NEXTera ENERGY SEABROOK

June 8, 2012

SBK-L-12122
Docket No. 50-443

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville, MD 20852

Seabrook Station
Response to Confirmatory Action Letter

Reference: NRC letter to NextEra Energy Seabrook, CAL No. 1-2012-002, Confirmatory Action Letter (CAL), Seabrook Station, Unit 1 – Information Related to Concrete Degradation Issues (ML121254172)

In the above reference, the U.S. Nuclear Regulatory Commission (NRC) issued a Confirmatory Action Letter, stating its expectation that NextEra Energy Seabrook, LLC (NextEra Energy Seabrook) will carry out the commitments outlined in the letter according to its previously provided schedule. Accordingly, NextEra Energy Seabrook is required to submit the integrated corrective action plan associated with the occurrence of ASR at Seabrook Station by June 8, 2012.

The enclosure of this letter contains the integrated corrective action plan associated with the occurrence of ASR at Seabrook Station.

Should you have any questions regarding this letter or the enclosure to this letter, please contact Mr. Michael O'Keefe, Licensing Manager at (603) 773-7745.

Sincerely,

NextEra Energy Seabrook, LLC

for

Paul O. Freeman
Site Vice President

IE36
NRR

Enclosure: ASR Project Corrective Action Plan

cc:

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Enclosure to SBK-L-12122

Seabrook Station

ASR Project Corrective Action Plan

ASR Project
Corrective Action Plan

6 June 2012

1.0 Background

Alkali-aggregate reactions (AAR) occur over time between the alkali hydroxides in the pore solution of concrete and certain minerals found in some aggregates. Alkali Silica Reaction (ASR) is the predominant type of AAR. It involves a chemical reaction between alkalis in the cement paste (Portland cement) and reactive forms of silica (SiO_2) in the aggregates. This reaction is dependent on several factors including; the amount and form of reactive material in the aggregate (e.g. reactive forms of quartz), the amount of alkali in the cement (more alkali - faster reaction), temperature (higher temp - higher reaction rate), and moisture content (90% humidity required). The reaction forms an expansive gel in the affected concrete. As the reaction progresses and the gel expands, micro-cracks are formed in the aggregate often extending into the cement paste. The main observable effect of ASR affected structures is expansion due to the crack and gel formation. When expansions reach levels of about 0.05%, visible cracks begin to form on the exposed surfaces. These cracks are often in a characteristic map cracking pattern and may also have signs of ASR gel material. While very reactive aggregates can cause rapid expansion rates that manifest in visible cracks and measurable expansion rates in a few years, American Society for Testing and Materials (ASTM) testing for reactive aggregates and specification of low alkali cement has been somewhat effective in preventing ASR in these time frames. Slow reacting aggregates may not manifest ASR distress for decades.

ASR has been identified in 131 localized areas of multiple Seismic Category I structures and Maintenance Rule structures at Seabrook Station. Initial discovery was made when concrete core samples were removed from below grade structures that had been in contact with groundwater for several decades. Initial diagnosis was based on petrographic examinations of the removed core samples. Material property testing was also conducted on the removed core samples to determine compressive strength and modulus of elasticity. Though initial testing indicated reductions in compressive strength, later testing confirmed that there were no reductions in compressive strength which is consistent with published data of ASR impacted concrete samples. Reductions in modulus of elasticity were seen in the removed core samples which is also consistent with published data. Splitting tensile tests were not conducted on the core samples. This testing was originally planned; however, additional technical information indicated that splitting tensile tests of core samples is not representative of actual in situ performance of reinforced concrete members. Once removed from the structural context (e.g. reinforcement or confining loads) the behavior of the core samples do not correlate to the confined structure.

Current efforts are focused on reconciling the current ASR condition with the licensing design basis, establishing the basis for an ASR monitoring plan, and evaluating mitigation/remediation strategies, if warranted.

2.0 Purpose

Evaluate and resolve the impact to structural performance due to the discovery of ASR in several onsite structures. Current conditions are considered to be degraded but operable. This project includes four main elements: Diagnosis, Evaluation of Current Impacts, Prognosis and Mitigation if warranted.

3.0 Diagnosis

Original diagnosis involved the removal of several 4″ diameter by 14″ - 16″ deep concrete core samples in the affected areas. These core samples were tested for compressive strength and modulus of elasticity and compared to test results from standard concrete cylinders cast during the original concrete construction placements. The core samples were subjected to petrographic examinations per ASTM C856 which revealed the presence of micro cracking in the coarse aggregate and cement paste along with the characteristic formation of ASR gel staining.

The first core samples were removed in April and May of 2010. Twelve (12) core samples were taken from the lower electrical tunnel in the Control Building. This area was selected because it is qualitatively the most significant groundwater intrusion area with extensive pattern cracking and secondary deposits on the walls. The initial visual examination of the core samples was positive. The core samples displayed the visual characteristics of high quality, competent concrete and confirmed the use of proper concrete placement procedures. However, subsequent quantitative testing comparing the core samples to original test cylinders cast during construction of the Control Building in 1979 indicated a reduction in concrete strength and modulus of elasticity. Further petrographic examinations in accordance with ASTM C856 identified the presence of ASR. Reduced concrete material properties were reconciled against the original design basis calculations. In practice, the modulus of elasticity properties for below grade structures is relatively negligible due to the concrete backfill between the outside wall face and granite bedrock.

Subsequently, additional concrete core samples were removed from the same areas in the lower electrical tunnel and were tested at a second independent testing laboratory. Test results established that there was no reduction in the compressive strength of the concrete affected by ASR when compared to control core samples not affected by ASR. These test results are consistent with the concrete industry's understanding that ASR does not typically affect the compressive strength of concrete.

Additional concrete core sampling was performed to determine the extent of condition both from the perspective of additional areas that might be affected by ASR and also the extent of ASR degradation within a given area. The extent of condition core samples were taken in five different areas of the plant:

1. Containment Enclosure Bldg – Four (4) concrete core samples have been taken including areas of concern (wetted) and control areas (limited-wetted adjacent areas).

2. RCA walkway - Four (4) concrete core samples have been taken including areas of concern (wetted) and control areas (non-wetted adjacent wall).
3. DG Oil Storage Room - Four (4) concrete core samples have been taken including areas of concern (wetted) and control areas (non-wetted adjacent areas).
4. RHR Vaults - Four (4) concrete core bore samples have been taken including areas of concern (wetted) and control areas (non-wetted adjacent areas).
5. EFW Pump house stairwell - Four (4) concrete core bore samples have been taken including areas of concern (wetted) and control areas (non-wetted adjacent areas).

These twenty core samples were sent to an independent testing laboratory in April 2011 for compressive strength testing, modulus of elasticity testing and petrographic examinations. These petrographic examinations confirm that the original Control Building lower electrical tunnel core samples show the most significant ASR distress. Testing of the core samples indicated the compressive strength in all areas actually increased since the original concrete placements and that compressive strength is greater than the strength required by design. The unrestrained modulus of elasticity was generally lower compared to the calculated modulus of elasticity.

The core samples provided several insights into the extent of ASR cracking over the affected areas. First, the areas affected were highly localized in that core samples taken from adjacent locations did not exhibit signs of ASR characteristics or features. Secondly, when the length of the cores were evaluated (i.e., depth into the wall) it was observable that the cracking was most severe at the exposed surface and reduced towards the center of the sample. This is consistent with the industry's understanding of the confinement effects on ASR expansion.

The degree of concrete expansion (observable as surface cracking) is most severe at the surface of the concrete due to several factors. The surface or cover concrete is typically 2 inches over the steel reinforcing bars. Because this surface is not within the steel reinforced part of the wall, the concrete is free to expand as the ASR gel is formed and ultimately cracks. Additionally, the surface of the wall is subject to wetting and drying which can increase the flow of alkalis in this area. Consequently, crack mapping and indexing of the concrete surface is an appropriate, reliable diagnostic tool for determining the extent and progression of ASR. This method is endorsed and implemented by the Federal Highway Administration (FHWA-HIF-09-004 Appendix B).

ACTION: Monitor the surface cracking of the ASR impacted areas at a 6 month frequency.

Walk-down inspections and assessments of onsite concrete structures were conducted with participation from a trained, experienced petrographer during which additional areas of ASR degradation were identified. In total, 131 specific areas were identified as exhibiting features of ASR. Initial and subsequent six-month interval crack measurements and crack indexing will be taken at 20 locations in areas that exhibit the highest crack indices.

ACTION: Update the Maintenance Rule structural monitoring program to ensure that new/changing conditions related to ASR will be captured.

4.0 Evaluation of Current Impact

Operability of Affected Class I Structures - The results of the unrestrained core testing were documented in the Corrective Action Program (ARs 581434 and 1664399) and prompt operability determinations (POD) were performed for the affected structures. The affected structures were treated as degraded but operable and the PODs document reasonable assurance that the structures will continue to perform their design functions.

Initial testing of removed core samples indicated reductions in the modulus of elasticity from the values assumed in the original design. The first compressive strength tests on the electrical tunnel cores appeared to indicate an approximately 22% decrease in compressive strength compared to that of the original test cylinders cast during construction of the Control Building in 1979. The modulus of elasticity was approximately 47% of the expected value. While it is now understood that the testing of unrestrained cores does not represent the actual in situ conditions of the structure, the original PODs conservatively assumed that the observed reductions were occurring throughout the structures.

In addition to the modulus of elasticity concerns, the PODs also addressed the potential impact to anchor bolt pull out strength, shear strength and potential dynamic response differences. To support the PODs, an initial anchor bolt testing program was performed at the University of Texas at Austin (UT-A) with technical review and oversight provided by MPR Associates. The testing program included two types of anchors consistent with Seabrook designs. The anchors were installed in existing ASR affected bridge girders at the UT-A. The test results demonstrated that there was no significant impact on the capacity of the anchors.

ACTION: Additional anchor testing will be performed at the UT-A using reinforced concrete blocks more characteristic of the Seabrook Station design, and pre-ASR and post ASR test protocols. Testing will include measurement of expansion and petrographic confirmation of ASR distress levels. Action levels based on anchor performance at various levels of ASR expansion (crack index) will be developed.

There is considerable evidence, including results from large scale beam testing performed by the UT-A as well as testing of removed bridge beams in Japan that indicate ASR does not in practice adversely affect structural strength of tri-axially reinforced structures. In fact the ASR mechanism has a pre-stressing effect that increases the tested stiffness of the beam. Therefore, the confinement of the concrete by the rebar cage is important to actual structural performance. The affected structures at Seabrook in general do not include transverse (shear) reinforcement; thus, the existing large scale beam testing is not directly applicable at Seabrook. A conservative bounding analysis was performed to determine the potential affects of ASR on the shear/tensile capacity and reinforcement anchorage. MPR Associates performed this evaluation using the worst case published data available for small scale testing of non-transverse reinforced concrete blocks. The data scatter is high in this small scale sample, but the worst case reported values were used to assess tensile strength and lap splice separation. In most cases even using these very bounding values, the Seabrook structures contained sufficient margin to demonstrate compliance with ACI 318 code allowables. In a limited number of cases the bounding results were below ACI code allowables but still had significant margin to ultimate failure.

ACTION: Revise the PODs to incorporate the bounding evaluation of potential shear/tensile impacts from ASR.

To address the potential that there may be an adverse dynamic response associated with reduced modulus of elasticity test results on the removed core samples; a finite element model of the most limiting area was developed. Using this model a differential analysis of the structure with various modulus changes was performed. In conclusion, the dynamic response was insensitive to the modulus changes.

ACTION: The results of the finite element modeling of the CEVA structure will be added to the POD.

A Root Cause Evaluation (RCE) analysis was completed per AR 1664399. Actions to address the two root causes and contributing cause identified are tracked in this significance level 1 AR.

5.0 Prognosis

Given that ASR is occurring in some plant structures, it is natural to consider how far the reaction has progressed to date and what levels of ASR expansion are expected in the future. Regrettably, there are no standard testing methods that will give accurate answers in a short amount of time. Reaction rates are most effectively measured as expansion rates of the concrete. Accelerated laboratory tests are inherently not representative of actual in situ expansion rates, because several of the variables that affect reaction kinetics (e.g., temperature, moisture levels, alkali concentrations and diffusion rate, surface area and mineral composition of aggregates) are changed at the same time and drastically increased to drive the relatively slow process to occur rapidly. The expansion rates seen in these accelerated laboratory tests are useful for screening of aggregates and concrete mixes, but the rates do not correlate to the observed rates in the actual structures. Though accelerated laboratory testing cannot be completely representative of the conditions at Seabrook Station, it can provide valuable data that will aid in monitoring the behavior of the structures.

Additional testing is being performed to provide information on both the reaction rate of the Seabrook materials and the extent of the reaction that has occurred to date. The testing is a modified use of the Accelerated Mortar Bar Test (AMBT) ASTM C1260 and the Concrete Prism Test (CPT) ASTM C1293. Typically, the AMBT is used to screen aggregates and to determine the efficacy of various supplementary cementing materials (e.g. fly ash, slag, silica fume, and natural pozzolans). The test is conducted for 14 days and an expansion of 0.1% is the current acceptability criteria. The AMBT is being conducted using recovered aggregates from both the reacted areas (ASR affected concrete) and un-reacted areas (non-ASR affected concrete). A comparison of the two responses will provide some indication of the progression of ASR to date and potential for future expansion.

ACTION: Complete AMBT and CPT of reacted and unreacted aggregates.

Because in situ conditions will affect the actual reaction rate observed, a comprehensive monitoring plan is required to monitor the actual expansion/crack propagation in the affected areas. In practice, the ASR reaction may be limited by the alkali available due to the use of low alkali cement in the original concrete mixes.

ACTION: Testing for remaining soluble alkali will be conducted to determine if the ASR is limited by alkali availability.

As previously stated, in situ conditions will affect the actual reaction rate observed, therefore a comprehensive monitoring plan is required to monitor the actual expansion/crack propagation in the affected areas. Monitoring the progression of ASR can be effectively accomplished by detailed visual inspections and trending of the observable surface of the structures. Crack mapping and expansion monitoring provides the best correlation to the progression of ASR in the structure. These measurements will be taken at 6 month intervals and typically 3 years of data is needed to establish a trend.

Large scale testing of representative reinforced concrete beams will be conducted at the UT-A using reinforcing details from Seabrook Station structures. These concrete beams will undergo accelerated ASR reaction and will be monitored for ASR expansion and crack index. Testing will establish the potential future impact to structural stability and provide action levels that are correlated to visual crack indices monitored on the exposed surfaces of structures.

ACTION: Large scale destructive testing of accelerated ASR beams will be conducted to determine the actual structural impact of ASR. Actions levels will be established based on correlation between the structural testing results and observed expansion levels/crack mapping.

6.0 Mitigation

Most mitigation techniques that have shown efficacy are done at the time of concrete mixing. Various supplementary cementing materials have been shown to reduce the likelihood or rate of ASR reaction including use of fly ash, silica fume, natural pozzolans and lithium. However, the only technique that could be implemented on existing hardened concrete is lithium. Despite many years of research by the FHWA, there are no lithium treatments that have been able to penetrate more than a few centimeters into existing concrete, rendering these techniques ineffective as presented at the 14th International Conference Alkali-Aggregate Reactions (ICAAR) held May 20-25, 2012 in Austin, TX. This includes topical application, vacuum and pressure techniques. There is some promise with applying an electrical current to the rebar to migrate the lithium ions, however, the sodium (Na) and potassium (K) ions also migrate to the rebar increasing the likelihood of corrosion.

ACTION: Evaluate industry developments with the application of lithium via the current diffusion or new methods.

Elimination of groundwater inflow could slow ASR progression and limit expansive gel effects. Drying of ASR affected concrete could also reverse some expansion that has occurred due to drying of the ASR gel; however, the structural implications are negligible.

ACTION: Evaluate the ability to prevent groundwater ingress.

Remediation techniques can be developed and tested from additional test beams being cast during the large scale beam tests. The efficacy of these techniques can be proven using reacted test beams. The need for these remediation techniques will be evaluated based on the progression of the expansion in the in-situ walls and monitoring against action levels developed in the large scale beam testing program.

ACTION: Evaluate the need for remediation techniques based on results of the large scale beam testing at UT-A.

Summary of Actions

	Action Description	Due Date(s)
Diagnosis	Perform the initial six-month interval crack measurements and crack indexing at 20 locations in areas that exhibit the highest crack indices. Crack measurements will be performed at six-month intervals until a reliable trend of ASR progression is established. (Ref. NRC CAL AR 1758920)	7/15/12 1/15/13 7/15/13 1/15/14 7/15/14
	Update the Maintenance Rule Structural Monitoring Program to include monitoring requirements for selected locations in areas that exhibit ASR. (Ref. NRC CAL AR 1758920)	7/15/12
Current Impact	Perform additional anchor testing using concrete blocks with design characteristics similar to Seabrook Station. (Ref. NRC CAL AR 1758920)	12/31/12
	Revise the POD associated with the B Electrical Tunnel. Incorporate the bounding evaluation of potential shear/tensile impacts from ASR. Submit the root cause evaluation for the organizational causes associated with the occurrences of ASR. Submit the evaluation "Impact of ASR on Concrete Structures and Attachments". (Ref. NRC CAL AR 1758920) Revise the POD associated with the CEB, RHR Equipment Vaults, EFW Pump House, and DGB. Incorporate the bounding evaluation of potential shear/tensile impacts from ASR. Include results of the finite element modeling. Include the expanded scope buildings in the revised POD. (Ref. NRC CAL AR 1758920)	Completed 5/25/12 Completed 5/25/12 Completed 5/25/12 6/30/12

	Action Description	Due Date(s)
Prognosis	Complete short term aggregate expansion testing per ASTM C1260 Accelerated Mortar Bar Expansion Test (AMBT). Complete long term aggregate expansion testing per ASTM C1293 Concrete Prism Test (CPT). (Ref. NRC CAL AR 1758920)	6/30/12 6/30/13
	Testing per FHWA publication, FHWA-HIF-09-004 for remaining soluble alkali will be performed as a method to determine if the ASR could be limited by alkali availability.	12/30/12
	Large scale destructive testing of reinforced concrete beams with accelerated ASR will be conducted to determine the actual structural impact of ASR. Actions levels will be established based on correlation between the test results and observed expansion levels/crack indices (Ref. NRC CAL AR 1758920 for sub-action to submit testing details to NRC by 6/30/12)	7/25/14
Mitigation	Evaluate industry developments with the application of lithium via the current diffusion or new methods. (Ref. RCE AR 1664399)	8/31/12
	Evaluate the ability to prevent groundwater ingress. (Ref. RCE AR 1664399)	12/30/13
	Evaluated the need for remediation techniques based on results of the large scale beam testing at UT-A. (Ref. RCE AR 1664399)	12/30/14