3	Detailed Evaluation	6 months

As there are no published standards that include inspection frequencies for ASR-affected structures and neither ACI 318-71 nor ASME Code, Section III, Division 2 have guidance for inspecting ASR-affected structures, the monitoring frequencies in table above are based on guidelines developed for inspecting transportation structures with ASR degradation and on the relative margin to design acceptance criteria from the structural analysis described in the Methodology Document. 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 interval for recording monitoring elements for deformation for each structure can be increased to the interval in the next lower Stage (i.e., Stage Three to Stage Two and Stage Two to Stage One) if no change in measurements are observed for 3 years. Stage One structures that have shown no change in deformation for 10 years may increase the inspection interval to once every 5 years. Structures that show no evidence of building deformation will continue to be inspected with a frequency as established by the Structures Monitoring Program.

Components Impacted by Structural Deformation

With deformation, an aging effect of concern is component functionality and structural interferences. Condition walkdowns are performed with a focus on safety-related components such as pumps, valves, conduits, piping etc. The effects of deformation on plant equipment and seismic gaps will be managed through the Corrective Action Program based on input from the Structural Monitoring Program. The identification of items of interest is entered into the NextEra Energy Seabrook Corrective Action Program (CAP) to be dispositioned for impact on plant structures. Specific features to look for include, but are not limited to, the following:

- Distorted flexible couplings
- Non-parallel pipe/conduit/HVAC joints
- Gaps, distortions, or tears in seals
- Crimped tubing
- Distorted support members/structural steel
- Distorted/bent anchor bolts

---

[5] NextEra Energy Seabrook has the ability to apply more stringent monitoring intervals depending on the structure-specific considerations and conditions.

- Offset rod hangers
- Support members exceeding minimum clearance
- Cracked welds
- Support embedment plates – not flush with walls
- Misaligned pipe flanges
- Misaligned pipes in penetrations
- Roof membranes and weather seals degraded
- Electrical box, panel, or fitting distorted

Component specific features may indicate irreversible deformation of the affected component or irreversible plastic deformation of the structure such as rebar yielding or rebar slip. If these features are observed, then they will be documented in the corrective action process so that future monitoring walkdowns will observe the same features. Inspections of these features are in addition to the installed monitoring elements such as strain measurements and measurements of the relative deformation between structures. All of these measurements will be performed at a frequency that ensures functionality of the affected components is not lost prior to the next inspection interval. At a minimum, measurements will be taken at the frequency described the Methodology Document and summarized above.

The walkdowns will be performed in accordance with the Structures Monitoring Program and ASME Section XI, Subsection IWL Program documents. NextEra Energy Seabrook will update the walkdown guidance documents as necessary to accommodate new Operating Experience (OE) identified during the walkdowns.

ELEMENT 4 - Detection of Aging Effects

As discussed in Element 3, baseline walkdowns are performed to identify the potential effects caused by building deformation. The results of the baseline walkdowns are used to determine the key assumptions in the structural analysis. Subsequent monitoring will be performed as part of future Structures Monitoring Program (SMP) walkdowns. The recommended inspection frequencies, as defined in the Methodology Document and summarized in Element 3, will be applied in locations where symptoms of deformation are identified; otherwise, the inspection frequency will follow the requirements of the SMP. The SMP includes periodic visual inspection of structures and components for the detection of aging effects specific for that structure. The inspections are completed by qualified individuals at a frequency determined by the characteristics of the environment in which the structure is found. NextEra Energy Seabrook will consider the rate of expansion and building deformation and will take appropriate action if the structural integrity of the structure of interest and the associated components is projected to be lost prior to the next scheduled inspection.

Components Impacted by Structural Deformation

As discussed in Element 3, baseline walkdowns to identify the potential effects for equipment impacted by building deformation will at minimum frequency of two years in accordance with the Structures Monitoring Program. The SMP includes periodic visual inspection of components impacted by structural deformation for the detection of aging effects specific for that structure. The inspections are completed by knowledgeable individuals at a frequency determined by the characteristics of the environment in which the structure is found. NextEra Energy Seabrook will consider the rate of expansion and building deformation and will take appropriate action if the functionality of associated components is projected to be lost prior to the next scheduled inspection.

ELEMENT 5 - Monitoring and Trending

Once the inspection frequencies are determined as described by Element 3, visual inspections will be used to monitor and trend future building deformation. Any new indications of building deformation will be placed in the Corrective Action Program, and evaluations will be performed to determine if inspection frequencies should be changed to ensure that future effects of degradation would be identified before loss of components' intended function.

ELEMENT 6 - Acceptance Criteria

As described in the Methodology Document, the threshold factor is the design margin expressed as the amount which ASR loads can increase beyond currently measured values that are used in the calculations such that the structure or structural component will still meet the allowable limits of the code. Threshold factor is an outcome of the evaluation, not an input to the analysis methodology approach. A unique threshold factor is calculated for each building based on the available margin, and is used to establish threshold limits for structural monitoring parameters. Threshold factors may be revised based on further analysis by using additional inspection and measurement data and/or a more refined structural analysis method without reducing the code inherent margin of safety.

An administrative limit of 97% of the threshold limit is set in addition to reductions of 90%, 95%, and 100% set for Stage One, Two, and Three threshold limits, respectively. The additional 3 percent margin plus the reduction to threshold factors for Stage One and Two analyses provide time to perform additional inspections to confirm that the limits are being approached and to initiate corrective actions. When the quantitative or qualitative threshold monitoring variables reach the administrative limits further structural evaluation in accordance with procedures specified in this methodology document shall be performed to re-evaluate the structure or to consider structural modification to alleviate the concern for the approaching variable(s) to the specified limit(s).

More frequent ASR threshold monitoring may also be performed. If a structural modification approach is considered, the as-modified structure shall be evaluated using the procedures and acceptance criteria defined in this methodology document to confirm the as-modified structure meets the ASR susceptibility evaluation; and analysis shall be performed to calculate a new threshold factor for the as-modified structure.

Chemical prestressing from ASR expansion results in strain of the rebar. The codes of record combined with the analytical approaches and acceptance criteria described in the Methodology Document ensure that the behavior of ASR-affected structures remain elastic. Monitoring of ASR-affected structures against the monitoring parameters and threshold limits identified in the calculations ensures that the rebar is not strained beyond acceptable limits.

ELEMENT 7 - Corrective Actions
Structural evaluations are performed to ensure impacted structures are in compliance with the Current Licensing Basis are documented in the Corrective Action Program. The NextEra Energy Quality Assurance Program and Nuclear Fleet procedures will be utilized to meet Element 7 Corrective Actions. (Ref: LRA A.1.5 and B.1.3.)

ELEMENT 8 - Confirmation Process
The FPL/NextEra Energy Quality Assurance Program and Nuclear Fleet procedures will be utilized to meet Element 8 Confirmation Process.

ELEMENT 9 - Administrative Controls
The FPL/NextEra Energy Quality Assurance Program and Nuclear Fleet procedures will be utilized to meet Element 9 Administrative Controls.

ELEMENT 10 - Operating Experience

Building Deformation – Containment Enclosure Building (CEB)
In late 2014, a walkdown was performed to investigate a concern from the NRC that water, leaking from SB-V-9, was leaking into the Mechanical Penetration (Mech Pen) area though building seals. The walkdown documented that a Mechanical Penetration area seal was found torn. The damaged seal was a vertical seismic gap seal between the Containment Enclosure Building (CEB) and the Containment Building (CB). It was then stated 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 (i.e. shrinkage or material deterioration).

Following the discovery mentioned above, Engineering identified that the damage to the seal was caused by CEB outward radial deformation. NextEra Energy Seabrook engaged an engineering firm to perform visual assessments of accessible areas surrounding the CEB to determine the behavior of the CEB, whether the CEB movement is localized or widespread, and if other plant structures or components had been impacted. A Cause and Effect Diagram was prepared to understand the physical phenomena occurring with the CEB. Parametric studies using a linear finite element model of the CEB with boundary conditions modeling parameters appropriate for estimating structural deflections and deformed shapes were performed. The results were compared to in-situ field measurements taken between structures and at seismic isolation joints between various structures. The deformation patterns simulated by finite element analysis (FEA) were generally similar to field measurements. The results of the FEA showed that the deformation of the CEB was most likely due to Alkali-Silica Reaction (ASR) expansion in the concrete when combined with the expected creep and swelling of the concrete.
The root cause to the event was determined to be the internal expansion (strain) in the CEB concrete produced by ASR in the in-plane direction of the CEB shell and ASR expansion in the backfill concrete coincident with a unique building configuration. The Root Cause Evaluation identified that there are many different symptoms of building deformation. These include:

- Conduit, duct, or piping seismic connection deformation
- Gate or door misalignment
- Seismic gap seal degradation
- Seismic gap width variations
- Fire seal degradation

(Note: above list is not intended to be all inclusive)

As a result walkdowns were performed to identify the above symptoms that may have been missed during the Structures Monitoring Program Walkdowns that were conducted prior to this discovery. The items identified were entered NextEra Energy Seabrook's Corrective Action Program.

Building Deformation – RHR & FSB

NextEra Energy Seabrook has evaluated the observations of expansion resulting in building deformation in the Residual Heat Removal (RHR) Equipment Vault and the Fuel Storage Building (FSB).

As a result of the identified observations, additional monitoring has been established in the Residual Heat Removal Vaults (i.e. invar rod extensometers and crack gauges) and enhanced use of laser measurements is being evaluated for use in the Fuel Storage Building.

Both structures were ranked as having a high potential of being affected by building deformation due to ASR. Both structures have been evaluated in accordance with the Methodology Document and were evaluated as Stage Three structures with a corresponding 6-month inspection/monitoring frequency.

Building Deformation – "B" Electrical Tunnel

NextEra Energy Seabrook has evaluated the "B" Electrical Tunnel in accordance with the Methodology Document. With the ASR loadings, the governing failure mode is out-of-plane shear of the first story North and South tunnel walls. Formation of flexural cracking at mid-height and over the visible face of these walls would precede formation of the through-thickness inclined shear cracks (before shear capacity is reached). No horizontal cracking in this vicinity of the walls have been observed, so the walls are currently not loaded to the level to cause cracking. Reference the respective Prompt Operability Determination (POD), AR 02215578.

As a result of the evaluation, an enhanced monitoring frequency has been established for select portions of the "B" Electrical Tunnel.

Building Deformation – CEVA North Wall

The lower portion of the CEVA Structure North Wall between elevation (+) 3ft and elevation (+) 19 feet exhibits extensive cracking and out-of-plane deformation (bowing). This condition is due to the expansion of the concrete fill that is below the floor slab at elevation (+) 12ft of the CEVA Structure and south of the North wall between (+) 3 ft and elevation (+) 19 ft. Based on the deformation and cracking observed, the wall cannot be qualified to ACI 318-71. A validation study was performed on the wall to characterize the potentially delamination that is occurring. This consisted of performing Impact Echo Testing and extracted partial depth cores.

As a result of the evaluation, enhanced monitoring has been established and Engineering Change is being developed for a structural retrofit to restore the wall back to be in compliance with ACI 318-71.

Building Deformation - Safety-Related Electrical Manholes
Safety Related Electrical Manholes (EMH) W01, W02, W09, W13 through W16 were analyzed in accordance with the LAR 16-03 methodology, which includes the ASR loadings. The evaluation showed that the manhole structures would not meet the acceptance criteria in ACI 318-71, including ASR demands which were further increased by threshold factors to account for potential future ASR expansion, with the site design criteria surcharge load of 500 psf included.

Based on the evaluations the surcharge loadings within 8 feet of EMH W13 through W16 will be kept below 200 psf through physical and administrative controls.

Plant Specific Operating Experience
AR 02044627 notes that the as-measured width of seismic isolation gaps is less than the nominal value of 3 inches specified on concrete drawings for isolation between structures. There are a total of 93 as-measured gaps less than 3 inches between the following abutting structures: Containment Building, Containment Enclosure Building, Mechanical Penetration Area, West Main Steam and Feed Water Pipe Chase, Electrical Penetration Area and Emergency Feed Water Pump House. Initial finite element analysis completed determined that the deformation is attributed to ASR expansion and creep. The compensatory measure implemented requires measuring seismic isolation gaps every six months.

AR 2114299 documents that a seismic isolation joint located on an expansion boot near ductwork in the Containment Enclosure Building is vertically misaligned by approximately 2". The boot appeared to be in good shape; it was not dry or cracking. The AR determined that the cause of the misalignment is building deformation of the Containment Enclosure Building. The engineering evaluation concluded that the displaced ducts resulted in some slipping of the expansion joint material relative to the clamp at the areas of highest relative movement and that there is reasonable assurance that the joint material would most likely slip rather than tear or elongate during a seismic event. The condition was found acceptable as is and no loss of intended function was identified.

AR 02107225 documents a deformed and misaligned flexible coupling on a conduit located in the West Pipe Chase area. Based on a field walkdown, the coupling was misaligned by 1.75" which is greater than the established 1.25" acceptable limit. The cause of the misalignment was building deformation. Therefore, engineering analysis was performed to ensure that the enclosed cable can continue to perform its safety function. Even though the cable could continue to perform its safety function, the flexible conduit was repaired to restore design margin.

AR 02129621 documents the seismic gap between Containment and the CEB horizontal cantilevered concrete shield block at Azimuth 230 elevation 22' is less the minimum required seismic gap of .277 inches. The cause of the reduced gap was building deformation. An engineering analysis was performed to ensure that the structural remains operable while steps are taken to restore to design requirements.

Newly Identified Operating Experience (OE)
NextEra Energy Seabrook will update the Aging Management Program for any new plant-specific or industry OE. This includes ongoing industry studies performed both nationally and internationally. Research data taken from these studies will be used to enhance the Building Deformation Aging Management Program, if applicable. In addition NextEra Energy Seabrook has submitted a License Amendment Request to the Commission in accordance with 10CFR50.90 to incorporate a revised methodology related to ASR material properties and building deformation analysis for review and approval. NextEra Energy Seabrook will incorporate changes related to this LAR submittal as necessary to maintain alignment of the aging management program to the current license basis.

EXCEPTIONS TO NUREG-1800
None

ENHANCEMENTS
The station's Structures Monitoring Program, SMPM has been revised to include building deformation aging effects, inspection criteria, and acceptance criteria.

CONCLUSION
To manage the aging effects of building deformation due to ASR, swell, creep, and expansion, the existing Structures Monitoring Program and ASME Section XI, Subsection IWL Program, have been augmented by this plant specific Building Deformation Aging Management Program. This program:

- Characterizes the extent of deformation associated with each ASR-affected structure,
- Analyzes the structural adequacy of affected structures,
- Determines the projected rate of future deformation,
- Defines monitoring parameters, locations, thresholds and inspection frequencies to ensure that structural adequacy is maintained and that the plant has ample time to implement corrective action before structural adequacy is lost.

Establishes monitoring frequencies to ensure the functionality of components associated with ASR-affected structures is not lost prior to the next inspection interval.