NEXTera ENERGY SEABROOK

May 1, 2013

SBK-L-13080
Docket No. 50-443

Mr. William Dean, Administrator
U.S. Nuclear Regulatory Commission
Region I
2100 Renaissance Boulevard
Renaissance Park
King of Prussia, PA 19406

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, dated May 16, 2012. (ML121254172)

In the above reference, the NRC issued Confirmatory Action Letter (CAL) No. 1-2012-002 which confirmed commitments NextEra Energy Seabrook, LLC (NextEra Energy Seabrook) made regarding planned actions to address alkali silica reaction (ASR) in certain structures at Seabrook Station.

In accordance with the CAL, NextEra Energy Seabrook is submitting Enclosures 1 through 7 of this letter to provide updated information to address CAL items 2, 4, and 8.

Enclosure 1 contains the revised summary of the ASR root cause evaluation in accordance with CAL Item 2.

Enclosure 2 provides the update to the integrated corrective action plan in accordance with CAL Item 4.

In accordance with CAL Item 8, Enclosure 3 provides the proprietary version of the large scale test program, "Specification for Shear and Reinforcement Anchorage Testing of ASR-Affected Reinforced Concrete."

Enclosure 4 provides the non-proprietary, redacted version of the "Specification for Shear and Reinforcement Anchorage Testing of ASR-Affected Reinforced Concrete."

Enclosure 5 provides the proprietary version of the so-called overarching document, "Approach for Shear and Reinforcement Testing of Concrete Affected by Alkali Silica Reaction," an overview of the large scale testing to take place at the contracted research and development facility.

Enclosure 6 provides the non-proprietary, redacted version of, "Approach for Shear and Reinforcement Testing of Concrete Affected by Alkali Silica Reaction."

Enclosure 7 of the letter contains a NextEra Energy Seabrook Application for Withholding Proprietary Information from Public Disclosure and accompanying affidavit.

Enclosures 3 and 5 of this letter, "Specification for Shear and Reinforcement Anchorage Testing of ASR-Affected Reinforced Concrete" (proprietary), and "Approach for Shear and Reinforcement Testing of Concrete Affected by Alkali Silica Reaction"(proprietary), respectively, contain NextEra Energy Seabrook proprietary information. This letter is supported by an affidavit signed by NextEra Energy Seabrook, setting forth the basis on which the information may be withheld from public disclosure by the Commission and addressing the considerations listed in 10 CFR 2.390(b)(4). Accordingly, it is respectfully requested that the information which is proprietary be withheld from public disclosure in accordance 10 CFR 2.390.

In accordance with CAL Item 9, the structures monitoring program has been revised and is available for NRC review.

If you have any questions of a technical nature, please contact Mr. Richard Noble, ASR Project Manager at (603) 773-7308.

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

Sincerely,

NextEra Energy Seabrook, LLC

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Enclosure 1 to SBK-L-13080

ASR Root Cause Evaluation Summary

Root Cause Evaluation Summary

A. Narrative of the event and response

In 2009, as part of the Seabrook License Renewal process, basis documents were developed to support aging management programs, including a structures monitoring program. The basis document for the structures monitoring aging management program identified that the aggressiveness of the groundwater chemistry on concrete structures in contact with groundwater/soil needed to be validated. Historically, groundwater intrusion impacts had been treated as a mostly housekeeping issue, because the original concrete mix design was thought to have precluded deleterious chemical degradation mechanisms. In 2010, concrete core samples were taken from the lower electrical tunnel areas for testing and examination. This area had been subjected to significant groundwater intrusion for several years. The core samples displayed the visual characteristics of high quality concrete. However, subsequent quantitative testing revealed a reduction in the compressive modulus of elasticity (Young's Modulus). Further investigation included petrographic examinations which unexpectedly identified the presence of Alkali-Silica Reaction (ASR).

An extent of condition evaluation was performed which entailed removal of additional concrete core samples for testing and petrographic examination. In June, 2011, after receiving the laboratory test and examination reports, Seabrook confirmed concrete degradation by ASR in selected areas of four safety-related structures. This discovery was unexpected since it was believed that the concrete materials used at Seabrook would not be susceptible to ASR since:

1. the coarse aggregate is largely igneous rock that was routinely tested during construction and passed petrographic examinations and expansive reaction tests that normally detect alkali-silica reaction ; and
2. low-alkali Portland cement was abundantly used.

During this extent of condition assessment, Design Engineering identified that years after the Seabrook concrete was placed, the ASTM standards were updated to caution that the tests specified may not accurately predict reactive aggregates when dealing with late or slow-expanding reactive aggregates containing strained quartz or microcrystalline quartz such as the coarse aggregates used at Seabrook. It was also learned that the concrete industry in conjunction with the ASTM developed new, more accurate and reliable test methods to assess potentially reactive coarse and fine aggregates that are used in concrete.

Alkali-Silica Reaction (ASR) is a reaction that occurs over time in concrete between the alkaline cement paste (Portland cement) and reactive non-crystalline silica in aggregates. A gel material of increased volume is formed within the aggregate resulting in micro cracks in the aggregate itself and often the cracking continues into the cement paste. The most severe cases of ASR produce a damaging network of microcracks, resulting in bulk expansion of the concrete (not necessarily isotropic) and severe deterioration of its mechanical properties.

The conditions required for ASR to occur are:

- A sufficiently high alkali content of the cement (or alkali from other sources),
- A reactive aggregate, and
- Moisture - ASR will not occur without the presence of moisture /water, since alkali-silica gel formation requires moisture/water

Building structures, including foundations for Seabrook Station seismic Category I buildings, are conventionally reinforced concrete mats and walls of varying thicknesses. Foundation mats are supported on sound bedrock or on fill concrete extending to sound bedrock. Essentially, the site can be viewed as an excavated bowl carved out of the bedrock with varying cavities with depths as much as 80 feet below grade elevation. The concrete mix designs for Seabrook Station structural concrete and fill concrete were developed by the Architect/Engineer (A&E) and an independent testing laboratory in the mid to late 1970's. The mix designs were developed in accordance with the applicable ACI and ASME codes and ASTM standards. Concrete aggregates were routinely selected and tested based on ASTM standard tests at that time to ensure aggregates with low susceptibility to expansive reactions such as alkali-silica reaction. The concrete mixes were batched on site and placed in accordance with the A&E specifications and site procedures. All safety related concrete batching and placements were overseen by the civil contractor quality control and the A&E quality assurance personnel and tested by an independent testing company. The original site design utilized an impermeable elastomeric waterproofing membrane system under the foundations and around the outside perimeter of most of the below grade building walls to act as a groundwater barrier. This waterproofing membrane was installed in accordance with A&E specifications and site procedures and overseen by the civil contractor quality control and the A&E quality assurance personnel.

Seabrook has experienced groundwater inleakage into below grade structures since construction. The site was dewatered during original construction to facilitate construction activities below grade. The dewatering systems were removed or de-activated following construction and most are not available for current use. The groundwater inleakage is believed to be due to the waterproofing membrane being damaged during construction resulting in an ineffective barrier. Groundwater flows through numerous fissures in the bedrock and through breaches in the membrane to the structures resulting in a complicated and changing groundwater flow picture. Historically, this groundwater in-leakage was viewed as a corrosion threat to rebar, embedments and adjacent components/supports, but was not recognized as a potential threat to the material properties of structural concrete. This resulted in an organizational mindset that did not mandate the elimination or mitigation of this groundwater inleakage. Most of the efforts to date to address the groundwater in-leakage have focused on local dewatering to reduce the hydrostatic head at specific locations. These efforts have had marginal success.

When evaluating condition reports for groundwater in-leakage and/or degraded concrete, Engineering incorrectly believed that the cement and aggregate selection for the Seabrook concrete precluded ASR development, so Engineering viewed the water only as a corrosion threat to structure/components impacted by the in leaking groundwater.

Calculations completed by Design Engineering after the ASR was identified have demonstrated that the reduced modulus of elasticity has negligible effect on the structural integrity or durability of the concrete, and no adverse effect on the design function of the affected buildings. Prompt Operability Determinations (PODs) were performed which concluded, with reasonable assurance, the structures are fully capable of performing their safety function and are operable with reduced margin. Design Engineering has supplemented its concrete expertise with consultants and developed an action plan addressing concrete degradation by ASR which defines a strategy for establishing the service life of structures and identifies the actions necessary to execute the strategy.

The following problem statement for this root cause was developed by the Root Cause Evaluation (RCE) team and approved by the Management Review Committee:

> In 2010, Seabrook discovered ASR related concrete degradation in several structures. Determine how the ASR developed and why its presence was not identified until 2010.

By the root cause evaluation process, the simple test to determine if a causal factor is a "root cause" is to remove that causal factor from the failure scenario. If the event does not occur when a particular causal factor is removed, that causal factor is a "root cause". As noted previously, for ASR to occur, three factors are required:

- A sufficiently high alkali content of the cement,
- A reactive aggregate, and
- Moisture

When evaluating concrete areas identified with ASR, the RCE team identified areas that were above ground, so the "moisture" source was something other than groundwater. Based on that identification, the RCE team determined that groundwater inleakage could not be the "root cause" of this event. While groundwater exacerbated the condition, if groundwater inleakage was eliminated, Seabrook would still have areas of concrete with ASR. Since elimination of the groundwater would not prevent ASR, groundwater was determined to be a contributing cause.

B. Root Cause(s)

Based on the problem statement, the RCE team identified the following two root causes:

RC1 - The ASR developed because the concrete mix designs unknowingly utilized a coarse aggregate that would, in the long-term contribute to Alkali-Silica Reaction. Although the testing was conducted in accordance with ASTM standards, those testing standards were subsequently identified as limited in their ability to predict slow reactive aggregates that produce ASR in the long term.

RC2 – Based on the long standing belief that ASR was not a credible failure mode due to the concrete mix design, dispositions for condition reports involving groundwater intrusion or concrete degradation; along with the structure health monitoring program did not consider the possibility of ASR development.

One contributing cause was identified:

Failure to prioritize groundwater elimination or mitigation resulted in more concrete area exposed to moisture.

C. Corrective Actions to Prevent Recurrence of the Root Causes

Corrective actions to prevent recurrence are:

RC1 – Nothing can be done to correct the concrete mix design issue for the existing buildings. The ASTM standard issue is outside the control of Seabrook Station. However, it should be noted that the standard has been updated to caution that the specified aggregate test is not effective in identifying slow reactive aggregate. Additional ASTM standards have been issued to better identify concrete mix strategies to minimize the potential for ASR.

New concrete structures will be constructed with concrete mixes that include pozzolanic materials like fly ash or slag cement that prevent ASR.

The focus of the Seabrook corrective actions associated with the ASR phenomenon will be to address the present material properties and in-situ strength of affected structures and the potential for continued degradation for below grade and above grade structures.

RC2 –Develop a process for system/program/structure monitoring plans focusing on vital failure modes, critical system parameters and utilizing the evaluation of specific OE for each failure mode and parameter. This process is to include the identification and tracking of long-term prevention strategies, and periodic reassessment of failure modes that were excluded from the monitoring criteria to ensure that the monitoring/mitigating strategies remain applicable and effective. Inclusive in this process will be periodic evaluation for new operating experience information. This process will also include a feedback loop for re-evaluating the strategy if a failure does occur.

D. Actions Taken to Address the Contributing Cause

CC1 - Several plant modifications have been implemented over the years to address groundwater in-leakage. Epoxy injections into concrete cracks performed in the1990s, had limited success due to in leakage migrating to areas adjacent to the injection sites.

Starting in the early 2000s, dewatering skids were installed in buildings to reduce groundwater pressure on the exterior surfaces of structures. Skids consisted of pumps, holding tank, and piping that diverted the groundwater from the exterior of the structure to the storm drain system. These modifications had limited local impact.

Consultation with experts to address groundwater intrusion has also been pursued. In 1998 the Station contracted a Northeastern University Hydrologist to identify potential options for dewatering the Seabrook site. In 2003 the Station contracted

Altran Corp to review our assessment of areas impacted by groundwater and provide any recommendations to enhance the assessment process. Most recently in 2011/2012, the Station contracted RSS Corp to perform fate and transport study to assess groundwater flow at Seabrook site.

Evaluation of additional groundwater mitigation is ongoing.

Enclosure 2 to SBK-L-13080

ASR Project Corrective Action Plan

ASR Project
Corrective Action Plan
April 2013

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 gels expand, micro-cracks are formed in the aggregate often extending into the cement paste. The main observable effect of ASR on structures is expansion and cracking due to 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, 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. The initial discovery was made when concrete core samples were removed from below grade structures that had been in contact with groundwater for several decades. The 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. No actual reductions in compressive strength were confirmed, 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 does not correlate to that of the confined structure.

Current efforts are focused on reconciling the existing ASR condition with the licensing design basis, establishing an ASR monitoring plan, and evaluation of 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 Strategy if warranted.

3.0 Diagnosis

Initial diagnosis involved the removal of 4″ diameter by 14″ - 16″ deep concrete core samples in the affected areas. These core samples were tested to determine their compressive strength and modulus of elasticity and compared with test results from standard concrete cylinders cast during the original concrete construction placements. In addition, petrographic examinations per ASTM C856, revealed the presence of micro cracking in the course aggregate and cement paste with the characteristic formation of ASR gel staining.

The first core samples were removed in April and May of 2010. Twelve core samples were taken from the lower electrical tunnel in the Control Building. This area was selected because, qualitatively, it had the most significant groundwater intrusion, and the walls show the most extensive pattern cracking and secondary deposits. The initial visual examination of the core samples was positive - the core samples displayed the visual characteristics of high quality, competent concrete and proper concrete placement procedures. However, subsequent quantitative testing revealed a reduction in concrete strength and elasticity modulus (Young's Modulus). 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 unimportant due to the concrete backfill between the outside wall face and granite bedrock.

Subsequently, additional concrete core samples were removed from the same locations in the lower electrical tunnel and were tested at another independent testing laboratory. The results of these tests established that there was no reduction in the compressive strength of the concrete affected by ASR, when compared to control core samples that were 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 that the compressive strength in all areas actually increased since the original concrete placements, and that the compressive strength is greater than the strength required by the design calculations for the structures. The tested unrestrained modulus of elasticity was generally lower compared to the calculated modulus of elasticity.

The core samples provided two key insights into the extent of ASR cracking in the affected areas. First, the areas affected were highly localized; samples taken from adjacent locations did not show signs of ASR characteristics or features. Second, when the length of the cores were evaluated (i.e., depth into the wall) it was observed that the cracking was most severe at the exposed surface and reduced towards the center of the wall. This is consistent with the existing literature and with our understanding of the confinement effects on ASR expansion.

The potential impact of ASR on the structural strength of concrete is a consequence of strains resulting from the expansive gel. These strains produce the associated cracking. The potential structural effects of ASR expansion include impacts to compressive strength, shear strength, and modulus of elasticity, as well as effects on reinforcing steel development lengths and anchor bolts are all a result of the expansion and micro cracking. The degree of strain and resulting specific structural impact is heavily dependent on the structural context of the affected member. Actual material property impacts from ASR are affected significantly by the degree of confinement (structural context). Evaluations of structural impact must therefore take into account the reinforcement details of the affected structure. Accordingly, these impacts can not be directly measured by testing of unrestrained removed concrete core samples. For this reason, a large scale testing program is being implemented, as discussed later in this document.

Expansion can be measured in test specimens by using embedded steel rods or pins to measure the strain in the material. For existing structures, the historical strain data is not recoverable because pins were not installed at the time of construction. However, cracking can be used as an indication of accumulated strain. Monitoring of surface cracking, and specifically crack mapping, is the most effective way to correlate the accumulated expansion in the structures. Other NDE methods have been and are being investigated. However, alternate methods do not have a proven track record and need to be validated against the direct indications of cracking and expansion. NextEra Seabrook is actively working with EPRI to develop improved NDE techniques for concrete. Since cracking and expansion can be directly measured on the exposed concrete surfaces this is the most direct and accurate method to monitor ASR progression.

The degree of cracking is most severe at the surface of the concrete due to several factors. The surface or cover concrete extends beyond 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 expands. Additionally, the surface of the wall is subject to wetting and drying which can increase the flow of alkalis in this area. Consequently, the exposed surface will have the largest and most visible cracking. This makes crack mapping and indexing of the concrete surface an appropriate and reliable diagnostic tool for monitoring the progression of ASR. The use of surface crack indexing is endorsed and implemented by the Federal Highway Administration (FHWA-HIF-09-004 Appendix B). The approach being applied to Seabrook is a combined crack index (CCI) that averages the crack indexes in the x and y in-plane directions. Three tiers are used to monitor ASR conditions.

Structural Monitoring Program	**Recommendation for Individual Concrete Components**	**Combined Cracking Index CCI**	**Individual Crack Width**
Tier 3 - Unacceptable (requires further evaluation)	Structural Evaluation	1.0 mm/m or greater	1.0 mm or greater
Tier 2 - Acceptable with Deficiencies	Quantitative Monitoring and Trending	0.5 mm/m or greater	0.2 mm or greater
	Qualitative Monitoring	Any area with indications of pattern cracking or water ingress	
Tier 1 - Acceptable	Routine inspection as prescribed by Structures Monitoring Program	Area has no indications of pattern cracking or water ingress – No visual presence of ASR	

m= meter

Tier 3 monitoring also includes expansion measurements of stainless pins installed permanently in the gridded CCI locations. These measurements are being tracked along with the CCI values to identify trends. Future plans include the installation of additional deeper pins that can be used to measure out of plane expansion and in plane expansion of the bulk wall. The pins will be installed in a representative group of Tier 3 monitoring areas. This information will be trended for future correlation to CCI trending data. Similar data from installed pins in the test specimens for the large scale test program will also be taken and evaluated. Finally, additional cores will be taken from both test specimens and in situ locations at various CCI levels (degrees of ASR expansion) to compare and validate internal ASR impacts via petrographic analysis.

ACTION: Update the structural monitoring program to describe installation and monitoring of stainless pins for in-plane and out of plane expansion. *Working*

ACTION: Continue to monitor the surface cracking (CCI) of the ASR impacted areas on the frequencies established in the revised Structural Monitoring Program. *Working (Two 6 month, Tier 3 intervals have been completed to date.)*

Walk-down inspections and assessments of onsite concrete structures were conducted with participation from a trained and experienced petrographer, during which additional areas of ASR impact were identified. In total, 131 specific areas were identified as exhibiting features of ASR. Additional walk-downs of areas that were not readily accessible are planed as a Phase 3 walk-down effort. In general these areas are being inspected as the opportunity to access them arises. However, a schedule has been developed and presented to the NRC working group as part of their ongoing inspection activities. An example of the Phase 3 effort is the inspection of the service water vault during the fall 2012 refueling outage. The service water vault is an underground structure requiring excavation and dewatering to open. ASR inspections identified no signs of ASR in this structure. No current opportunity is available to inspect the spent fuel pool concrete for ASR therefore a specific activity will be developed for this structure and added to the Phase 3 schedule.

ACTION: Update the Phase 3 schedule with a plan for inspecting the spent fuel pool concrete for ASR. *Working*

ACTION: Update the structural monitoring program to ensure that new/changing conditions related to ASR will be captured. The Initial revision required by this action was completed. Additional revisions in April 2013 include definition of the 30 month interval for monitored areas meeting the ASR tier 2 criteria. Future revisions will include discussions of plans to monitor expansions by installing stainless reference pins and use of additional petrographic examination to validate CCI correlations with test specimens. *Working*

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 (AR 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 from the electrical tunnel were compared to the original test cylinders cast during construction of the Control Building in 1979. This comparison initially also appeared to indicate an approximately 22% decrease in compressive strength. Removed cores are expected to yield compressive strength values of 10% to 15% lower than cylinder tests. Also some differences in test methods may account for some of the observed differences. Finally, when additional cores were taken and tested from both ASR impacted areas and non-ASR impacted areas the tested compressive strengths were essentially the same. This is consistent with the industry literature which predicts minimal impact to tested compressive strength at relatively low ASR expansions. The modulus of elasticity was approximately 47% of the expected value. While it is now understood that the testing of unrestrained cores does not account for the structural context of the actual in situ concrete elements, the original PODs conservatively assumed that the observed reductions in modulus 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, lap splice strength, structural stiffness and potential dynamic response differences. To support the PODs, an initial anchor bolt test 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 at lower levels of ASR cracking. The performance of the anchors in areas of higher surface cracking was consistent with performance expected for cracked concrete resulting from any cracking mechanism.

ACTION: Additional anchor testing will be performed at the UT-A using reinforced concrete blocks designed to be similar to the characteristics of Seabrook Station structures, and pre-ASR and post-ASR test protocols. Testing will include measurement of expansion and petrographic confirmation of ASR distress levels. Any reductions in anchor performance at various levels of ASR expansion (crack index) will be identified and correlation will be made to in-situ levels of ASR expansion. Acceptance of the testing results to resolve ASR concerns associated with design basis structural calculations will follow the regulatory process for approval. This will include evaluation pursuant to 10CFR50.59 and entry into the License Amendment Request (LAR) process as applicable.

There is considerable evidence, including large scale beam testing performed by the UT-A and testing of removed bridge beams in Japan that indicates ASR does not in practice adversely affect structural strength of triaxially reinforced structures. In fact, the ASR mechanism has a chemical pre-stressing effect that can increase 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 are steel reinforced, but in general they do not include transverse (shear) reinforcement. Thus, the pre-existing large scale beam testing is not directly applicable to the majority of structures at Seabrook. However, because the impacted parts of the containment cylinder are heavily three-way reinforced, this existing data is applicable to structural evaluation of the containment. As a result, a separate POD was issued for the containment. Additional differences with the containment construction are addressed in the containment POD. Importantly, the steel reinforcement splices for the containment use a cad weld process that does not rely on concrete strength like the more common lap splice detail in the majority of other buildings. Also the containment is designed to ASME codes unlike the structures addressed in the other PODs.

For the plant structures other that the containment, a conservative bounding analysis was performed to determine the potential impact 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 1971 code allowables. In a limited number of cases, the bounding results were below ACI code allowables but still had significant margin to ultimate failure. The bounding analyses were done for the worst case ASR conditions (those with the highest CCI values). To address a potential that some of the lower CCI value structures might have more limiting structural impacts, a complete assessment of the remaining areas with a CCI > 1.0 mm/m was completed and added to the Interim Assessment (FP 100716). The additional evaluations confirmed that the structural impacts were bounded by the original higher CCI evaluations.

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

A finite element model of the most limiting area (CEVA structure) was developed to address the potential that there may be an adverse dynamic response associated with apparent modulus of elasticity tests taken on the removed core samples.. Using this model a differential analysis of the structure with various modulus changes was performed. This analysis concluded that the dynamic response was insensitive to the modulus changes.

ACTION: Add the results of the finite element modeling of the CEVA structure to the PODs. *Complete*

A root cause evaluation analysis was completed per AR 1664399. Actions to address the two root causes and contributing cause are tracked in this significant level 1 AR.

An update to the UFSAR describing the discovery of ASR has been approved and will be included in the 2013 update. This UFSAR change will be revised when the PODs are closed out and any required changes to the design basis have received NRC approval.

5.0 Prognosis

Given that ASR is occurring in some plant structures, it is natural to ask 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 of aggregates 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.

Additional testing was performed in an effort 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 conducted was a modified version of the Accelerated Mortar Bar Test (AMBT) ASTM C1260. 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 performed to evaluate the Seabrook ASR condition, utilized recovered aggregates from both the reacted areas (ASR affected concrete) and un-reacted areas (non-ASR affected concrete). A comparison of the two responses was made to provide some indication of the progression of ASR to date and potential for future expansion.

Originally it was planned to also perform a test based on the Concrete Prism Test (CPT) ASTM C1293. However, based on the information obtained from the completed Accelerated Mortar Bar Test (AMBT) ASTM C1260, the action to perform a CPT test was deleted. The AMBT results indicated that the reacted and unreacted samples both contained sufficient reactive silica to be considered reactive aggregates. The observed rates were essentially the same for both reacted and unreacted aggregates indicating that in practice there was no change in reactivity and therefore no expectation that the rate would level off in the foreseeable future.

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

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 theory the ASR reaction can be limited by the alkali available due to the use of low alkali cement in the original concrete mixes. Originally it was planned to test for the amount of remaining soluble alkali to determine if the reaction might be limited by alkalinity at some point. However, additional research has identified that there are other potential sources of alkalinity in addition to the cement paste. Specifically, the fill concrete poured against the walls could be an additional source of alkali. Additionally, there is some indication that certain aggregates can be a source of alkali, especially those with significant amounts of mica. The course aggregates used at Seabrook do contain mica and therefore may be a source of alkali. The action to test the concrete for soluble alkali will be cancelled because it will not account for alternate alkali sources and may be non-conservative.

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

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 are 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 reinforcement details from Seabrook structures. These concrete beams will undergo accelerated ASR reaction and will be monitored for ASR expansion and CCI. CCI will be used as a surrogate for engineering strain, which would be the best correlation, because CCI can be most readily measured in the in situ structures. Testing will establish the potential future impact to structural performance and provide action levels that are correlated to visual crack indices monitored on the structure exposed surfaces.

ACTION: Large scale destructive testing of accelerated ASR beams will be conducted to determine the actual structural impact of ASR. Structural performance 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 one that can be potentially used on existing hardened concrete is lithium. Federal Highway Administration Publication No. FHWA-HRT-06-133, "The Use of Lithium to Prevent or Mitigate Alkali- Silica Reaction in Concrete Pavements and Structures," was issued in March 2007 and provides the early history of this study. 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). Techniques investigated include topical application, vacuum and pressure techniques.

There is some future potential for techniques that apply 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. Consequently, the application of lithium is not being pursued at this time.

ACTION: Continue to monitor industry developments with lithium via current diffusion or new methods. *Complete*

Elimination of groundwater inflow could slow ASR progression and limit expansive gel effects. Drying of ASR affected concrete could also potentially reverse some expansion that has occurred due to drying out of the ASR gels; however, the structural implications are negligible. Most recently in 2011/2012 NextEra engineering contracted RSS Corp to perform a detailed fate and transport model of the groundwater flow at Seabrook site. This model is being used to evaluate future dewatering efforts. One notable area in which progress on dewatering is being made is the containment. The containment is essentially a dome within a dome as it is surrounded by the containment enclosure building and not exposed to the elements. The only source of water in contact with the containment has been a relatively small area where ground water accumulated in the annulus area between the enclosure building and the containment. This area is now being monitored and dewatered such that water is no longer in contact with the containment outer wall.

ACTION: Continue to evaluate methods to mitigate 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

Note: In some cases the completed dates may be for earlier revisions but some additional revisions to these actions may be ongoing.

	Action Description	**Due Date/Dates**
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) Install and monitor stainless steel pins for in-plane and out of plane expansions in five representative Tier 3 areas.	Completed 6/15/12 Completed 12/15/12 Next Interval 6/15/13 Initial data 6/30/13
	Update the Maintenance Rule Structural Monitoring Program to include monitoring requirements for selected locations in areas that exhibit ASR. (Ref. NRC CAL AR 1758920) Update the phase 3 schedule with a plan for inspecting the spent fuel pool concrete for ASR.	Completed 7/15/12 6/30/13
Current Impact	Perform additional anchor testing using concrete blocks with design characteristics similar to Seabrook Station. (Ref. NRC CAL AR 1758920)	12/31/13
	Revise the POD associated with the B Electrical Tunnel. 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. 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 Completed 6/30/12

	Action Description	Due Date/Dates
Prognosis	Complete short term aggregate expansion testing per ASTM C1260 Mortar Bar Expansion Test. Complete long term aggregate expansion testing per ASTM C1293 Concrete Prism Test. (Ref. NRC CAL AR 1758920)	Completed 6/30/12 Action Deleted
	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.	Action Deleted
	Large scale destructive testing of reinforced concrete beams with accelerated ASR will be conducted to determine the actual structural impact of ASR. A 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)	7/25/15
Mitigation	Evaluate industry developments with the application of lithium via the current diffusion or new methods. (Ref. RCE AR 1664399)	Completed 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

Enclosure 4 to SBK-L-13080
Non-Proprietary

Specification for Shear and Reinforcement Anchorage Testing of ASR-Affected Reinforced Concrete

MPR
ASSOCIATES INC.
ENGINEERS

Specification for Shear and Reinforcement Anchorage Testing of ASR-Affected Reinforced Concrete

0326-0062-05
Revision 5
(Seabrook FP # 100759)

April 24, 2013

QUALITY ASSURANCE DOCUMENT
This document has been prepared, reviewed, and approved in accordance with the Quality Assurance requirements of 10CFR50 Appendix B and/or ASME NQA-1, as specified in the MPR Nuclear Quality Assurance Program.

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Prepared for

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Revision Description Sheet

Revision Number	Sections Revised	Revision Description
0	All	Initial Issue
1	15, A3.2, A4.1, A4.2, A4.3, A.4.4	Revised per NextEra comment
2	6.1	Added requirement for Purchaser to review and approve first material purchase orders
	7	Modified hold points for procurement of material and performance of procedures by FSEL
	A1	Removed reference to ACI-318-71 for proof testing
	B2.3 and Table A-1	Updated coarse aggregate grading acceptance criteria based on revision to Reference 2.
3	4.4 and 9.0	Added clarification that calibration controls are not required for standard off-the-shelf measuring equipment which are not likely to change or drift during use.
	B2.2, B2.3 and Table A-1	Updated coarse aggregate grading acceptance criteria based on revision to Reference 2.
4	1.2 and 9.0	Editorial changes
	A3.2	Removed the requirement to perform coarse aggregate grading verification testing prior to unloading the remaining material
	A4.1 and A4.2	Added clarification that the use of Purchaser-approved sub-vendors for testing activities is acceptable.
5	6.2	Modified the information to be reported in the interim test report.
	15	Updated revision number for Reference 1.

5 (cont.)	A1 and A2	Modified the listing of information to be developed by the test program.
	A3.2	Clarified Note 4 of Table A-1.
	A3.3	Removed reference to elastomeric material.

1.0 SCOPE OF WORK

1.1 This Specification provides the requirements for testing of concrete beams affected by Alkali-Silica Reaction (ASR). The test results will be used to quantify the effect of ASR on the limit states of out-of-plane shear and reinforcement anchorage for the walls and slabs without transverse reinforcement at Seabrook Station.

1.2 The Vendor shall perform the following scope of work:

- Prepare detailed test procedures governing specimen preparation, calibration, conduct of testing, and documentation of results.
- Revise the quality system manual for MPR-sponsored testing to expand coverage to the shear and reinforcement anchorage test programs described herein, including material procurement. The quality system manual may also include performing QA inspections.
- Procure all equipment and materials necessary for the scope of testing and perform material verification testing as necessary (e.g., tensile testing of reinforcing steel and concrete compressive strength testing).
- Procure all services necessary to support the scope of testing (e.g. calibration and testing services).
- Detail test specimens in accordance with Appendix A of this specification.
- Detail practical retrofits that can be implemented to restore reasonable reductions in structural performance due to ASR.
- Perform trial batching and expansion testing to support selection of the concrete mix to be used for test specimen fabrication.
- Perform combined cracking indexes (CCI) in accordance with Appendix A of this specification.
- Prepare specimens for the tests in accordance with Appendix A of this specification. This involves fabricating the specimens from purchased cement, aggregate, and reinforcing steel and driving ASR degradation in the identified concrete specimens.
- Conduct the tests in accordance with Appendix A of this specification.
- Prepare cored specimens for petrographic examination in accordance with Appendix A of this specification.
- Prepare test reports documenting the test results.

Details regarding the above activities are provided in Appendices A and B. This scope of work shall be performed in accordance with the Vendor's project-specific quality system and associated procedures.

2.0 DEFINITIONS

Vendor: Ferguson Structural Engineering Laboratory at The University of Texas at Austin
Purchaser: MPR Associates, Inc.
Client: NextEra Energy Seabrook LLC

3.0 SCHEDULE

A detailed schedule shall be prepared by the Vendor and submitted to the Purchaser for approval. The detailed schedule shall include the following activities: development of the quality system manual documentation, test specimen preparation, and testing. The Vendor shall update the schedule periodically and notify the Purchaser of any delays that impact the overall schedule. The Purchaser's contact is James Moroney, (703) 519-0521.

4.0 TESTING REQUIREMENTS

4.1 All tests shall be performed in accordance with detailed Purchaser-approved procedures developed by the Vendor in accordance with this specification.

4.2 The preparation and characterization of test specimens shall be conducted in accordance with the requirements provided in Appendices A and B and the Vendor's detailed test procedures.

4.3 Deviations from the requirements of this specification and/or the Vendor's approved test procedure are prohibited without prior written approval from Purchaser. Any changes to specimen preparation, test conditions, or any other test parameter shall be documented in revisions to the Vendor's test procedures and approved by the purchaser.

4.4 All measurement and test equipment which requires calibration and which are used by the Vendor in the scope of work shall be calibrated prior to use. The calibration records for all such equipment shall be provided by the Vendor to the Purchaser prior to use for the scope of work. Calibration controls are not required for standard off-the-shelf measuring equipment which are not likely to change or drift during use (e.g., rulers, tape measures, levels, and sieve trays).

4.5 Testing shall be performed in accordance with the quality requirements invoked in the Vendor's test procedures and the Vendor's Quality Assurance System, latest revision approved by the Purchaser.

4.6 Informational testing (i.e., testing to support test specimen detailing and fabrication and testing to select a concrete mix) does not need to be performed in accordance with

Purchaser-approved procedures and does not need to satisfy the quality requirements defined herein.

4.7 Materials for specimen manufacture which have specific requirements for verification testing (e.g., steel reinforcement and coarse aggregate) shall be stored in a location that is dedicated solely for use in the programs defined herein.

5.0 SUBCONTRACTING

No testing shall be performed by any subcontractor without prior written approval by the Purchaser. This specification shall be applied to work performed by the subcontractor.

6.0 DOCUMENTATION

The Vendor shall provide all calibration, non-conformance, specimen preparation, and testing procedures to the Purchaser for review and approval prior to implementation. Purchaser review and approval will be documented by signatures on the procedure cover page. The Purchaser approval of a specific procedure must be documented prior to performing the activity covered by the procedure. Test procedures shall include all test requirements specified in Appendices A and B of this specification.

6.1 The Vendor shall provide all test specimen drawings to the Purchaser for review and approval prior to fabrication of any test specimens. Purchaser review and approval will be documented by signatures on the drawings or attachment to a Purchaser-approved procedure.

6.2 The Vendor shall provide an interim test report after the control test(s) for each test program is completed. The interim test report shall address both the shear and reinforcement anchorage test programs in the same document. This report shall present the results of the control tests. The interim test report shall contain, as a minimum, the following documentation:

- a list of the procedures used,
- a copy of the test specimen drawings,
- photographs, figures or other documentation depicting the test set-up and conditions,
- test data recorded and results,
- the date the testing was performed,
- calibration records of the equipment used, and
- a listing of the measuring and test equipment used for each test (identified by equipment ID) and the associated calibration records.

The interim test report shall include a statement indicating conformance to the requirements of this specification and the Vendor's project-specific quality system manual—see Section 12.

6.3 The Vendor shall provide a revision of the interim test report following completion of the tests with a level of ASR consistent with that observed at Seabrook Station. The revision shall incorporate the results for the ASR-affected beams, including quantification of the impact of ASR on the shear capacity and the impact on reinforcement anchorage performance. Documentation to be included in the revised interim report shall be as defined in Paragraph 6.3 above.

6.4 The required test results specified in the Appendix to this document shall be documented by the Vendor in a test report (final test report). The test report shall address both the shear and reinforcement anchorage test programs in the same document. This test report shall be provided to the Purchaser for review and approval prior to formal submittal to the Purchaser. The test reports shall contain, at a minimum, the following documentation:

- a copy of the procedures used,
- a copy of the test specimen drawings,
- pictures or other documentation depicting the test set-up and conditions,
- test data recorded and results,
- the names of the individuals conducting the test,
- the training records for individuals performing activities covered by this specification,
- the date the testing was performed,
- calibration records of the equipment used, and
- listing of the measuring and test equipment used for each test (identified by equipment ID) and the associated calibration records.

The test report shall include a statement indicating conformance to the requirements of this specification and the Vendor's project-specific quality system manual—see Section 12.

7.0 HOLD POINTS

7.1 MATERIAL PROCUREMENT

The Vendor shall notify the Purchaser three (3) days prior to first issuance of the purchase orders for fine aggregate, coarse aggregate , cement, and reinforcement. Work shall not proceed without written consent from the Purchaser.

7.2 PROCEDURE EXECUTION

The Vendor shall notify the Purchaser five (5) days prior to the hold points listed below. Work shall not proceed without written consent from the Purchaser.

- Procedure execution (excluding execution of concrete placement procedure and the shear and reinforcement anchorage test procedures as these are covered by the hold points which require 10 days notice)
  - First execution of any inspection, test, calibration or specimen preparation procedure
  - First execution of any inspection, test, calibration or specimen preparation procedure after a significant revision

7.3 KEY TEST PROGRAM ACTIVITIES

The Vendor shall notify the Purchaser ten (10) days prior to the hold points listed below. Work shall not proceed without written consent from the Purchaser.

- First crack indexing activity
- Each concrete placement activity
- Each shear or reinforcement anchorage testing activity

Note: Efforts for information only are not subject to the hold points described above.

8.0 RIGHT OF ACCESS

The Purchaser and the Client shall have right of access to the Vendor's facilities and records as required for QA inspection and audit purposes. (Scope of audits does not include financial records).

9.0 MEASURING AND TEST EQUIPMENT CALIBRATION

Pre-use, yearly, causal (calibration status in question due to damage, etc.), and post-use (program completion) calibration of Measuring and Test Equipment (M&TE) is required. M&TE shall either be calibrated and certified in accordance with an ISO 17025 accredited program or calibrated against standards that were calibrated and certified in accordance with an ISO 17025 accredited program. Calibration records are required for the M&TE used. Calibration records shall identify the person performing the calibration, calibration date, calibration expiration date, procedure used, standards used, and the as-found and as-left results. M&TE calibrated as part of the Anchor Test Program performed under MPR specification 0326-0058-26 does not require pre-use calibration for use in this program, provided the Vendor demonstrates the procedures are similar.

Calibration controls are not required for standard off-the-shelf measuring equipment which are not likely to change or drift during use (e.g., rulers, tape measures, levels, and sieve trays).

10.0 OUT-OF-TOLERANCE CONDITIONS

If any M&TE or measurement standard is found to be out of tolerance during the post-use calibration process, the Vendor shall provide notification of the out-of-tolerance conditions along with associated measurement data to the Purchaser so that appropriate actions can be taken by the Purchaser to assess the impact of this condition.

11.0 NONCONFORMANCES

Any nonconformances identified during performance of work governed by this specification shall be promptly reported to the Purchaser. Dispositions of repair or "use-as-is" require Purchaser written approval.

12.0 CERTIFICATE OF COMPLIANCE

All work shall be performed in accordance with Vendor's project-specific quality system and associated procedures. In lieu of a formal Certificate of Compliance, a statement of compliance can be provided within the test report. The statement of conformance is required to state that the testing complied with the project-specific quality system manual, the Purchaser-approved test procedures, the Purchaser-approved test specimen drawings, and this specification. The applicable quality system manual must be identified by the revision level and/or date.

13.0 WARRANTY

FSEL will remanufacture and retest up to four (4) beams to compensate for: faulty workmanship in beam manufacture or a material defect in a beam that invalidates the test result or precludes testing; damage to a beam attributable to an error by FSEL or FSEL subcontractors that renders the beam unsuitable for testing; or an error or malfunction during testing that results in unusable data.

[redacted]

[redacted]

[redacted]

15.0 REFERENCES

1. MPR-3757, “Shear and Reinforcement Anchorage Test Specimen Technical Evaluation,” Revision 3.

2. ACI 318-71, “Building Code Requirements for Reinforced Concrete,” 1971 Edition.

3. Appendix B of “Report on the Diagnosis, Prognosis, and Mitigation of Alkali-Silica Reaction in Transportation Structures,” U.S. Dept. of Transportation, Federal Highway Administration, January 2010.

4. ASTM C192-07, “Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory,” 2007 Edition.

5. ASTM C42-12, “Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete,” 2012 Edition.

6. ASTM C39-12, “Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens,” 2012 Edition.

7. ASTM C469-10, “Standard Test Method for Static Modulus of Elasticity and Poisson’s Ratio of Concrete in Compression,” 2010 Edition

8. ASTM A615-09, “Standard Specification for Deformed and Plain Carbon Steel Bars for Concrete Reinforcement,” 2009 Edition.

9. ASTM C33-08, “Standard Specification for Concrete Aggregates,” 2008 Edition.

10. EPRI TR-017218, “Guideline for Sampling in the Commercial-Grade Item Acceptance Process,” Revision 1.

11. ASTM D75-09, “Standard Practice for Sampling Concrete Aggregates,” 2009 Edition.

12. ASTM D3665-07, “Standard Practice for Random Sampling of Construction Materials,” 2007 Edition.

13. ASTM C136-06, “Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates,” 2006 Edition.

14. ASTM C702-98 (Reapproved 2003), "Standard Practice for Reducing Samples of Aggregate to Testing Size," 1998 Edition.

15. ASTM C150-09, "Standard Specification for Portland Cement," 2009 Edition.

Appendix A – Outline of Testing

A1. Purpose

The purpose of the testing described herein is to assess the impact of ASR on out-of-plane shear performance and reinforcement anchorage (lap splice) performance. The test specimens will use the walls in the B Electrical Tunnel as the reference location for Seabrook Station.

The walls will be modeled as reinforced concrete beams constructed to be similar to the walls of the reference location. The testing will provide data to assess the effects of ASR on shear and reinforcement anchorage performance. This will be done for control beams and also for beams with various levels of degradation due to ASR. When necessary, testing will assess the effectiveness of retrofit techniques to improve the structural capacity of the beams at various levels of ASR degradation. While the structural evaluation of the walls of the reference location is a primary testing objective, the findings will apply to other buildings at Seabrook Station with similar structural characteristics.

A2. Test Overview

The following information will be developed by the Shear Test Program:

- Shear Capacity of ASR-affected Reinforced Concrete Beams– determine the extent to which the shear performance of the reinforced concrete beams has been affected as a function of ASR degradation.

- Flexural Stiffness of ASR-affected Reinforced Concrete Beams - determine the extent to which the flexural stiffness of the reinforced concrete beams has been affected as a function of ASR degradation.

- Efficacy of Retrofit Technique–determine the effectiveness of the retrofit technique in the enhancement of the shear performance as a function of ASR degradation.

Results from the testing may be used to determine whether any margin exists between the actual (experimentally-determined) shear strength of reinforced concrete beams and the calculated shear strength (by using relevant provisions of the design code, ACI 318-71).

The following information will be developed by the Reinforcement Anchorage Test Program:

- Development Length in ASR-affected Reinforced Concrete Beams– determine the extent to which the development length (concrete/reinforcement bond) performance of the reinforced concrete beams has been affected as a function of ASR degradation.

- Efficacy of Retrofit Technique–determine the effectiveness of the retrofit technique in the enhancement of the development length (concrete/reinforcement bond) performance as a function of ASR degradation.

Results from the testing may be used to determine whether any margin exists between the actual (experimentally-determined) development length and the calculated development length (by using relevant provisions of the design code, ACI 318-71).

A3. Test Specimens

A3.1. Description

The following is a description of the reinforced concrete beams that will be used for ***each*** testing program:

- Control Beam – reinforced concrete beam unaffected by ASR,

- Series I Beam – ASR-affected reinforced concrete beam, and

- Series II Beam –ASR-affected reinforced concrete beam, which has the retrofit technique installed after reaching the desired level of ASR degradation.

From walkdown inspections at Seabrook Station, combined cracking indices[1] have been measured up to about 2.5 mm/m. Combined cracking indices shall be periodically measured for all test specimens with the same method used at Seabrook Station and defined in Reference 3. The range of cracking indices used for testing in the Series I Beams shall overlap and extend beyond the cracking indices observed at Seabrook Station (See Section A4.3 and A.4.4 for additional details). The range of cracking indices used for testing in the Series II Beams will depend on the Series I Beam test results. Series II Beams shall not be used for testing until the results of the Series I Beams are approaching or are below the calculated strength obtained by the provisions given in ACI 318-71.

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[1] The cracking index is a quantitative method to measure the total width of cracking per unit length, along the two horizontal and vertical sides of 20" squares (Reference 3). The combined cracking index averages the horizontal and vertical sides of the squares. The combined cracking index is indicative of the expansion of the concrete cover.

[2] In-plane expansion is equivalent to that monitored on concrete surfaces at Seabrook Station.

A3.2. Preparation of Test Specimens

Applicable standards for guidance in procedure development:

ASTM C192-07 (Reference 4) and C42-12 (Reference 5)

Requirements:

- A minimum of [redacted] reinforced concrete beams shall be prepared and cast for each testing program. The following type and quantity of reinforced concrete beams shall be prepared and cast:

  - Control Beam [redacted]
  - Series I Beams [redacted]
  - Series II Beams [redacted]
  - Spare Beams [redacted]

  Testing of a spare beam will be contingent on the testing results of the other beams, and will require written approval from the Purchaser with consent from the Client. One of the spares may be used as an additional control to assess variability in testing. A spare beam from the Shear Test Program may be used to evaluate for the effect of [redacted], by mutual written agreement from the Vendor, Purchaser and Client.

- Design parameters of each reinforced concrete beam shall be in accordance with Table A-1. The concrete mix may deviate from the mix design used at Seabrook Station to rapidly generate ASR damage similar to, and in excess of, that found at Seabrook Station. The technical justification for the design parameters, including non-identical parameters, is provided in Reference 1.

- Accelerated ASR degradation shall be driven in the Series I and II Beams per the procedures developed by the Vendor. If necessary, the beams can be cured in specific conditions to accelerate ASR.

- The range of cracking indices for the Series I Beams shall overlap and extend beyond the range of cracking indices observed at Seabrook Station. The range of cracking indices for the Series II Beams shall depend on test results of the Series I Beams.

- At least [redacted] concrete cylinders shall be cast and maintained in accordance with procedures based on ASTM C192-07 at the time each batch of concrete is cast. The allocation of each concrete cylinder is defined in below. Additional concrete cylinders may be cast at the Vendor's discretion for information only testing.

  - [redacted] cylinders will be available for concrete mechanical testing (see Section A.4.2)

  - [redacted] will serve as spares and remain available for future testing or examination as directed by the Purchaser

- At least [redacted] concrete core samples per test specimen shall be drilled and maintained in accordance with procedures based on ASTM C42-12. The concrete core samples shall be taken from the test region after the specimen testing is complete. The allocation of each concrete core is defined in below. Additional concrete cores may be drilled at the Vendor's discretion for information only testing.

  - [redacted] core shall be provided to the Purchaser for petrographic examination (see Section A.3.3). The concrete sample shall be provided at the time the specimen is tested.

  - [redacted] cores shall be used for concrete mechanical testing as described in Section A.4.2.

- Tensile testing of reinforcement shall be performed on samples from each test specimen as described in Section A4.1. All tensile testing of reinforcement shall be satisfactorily completed before use in a test specimen.

- Verification of coarse aggregate grading shall be performed as described in Section A4.1 unless otherwise directed by the Purchaser in writing.

Source of Test Samples:

Test samples shall be provided by the Vendor.

Reporting of Test Results:

The reinforcement strength and concrete cylinder mechanical test results for each beam shall be documented.

Table A-1. Design Parameters for Shear and Reinforcement Anchorage Test Beams (Reference 1, Table 3-1)

[redacted]

Table A-1. Design Parameters for Shear and Reinforcement Anchorage Test Beams (Reference 1, Table 3-1)

[redacted]

[redacted]

A3.3. Characterization of ASR Degradation

Objectives:

- Confirm the presence of ASR.
- Characterize the extent of ASR degradation by tracking the expansion of the concrete cover and concrete core (the concrete inside the reinforcement) due to ASR.

Applicable standards for guidance in procedure development:

N/A

Summary of Test Elements:

- Petrographic examinations of cores will be performed at the time each beam is tested. The petrographic examination will be performed by an outside organization selected by the Purchaser. The Vendor shall provide concrete core samples for the petrographic examination.
- The cracking index shall be determined for the Series I and II Beams for in-plane expansion[2] following the procedures outlined above in Section A3.1.
- The direct expansion measurement of the concrete core for each Series I and II test specimen shall be determined [redacted]

Reporting of Test Results:

The cracking indices for the concrete cover and the direct expansion measurement of the concrete core of each Series I and II beam shall be monitored and recorded periodically.

A4. Testing

A4.1 Reinforcement Material Verification Testing

Objectives:

The objective of the material verification testing is to verify the properties of key materials meets the specified industry standards and any additional specified requirements before use in any test

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[2] In-plane expansion is equivalent to that monitored on concrete surfaces at Seabrook Station.

specimen. Reinforcement material verification testing may be performed by sub-vendors that have been pre-approved by the Purchaser in accordance with Section 5 of this specification.

Applicable standards for guidance in procedure development:

ASTM A615-09 (Reference 8) and C33-08 (Reference 9)

Summary of Test Elements:

Testing shall be done on samples taken from longitudinal tensile reinforcement used in the test specimens per the sampling plan in Appendix B of this specification.

Verification of coarse aggregate grading shall be performed on samples taken from each transportation unit (i.e. truck) per the sampling plan in Appendix B of this specification unless otherwise indicated by the Purchaser.

Reporting of Test Results:

The results of the reinforcement testing and the coarse aggregate grading verification shall be documented on applicable test reports.

A4.2 Concrete Mechanical Testing

Objectives:

The objective of the concrete mechanical testing is to determine the compressive strength and elastic modulus of the concrete used in the test specimens at 28 days and at the time of shear and reinforcement anchorage testing. Concrete mechanical testing may be performed by sub-vendors that have been pre-approved by the Purchaser in accordance with Section 5 of this specification.

Applicable standards for guidance in procedure development:

ASTM C39-12 (Reference 6) and C469-10 (Reference 7)

Summary of Test Elements:

Compressive strength and elastic modulus testing shall be performed for each test specimen at 28 days and at the time of structural testing. The 28 day mechanical testing shall be performed on representative concrete cylinders that were cast at the time of test specimen concrete placement. The mechanical testing at the time of structural testing shall use concrete cores extracted from the test specimen and be performed within [redacted] calendar days of structural testing. Cores shall be extracted from the specimen after the specimen testing is complete. Other compressive strength testing may be performed for information only.

- Compressive strength testing of the concrete samples shall be conducted in accordance with procedures based on ASTM C39-12.
  - [redacted] cylinders to assess 28 day compressive strength.
  - [redacted] cores to assess compressive strength at the time of structural testing
- Elastic modulus testing of the concrete samples shall be conducted in accordance with procedures based on ASTM C469-10 using a compressometer with steel yokes.
  - [redacted] cylinders to assess 28 day elastic modulus
  - [redacted] cores to assess elastic modulus at the time of structural testing

Reporting of Test Results:

The compressive strength and elastic modulus shall be documented on applicable test reports.

A4.3 Shear Testing

Objectives:

The following are objectives of the Shear Test Program:

- Determine the margin between the actual (experimentally-determined) strength of the reinforced concrete beams and the strength calculated using relevant provisions of ACI 318.
- Determine the extent to which the shear performance of the reinforced concrete beams has been affected as a function of ASR degradation as measured by the cracking index of the concrete cover, the dimensional expansion of the concrete core, or petrographic examinations.
- Determine the extent to which the flexural stiffness of the reinforced concrete beams has been affected as a function of ASR degradation.
- Determine the effectiveness of the retrofit technique in the enhancement of the shear performance as a function of ASR degradation.

Applicable standards for guidance in procedure development:

N/A

Summary of Test Elements:

- Testing shall be performed on each of the following types of reinforced concrete beams in accordance with the steps provide below:

  - Control Beam
  - Series I Beam
  - Series II Beam
  - Spare Beam

  Each beam shall be given unique identification marks or numbers.

- The beams shall be simply-supported and loaded monotonically to failure. An example testing configuration is shown in Figure A-2.

- Load cells shall be placed in the load path to measure the reaction load.

- Displacement transducers shall be positioned appropriately along the side of each beam to measure the deflection of the beam.

- The Series I Beams shall be tested with ranges of cracking indices that overlap and extend beyond the range of cracking indices observed at Seabrook Station. At least [redacted] levels of cracking indices shall be tested. The first test shall have a combined cracking index of approximately 2.5 mm/m, to represent the current state of ASR degradation at Seabrook Station. Subsequent tests will be conducted at increasing levels of deterioration, selected depending on the shear capacity results of the first test in comparison to the calculated strength obtained by the provisions given in ACI 318-71. Note that the intent of the test program is to address a range of ASR cracking that extends beyond what is likely to occur at Seabrook Station over its operating life. Based on this, the testing should focus on a range of cracking indices from approximately [redacted], contingent upon previous test results. If possible, testing shall include one test specimen with a high enough cracking index that results in a shear capacity that is lower than the calculated strength values of ACI 318-71. The Purchaser will provide written approval at the time of each test indicating that the cracking index of the test specimen is acceptable.

- Cracking indices used for testing of Series II Beams shall be dependent on the results from the Series I Beam tests. Series II Beams shall not be used for testing until the results of the Series I Beams are approaching or are below the calculated strength obtained by the provisions given in ACI 318-71. The Purchaser will provide written consent to perform Series II testing.

- The retrofit technique used on the Series II Beams shall be installed after the desired level of ASR degradation has been reached. [redacted]

[redacted]

Reporting of Test Results:

Identification of structural cracking and other forms of structural distress shall be noted at each load step. The propagation of cracks shall be documented with photographs and the final failure shall be documented with video footage.

The margin between the actual (experimentally-determined) strength of the reinforced concrete beams and the calculated strength shall be determined by using relevant provisions of ACI 318-71.

The data from all of the tests will be used to develop the relationships between shear capacity and cracking index as well as flexural stiffness and cracking index. These relationships shall be generated for the Series I and II Beams. Load-deflection curves shall be developed for each beam.

A4.4 Reinforcement Anchorage Testing

Objectives:

The following are objectives of the Reinforcement Anchorage Test Program:

- Determine the margin between the actual (experimentally-determined) development length of the reinforcement and the calculated length by using relevant provisions of ACI 318-71.
- Determine the extent to which the development length (concrete/reinforcement bond) performance of the reinforced concrete beams has been affected as a function of ASR degradation as measured by the cracking index of the concrete cover, the dimensional expansion of the concrete core, or petrographic examinations.
- Determine the extent to which the flexural stiffness of the reinforced concrete beams has been affected as a function of ASR degradation.
- Determine the effectiveness of the retrofit technique in the enhancement of the development length (concrete/reinforcement bond) performance as a function of ASR degradation.

Applicable standards for guidance in procedure development:

N/A

Summary of Test Elements:

- Testing shall be performed on each of the following types of reinforced concrete beams in accordance with the steps provide below:

  - Control Beam
  - Series I Beam
  - Series II Beam
  - Spare Beam

  Each beam shall be given unique identification marks or numbers.

- The beams shall be simply-supported and loaded monotonically to failure. An example testing configuration is shown in Figure A-2.

- Load cells shall be placed in the load path to measure the reaction load.

- Displacement transducers shall be positioned appropriately along the side of each beam to measure the deflection of the beam.

- The Series I Beams shall be tested with ranges of cracking indices that overlap and extend beyond the range of cracking indices observed at Seabrook Station. At least [redacted] levels of cracking indices shall be tested. The first test shall have a combined cracking index of approximately 2.5 mm/m, to represent the current state of ASR degradation at Seabrook Station. Subsequent tests will be conducted at increasing levels of deterioration, selected depending on the shear capacity results of the first test in comparison to the calculated strength obtained by the provisions given in ACI 318-71. Note that the intent of the test program is to address a range of ASR cracking that extends beyond what is likely to occur at Seabrook Station over its operating life. Based on this, the testing should focus on a range of cracking indices from approximately [redacted], contingent upon previous test results. If possible, testing shall include one test specimen with a high enough cracking index that results in a shear capacity that is lower than the calculated strength values of ACI 318-71. The Purchaser will provide written approval at the time of each test indicating that the cracking index of the test specimen is acceptable.

- Cracking indices used for testing of Series II Beams shall be dependent on the results from the Series I Beam tests. Series II Beams shall not be used for testing until the results of the Series I Beams are approaching or are below the calculated strength obtained by the provisions given in ACI 318-71. The Purchaser will provide written consent to perform Series II testing.

- The retrofit technique used on the Series II Beams shall be installed after the desired level of ASR degradation has been reached. [redacted]

[redacted]

Reporting of Test Results:

Identification of structural cracking and other forms of structural distress shall be noted at each load step. The propagation of cracks shall be documented with photographs and the final failure shall be documented with video footage.

The margin between the actual (experimentally-determined) strength of the reinforcement anchorage and the calculated strength shall be determined by using relevant provisions of ACI 318-71.

The data from all of the tests will be used to develop the relationships between reinforcement anchorage capacity and cracking index as well as flexural stiffness and cracking index. These relationships shall be generated for the Series I and II Beams. Load-deflection curves shall be developed for each beam.

[redacted]

Figure A-1. Example General Layout of Shear and Reinforcement Test Specimens

[redacted]

Figure A-2. Example of General Layout for Shear and Reinforcement Anchorage Testing

Appendix B – Key Material Sampling Plan

B1. Longitudinal Reinforcement Mechanical Properties

The mechanical properties (yield strength, tensile strength and elongation) of the longitudinal reinforcement will be tested to ensure compliance with the applicable specifications. This will be done by destructively testing a sample of the longitudinal reinforcement bars. This section defines the sample size for the longitudinal reinforcement in each test specimen.

B1.1 Longitudinal Reinforcement Lot Formation

The lot size for the longitudinal reinforcement is defined as the longitudinal reinforcement in a single test specimen. A single test specimen will be cast at a time and reinforcement may be purchased for a single test specimen at a time. There are no restrictions on the Vendor for the procurement of the longitudinal reinforcement and it shall be assumed that there is no heat traceability or procurement line item traceability.

The number of longitudinal reinforcement bars in the shear and reinforcement test specimens may vary as different [redacted] specimens may be tested. This sample plan is based on a maximum assumed lot size of [redacted] longitudinal reinforcement bars per specimen. It is likely that the actual number of longitudinal reinforcement bars in the standard test specimen is [redacted] or less bars. Each lot is conservatively assumed to have a low degree of homogeneity based on the lack of procurement requirements as described in Section 2-3 of Reference 10.

B1.2 Sample Size

The following items are considered as part of the selection of the sample size for destructive testing using guidance for destructive testing from Reference 10.

- Product/supplier factors
  - Acceptance history of supplier's products: no known history of items previously used by Purchaser from the reinforcement supplier
  - Lot formation and traceability (degree of lot homogeneity): no purchase order requirements, potential for multiple product manufacturers
  - Item performance history: none credited
  - Complexity of item: simple steel components
  - Applicability of industry standards to the item: all fabricated to ASTM A615

- Safety significance of the item: used in a test specimen for safety related testing

- Inspection or testing factors
  - Number of other critical characteristics to be verified: reinforcement type and diameter
  - Whether verification technique is nondestructive or destructive: destructive
  - Correlation between nondestructive and destructive tests: none

Based on the factors listed above for multiple product manufacturers, a test sample size of [redacted] is established for the longitudinal reinforcement for each test specimen. Reference 10 recommends that the "reduced sampling plan" in Table 2-1 therein be used for destructive testing when manufacturer traceability cannot be established (Reference 10, Section 2.4.4.3). This would result in a sample size of [redacted] for a lot size of [redacted] (Reference 10, Table 2-1, reduced column).

B1.3 Required Testing

[redacted] longitudinal reinforcement bars shall be destructively tested for the mechanical properties of Reference 10. The reinforcement bars used in the testing shall be selected using one of the two methodologies listed below. The acceptance criterion for the testing is zero non-conforming items to the mechanical property requirements in ASTM A615. Note that the actual test values may be used for calculating the strength of the shear and reinforcement anchorage test specimens.

- Three additional reinforcement bars may be procured with the reinforcement bars used for the testing. In this case, the bars used for material verification shall be identical to the other reinforcement bars and shall be selected at random for destructive testing. Note that a lot size of [redacted] ([redacted] bars for the test specimen and [redacted] sample bars) also has a sample size of [redacted].
- The reinforcement may be purchased in longer lengths than needed for the concrete test specimen. In this case, sections will then be cut off of three randomly selected reinforcement bars for destructive testing. All reinforcement bars must have the additional length to allow for random selection of which bars will be tested.

B2. Coarse Aggregate Grading

The grading of the coarse aggregate will be tested to ensure that the size distribution of the coarse aggregate is in compliance with the applicable specifications. This will be done by non-destructive sieve testing of aggregate samples. This section defines the sample size for the coarse aggregate used for the test specimen.

B2.1 Coarse Aggregate Lot Formation

The lot size for the coarse aggregate is defined as the coarse aggregate contained in a single transportation unit (i.e. truck) as defined in ASTM D75 (Reference 11).

B2.2 Coarse Aggregate Sample Size

The minimum sample size for the coarse aggregate shall be a mass of 50 kg [110 lbs] or a volume of 40 L [10 gal] (Reference 11, Table 1). The sample size is based on a nominal maximum aggregate size[3] of [redacted] inch for the size [redacted] aggregate per the Technical Evaluation (Reference 1, Table 3-1). This sample size should be used for [redacted] aggregate. The sample should be obtained randomly from each truck in three approximately equal segments. The random segment selection shall be performed per ASTM D3665 (Reference 12).

This sampling approach per ASTM specifications is more applicable for aggregate sampling than the guidance provided by EPRI TR-017218 (Reference 10). The EPRI guidance was written in the context of components with significant complexity and small lot sizes, not truckloads of aggregate. The sampling requirements from ASTM D75 are more appropriate and provide a satisfactory sample size requirement in lieu of Reference 10.

B2.3 Coarse Aggregate Required Testing

The entire sample shall undergo non-destructive sieve analysis per ASTM C136 (Reference 13). Test portions may be extracted from the sample per ASTM C702 (Reference 14) as necessary. The acceptance criteria for the testing are the requirements for the [redacted] aggregate per ASTM C33 (Reference 9, Table 2). [redacted] This acceptance criterion is specified in Reference 1, Table 3-1.

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[3] Reference 2 defines nominal maximum aggregate size as the smallest sieve opening through which the entire amount of aggregate is permitted to pass (i.e. a sieve size indicating 90 – 100% passing). [redacted]

Enclosure 6 to SBK-L-13080
Non-Proprietary

Approach for Shear and Reinforcement Testing of Concrete Affected by Alkali Silica Reaction

MPR ASSOCIATES INC. ENGINEERS

MPR-3848
Revision 0
(Seabrook FP # 100818)
April 2013

Seabrook Station - Approach for Shear and Reinforcement Anchorage Testing of Concrete Affected by Alkali-Silica Reaction

Prepared for

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RECORD OF REVISIONS

Revision	Affected Pages	Description
0	All	Initial Issue

Executive Summary

This report describes the approach for shear and reinforcement anchorage testing in concrete affected by alkali-silica reaction (ASR) and provides an overview of the planned approach for using the test results to support evaluation of ASR-affected reinforced concrete structures at Seabrook Station.

The purpose of the testing is to systematically quantify the relative impact of ASR on structural performance by comparison of tests at various levels of ASR expansion to control tests (i.e., tests performed prior to development of ASR). In particular, test programs will focus on shear and reinforcement anchorage (i.e., development length). In summary, the approach for the test program and application of its results are described below:

1. Prepare reinforced concrete beams with properties (e.g., concrete mixture design, reinforcement configuration) that are structurally representative of a reference location (the B Electrical Tunnel) at Seabrook Station.

2. Perform control tests on beams that are not affected by ASR for failure in shear and in reinforcement anchorage to determine baseline performance.

3. Allow ASR to develop in other beams and repeat tests to determine the effect of ASR.

    - The concrete mixture will include constituents that accelerate development of ASR (e.g., [redacted], high-alkali cement, reactive aggregates, etc.), so that results are available in a reasonable timeframe.

    - Tests will be conducted at various levels of ASR. Extent of ASR will be assessed using a crack width summation technique (i.e., cracking index). The accuracy of that assessment will be evaluated by measuring expansion inside the reinforcement cage.

4. Evaluate test results to determine the structural capacity (as a function of ASR-induced expansion; i.e., cracking index) of ASR-affected members relative to baseline structural performance. Relationships will be determined for both shear performance and reinforcement anchorage.

5. If necessary, perform additional testing of specimens with retrofits installed to demonstrate that sufficient structural capacity can be restored.

6. Evaluate the capacity of selected ASR-affected structures at Seabrook Station using the test results as an input to characterize the impact of observed level of ASR (i.e., as quantified by a cracking index).

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Introduction

1.1 Purpose

This report describes the approach for shear and reinforcement anchorage testing in concrete affected by alkali-silica reaction (ASR) and provides an overview of the planned approach for using the test results to support evaluation of ASR-affected reinforced concrete structures at Seabrook Station.

1.2 Background

1.2.1 Overview of Alkali Silica Reaction

ASR occurs in concrete when reactive silica in the aggregate combines with alkali ions (Na^+, K^+) in the pore solution. The reaction produces a gel that expands as it absorbs moisture, exerting tensile stress on the surrounding concrete and resulting in cracking. Typical cracking caused by ASR is described as "pattern" or "map" cracking and is usually accompanied by dark staining adjacent to the cracks. Figure 1-1 provides an illustration of this process.

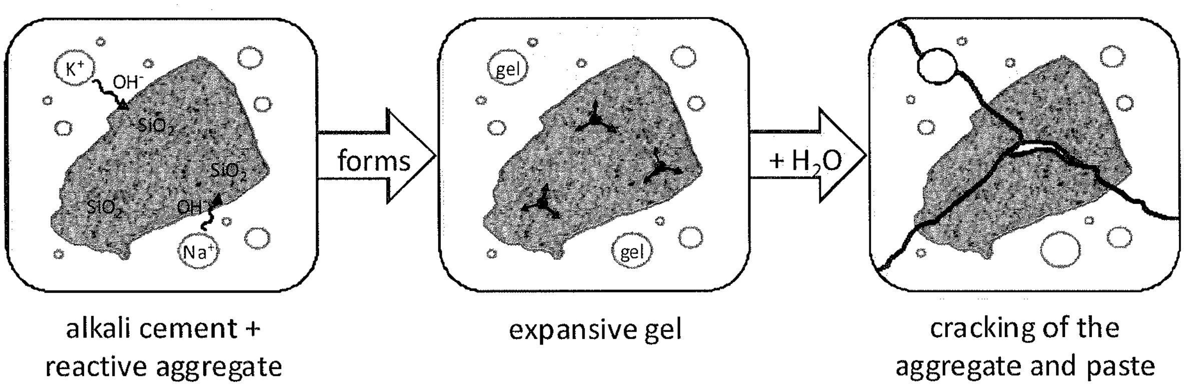


Figure 1-1. ASR Expansion Mechanism

The cracking may degrade the mechanical properties of the concrete, necessitating an assessment of the adequacy of the affected structures and supports anchored to the structures. References 1 and 2 provide insights on assessment of ASR-affected concrete. As noted in these references, the concrete properties most rapidly and severely affected are the elastic modulus and tensile strength. Compressive strength is also affected, but less rapidly and less severely. These trends are based on data from testing of concrete without reinforcement or other confinement.

1.2.2 Impact of Confinement

Reinforcing steel, loads on the concrete structure (e.g., deadweight of the structure), and the configuration of the structure (i.e., restraint offered by the structural layout) 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. Publicly available test data for structural performance of ASR-affected structures indicate a significant difference in results when adequate confinement is present. As an example, test data show that the one-way shear capacity of a specimen containing three-dimensional reinforcement was not significantly affected by ASR, but a similar specimen without such reinforcement exhibited loss of capacity by up to 25% (References 3 and 4).

The difference in structural performance observed in published test data results from 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.

1.2.3 "Prestressing" Effect

When reinforcement is present to restrain the tensile force exerted by ASR expansion, an equivalent compressive force develops in the concrete. If loads applied on the structure result in tensile stresses (direct, diagonal or otherwise), the compressive stresses in the concrete must be completely overcome before the reinforcement reacts additional tensile load. Cracking in confined concrete would not occur until the tensile load/stress in the concrete exceeds the compressive force/stress in the concrete from the prestressing effect. Under further load, the member relies on the reinforcement for tensile capacity, identical to traditional (i.e., non-prestressed) reinforced concrete. The prestressing effect does not reduce the ultimate tensile capacity of the reinforcement. In some cases, the prestressing effect of ASR creates a stiffer structural component with a higher ultimate strength than an unaffected member[1]. (Reference 4)

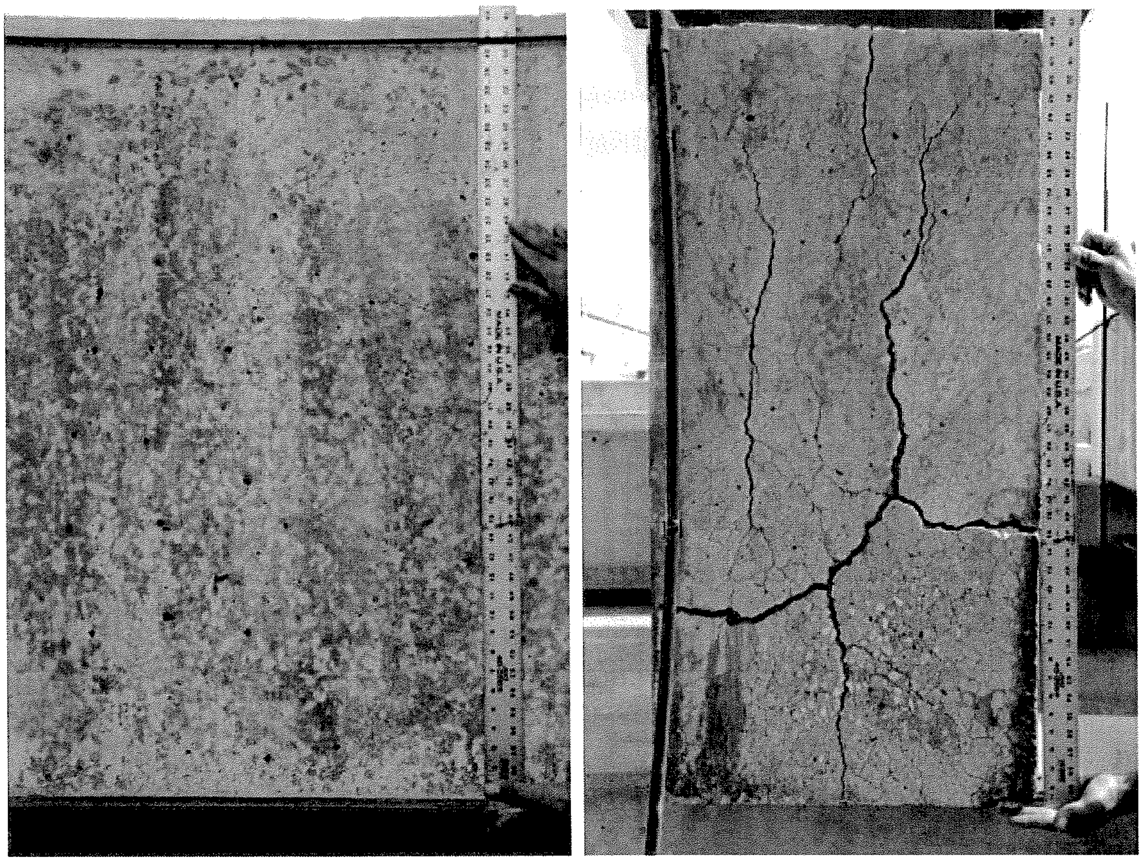
The concrete prestressing effect is only present when the concrete is confined. If the concrete is removed from the stress field, the concrete prestressing effect is lost. For example, a core taken from a reinforced concrete structure that has been affected by ASR will lose the confinement provided by the reinforcement and concrete surrounding that sample, and therefore is not representative of the concrete within its structural context. Measured mechanical properties from a core taken from a confined ASR-affected structure have limited applicability to in-situ performance; such results only represent the performance of an unconfined or unreinforced structure.

Reference 4 provides test data showing that the prestressing effect applies even when ASR expansion has yielded the reinforcing bars. For the testing reported in Reference 4, one specimen had ASR expansion that caused yielding of transverse reinforcement and another

[1] The planned approach for structural evaluations does not credit the possibility that ASR could increase the ultimate strength of the member in question. The planned approach will conservatively use the ultimate strength of the reinforcement as the capacity of the member.

specimen had no ASR expansion. The ASR-affected specimen carried more load than the non-reactive specimen, because the prestress in the concrete needed to be overcome before net tensile stresses could develop. In other words, the chemical-prestressing induced by ASR increased concrete contribution to shear strength, V_c.

Figure 1-2 illustrates the prestressing effect with photographs of two surfaces of the same ASR-affected, reinforced concrete beam. The entire beam was constructed of the same ASR-susceptible concrete and subjected to the same environmental conditions. The level of ASR reaction is the same on both surfaces, but the expansion and resultant cracking are different, as influenced by the presence of confinement by reinforcement. The side-face of the beam has reinforcement in the horizontal and vertical directions, and shows minimal cracking. The end-face of the beam has no in-plane reinforcement, and shows large cracks.



Confined Face of ASR-affected Beam (left); Unconfined face of Same ASR-affected Beam (right)

Figure 1-2. Effect of Confinement on ASR-affected Concrete

1.3 ASR AT SEABROOK STATION

NextEra Energy has identified ASR in multiple safety-related, reinforced concrete structures at Seabrook Station. MPR performed an interim structural assessment (Reference 5) of selected

ASR-affected structures at Seabrook Station[2]. Based on the current low level of expansion and the slow expansion rate, MPR concluded that these structures remained suitable for continued service for at least an interim period (i.e., at least several years).

For operability, the interim structural assessment used conservative methods based on published data, which was the best available information. However, the published data are not sufficiently representative of structural elements at Seabrook Station to use in a long-term assessment or in an aging management program (AMP). The literature review for the interim assessment identified gaps in publicly available test data that are applicable to the reinforced concrete at Seabrook Station, as follows:

- Shear capacity of ASR-affected reinforced concrete structures without transverse reinforcement - Most of the reinforced concrete buildings at Seabrook have two-dimensional reinforcement mats that do not include transverse (through-thickness) reinforcement. Most of the available data are based on beams which have reinforcement in all three directions, including the transverse direction. The data available for elements without transverse reinforcement are not directly applicable to Seabrook Station, because of the differences in strength and deformations (or ribs) on the longitudinal bars. .

- Representative specimen size - The worst-case shear capacity reduction identified in literature was for small-scale testing that used 5-inch × 3-inch beams. The shear phenomenon does not scale well. Larger beams would provide a more representative result for larger concrete members.

- Performance of reinforcement anchorage in ASR-affected concrete - This characteristic is most important with regard to moment transfer between reinforcement bars at lap splices. Available data on reinforced concrete are limited to specimens with smaller reinforcement bar sizes (#5) than the concrete used at Seabrook (generally #7 and larger). Further, the available data were obtained by using testing techniques that do not reflect the state-of-art.

- Extent of ASR cracking - Publicly available test data do not typically characterize the extent of ASR cracking in the test specimens, which would enable better comparison to ASR-affected structures at Seabrook Station. The most limiting data was typically obtained with concrete containing ASR at an advanced stage. While Seabrook Station does have indications of ASR, ASR is not at an advanced stage in most (if not all) locations.

To address these gaps and enable preparation of a long-term structural evaluation of ASR-affected structures, NextEra Energy and MPR are pursuing a large-scale testing program of reinforced concrete beams.

The long-term structural evaluation will assess the performance of ASR-affected structures relative to the original design code for Seabrook Station, American Concrete Institute (ACI) 318-71 (Reference 6). The testing will employ the same methodology used to develop the

[2] The interim structural assessment addressed structures without transverse reinforcement. Containment has transverse reinforcement, and therefore was not addressed in the interim structural assessment.

empirical relationships specified in the ACI code requirements (Reference 7, Part II for shear testing and Reference 8, Section 1.2 for reinforcement anchorage testing).

2
Summary

2.1 Objective of Test Program

The purpose of the testing is to provide structural performance information on varied degrees of ASR-affected reinforced concrete that can be correlated to ASR-affected concrete structures at Seabrook Station. In particular, test programs will focus on shear and reinforcement anchorage. The testing will determine the extent to which the shear performance and reinforcement anchorage of reinforced concrete beams are affected as a function of ASR-related expansion. Test data from both test programs may also be used to assess flexural stiffness of ASR-affected concrete.

In addition, MPR may use results from the testing to determine whether any margin exists between the actual (experimentally-determined) shear strength of reinforced concrete beams and the calculated shear strength (by using relevant provisions of the design code, ACI 318-71). Similarly, the margin for development length of reinforcement will also be determined.

If necessary, MPR may perform additional testing to determine the effectiveness of retrofit techniques for enhancing shear performance and development length in reinforced concrete beams.

2.2 Test Overview

The Shear Test Program and Reinforcement Anchorage Test Program will each involve testing of large reinforced beams [redacted] designed and fabricated to be structurally representative of concrete structural members at Seabrook Station. The concrete mixture design will provide structural characteristics representative of Seabrook Station. Adjustments to the design mixture used at Seabrook Station will be incorporated to induce accelerated expansion due to ASR. The Ferguson Structural Engineering Laboratory (FSEL) at the University of Texas at Austin will conduct the testing under a subcontract from MPR Associates.

2.2.1 Test Series

Each test program will include control tests and two series of tests with ASR-affected concrete. Each test series is described below.

- Control - The control tests will provide a baseline to judge potential reductions in capacity due to ASR. In addition, MPR may use these test results to quantify the margin available in a structure above the capacity calculated using the design code (ACI 318-71; Reference 6).

- Series 1 - The Series 1 tests will quantify the impact of ASR on structural performance (i.e., shear strength, reinforcement anchorage, and flexural stiffness) at varying levels of ASR expansion.

- Series 2 - The Series 2 tests will investigate the effectiveness of approaches for restoring structural performance by a retrofit, if test data indicate that such actions may be necessary to assure satisfactory structural performance at Seabrook Station. The retrofit will most likely involve establishing three-dimensional restraint by installing anchors.

2.2.2 Correlating Parameter

Structural performance will be determined as a function of ASR-related expansion, characterized by extent of cracking in the test specimen. Extent of cracking will be quantified using a Cracking Index, which is the ratio of the summation of crack widths observed over a defined length to the defined length (Reference 1). For consistency with practices at Seabrook Station, a Combined Cracking Index (CCI) will be used, which combines the summation of cracks widths over defined lengths in both the horizontal and vertical directions. The CCI is reported in millimeters of total crack width per meter of surface examined (i.e., mm/m).

Crack width summation is the most practical means for in-situ assessment of the severity of the concrete expansion (Reference 2). This methodology can be readily applied to structures (e.g., buildings at Seabrook Station) that were not originally designed for crack monitoring by more sophisticated means. While CCI is expected to be an effective correlating parameter to expansion, MPR will confirm the validity of this relationship [redacted].

MPR will use additional tests to validate the presence of ASR in the test specimens (e.g., petrographic evaluation, mechanical property testing). These test results may also provide qualitative, corroborating information on the CCI comparisons between test samples and in-situ concrete (e.g., petrographic examination should show more evidence of ASR at higher CCI levels). Such techniques will not be used as a primary correlating factor, because they provide a weaker correlation to the global structural condition than crack width summation due to: (1) the small sample size relative to the affected surface area and/or (2) the inability to account for structural context.

2.2.3 Range of ASR-Related Expansion

FSEL will perform Series 1 tests for at least [redacted] levels of ASR-related expansion. The lowest level of expansion tested will be similar to that observed at Seabrook Station (i.e., CCI of about 2.5 mm/m); FSEL will perform the [redacted] tests at higher levels of expansion (i.e., maximum CCI of up to about [redacted] mm/m). The levels of expansion selected for the second and third tests of Series 1 will exceed all CCI levels currently observed at Seabrook Station. Testing at these more severe expansion levels will bound further development of ASR cracking well into the future and potentially through the end of plant life.

The levels of expansion investigated in the Series 2 tests will be based on insights from the Series 1 tests. FSEL will prepare the beams for Series 2 tests at about the same time as the beams for the Series 1 tests, but testing of the Series 2 beams will only be required if there is a need for structural retrofits. If there is not a need for structural retrofits, the beams planned for Series 2 testing may be available to increase the sample size of the Series 1 testing.

2.3 Implementation of Results

The result of the test program will be empirical relationships that indicate residual shear strength, reinforcement stress at concrete failure, and residual stiffness all as a function of CCI. As part of the Structures Monitoring Program, NextEra Energy plans to obtain CCI measurements of selected locations at Seabrook Station. If the measured CCI exceeds the criterion specified in the Structures Monitoring Program, NextEra Energy will perform a structural evaluation. The relationships developed in this test program will be used to support such an evaluation.

Evaluations of structures at Seabrook Station will involve application of the empirical relationships to the nominal (i.e., non-ASR affected) capacity. The nominal capacity may be calculated from the design basis code. Alternatively, the capacity may be re-calculated using the test results from the control beams and adjustment factors for pertinent parameters (e.g., reinforcement ratio, beam depth).

3 Concrete Specimens

This section provides a summary description of the reinforced concrete beam specimens that are being used for the Shear Test Program and Reinforcement Anchorage Test Program.

The test specification (Reference 9) provides detailed specifications for the specimens. A technical evaluation of the specimens (Reference 10) provides the detailed basis for the design of the test specimens, including concrete mixture design.

3.1 FUNCTIONAL REQUIREMENTS

The test specimens were designed to satisfy the following functional requirements:

- Represent a selected reference location, so that test results can be used to calculate structural performance for the desired failure mode.
- Represent other structures at Seabrook Station such that test results can be applied to other ASR-affected structures (potentially with adjustments for variation in design parameters).
- Ensure failure in the desired failure mode.
- Enable rapid development of ASR to support testing in a reasonable time frame.

3.2 TEST SPECIMEN DESCRIPTIONS

3.2.1 Reference Location

MPR selected a horizontal section of the west wall of the B Electrical Tunnel at Seabrook Station as the reference location for the design of the test specimens. This location is reasonable because the reinforced concrete in the B Electrical Tunnel exhibits similar characteristics to other locations at Seabrook Station, which facilitates applicability of test results to other structures. Specifically:

- The extent of cracking caused by ASR is similar to other areas[3].
- The thickness of the walls (i.e., [redacted] feet) is consistent with most other structures.

[3] The maximum cracking index in the B Electrical Tunnel is [redacted], which is near the most severe ASR-affected location ([redacted]) identified at Seabrook Station (Reference 11). Data obtained from this test program will include results from specimens with cracking indices beyond existing cracking levels, which will envelop all cracking indices observed to date.

- The reinforcement configuration is typical of most other structures.

The specimen technical evaluation (Reference 10) identifies the key test specimen and concrete mixture design characteristics needed for ensuring that the test specimen mechanical properties are representative of the reference location. This evaluation includes a failure modes and effects analysis (FMEA) and provides a detailed comparison of the relevant parameters from the reference location to the design parameters for the test specimens. [redacted]. The evaluation identifies critical performance characteristics for the reference location, relative to shear and anchorage reinforcement performance, and demonstrates that the test specimen designs satisfy those characteristics.

Test results obtained on specimens that reflect the reference location can be applied to other locations at Seabrook Station to assess the impact of ASR relative to the nominal capacity of a non-ASR affected structure.

3.2.2 Summary of Specimen Layouts

Test specimens for the Shear Test Program and the Reinforcement Anchorage Test Program will be large, reinforced concrete beams. Most test specimens will be [redacted] feet-[redacted] inches long, [redacted] inches wide, and [redacted] inches thick. [redacted] test specimen will be [redacted] inches thick, with the same length and width as other test specimens. MPR will use the larger specimen to assess sensitivity of the baseline results to beam depth (See Section 5.3.2).

Figure 3-1 and Figure 3-2 provide a general layout of the Shear Test specimens and a schematic of the reinforcement pattern, respectively. Figure 3-3 and Figure 3-4 provide similar diagrams for the Reinforcement Anchorage Test specimens. The test approach and loading configurations are consistent with those used in developing applicable ACI code requirements (References 8 and 9).

References 12 and 13 provide detailed drawings of the specimens.

[redacted]

Figure 3-1. General Layout of Shear Test Specimen

[redacted]

Figure 3-2. Reinforcement Pattern in Shear Test Specimen

[redacted]

Figure 3-3. General Layout of Reinforcement Anchorage Test Specimen

[redacted]

Figure 3-4. Reinforcement Pattern in Reinforcement Anchorage Test Specimen

Reinforcement

Walls in the B Electrical Tunnel have a reinforcement mat along the interior and exterior faces, with bars arranged horizontally and vertically. [redacted] The specimens are designed such that the bottom of the beam corresponds to the interior wall face in the B Electrical Tunnel.

Note that the test specimens will have transverse reinforcement outside of the test region to ensure that the test specimen fails in the test region by a desired failure mode. These stirrups will also support constructability.

Comparison to Confinement at Seabrook Station

Confinement is an important element for assessment of structural performance of an ASR-affected concrete member. As previously discussed, confinement is provided by reinforcing steel, loads on the concrete structure (e.g., deadweight of the structure), and the configuration of the structure. To provide a specimen of reasonable size for testing, the specimen design did not incorporate structure deadweight and configuration. A technical evaluation of the test specimen design confirmed that the confinement effect of the reinforcement alone is sufficient for generating test data applicable to Seabrook Station (Reference 10). Neglecting the additional confinement provided by deadweight and the structural configuration will yield conservative test results.

3.2.3 Failure Mode

Shear Test Specimens

The shear test specimens are designed such that shear failure in the test region is the most likely failure mode. The shear specimens have a sectional shear span-to-depth ratio (i.e., a/d ratio) of [redacted]. There are two reasons for this dimensional requirement: [redacted]

The shear specimens use [redacted]% flexural reinforcement to preclude failure of the [redacted]-foot-thick specimen via flexure at loads less than the expected shear capacity. However, if shear capacity is greater than expected, failure by flexure could occur. In this case, the load at flexural failure can be used to calculate the minimum shear capacity of the test specimen. This result would also be conservative and hence acceptable.

The [redacted]% reinforcement used in the test specimen is different than the reference location at Seabrook Station (i.e., the B Electrical Tunnel), which has [redacted]% flexural reinforcement. Results will be normalized by reinforcement ratio to account for this difference (See Section 5.3.2).[4]

The configuration of the shear test specimen ensures that the specimen will fail in one of the desired failure modes and preclude failure in other failure modes. (Reference 10)

Reinforcement Anchorage Test Specimens

For a successful test, a reinforcement anchorage test specimen must fail by one of two mechanisms:

- Failure of the concrete-to-reinforcement bond.
- Reinforcement tensile failure in flexure. In this case, failure of the test specimen in flexure may demonstrate adequate reinforcement anchorage capacity.

[redacted] The design of the reinforcement anchorage test specimen ensures that the specimen will fail in one of the desired failure modes (Reference 10).

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[4] Per discussion with Seabrook Station personnel, the reinforcement ratio in the reference location (B electrical tunnel) is typical of many structures at Seabrook Station.

3.2.4 Accelerated Development of ASR

The concrete mixture design used for test specimens must rapidly generate ASR-related expansion similar to, and in excess of, that observed at Seabrook Station in a reasonable time frame to enable timely acquisition of data. To achieve this goal, the concrete mixture design of the test specimen needed to be adjusted relative to the mixture design used at Seabrook Station.

Starting from the original concrete mixture design used at Seabrook Station, MPR selected the test specimen concrete mixture by (1) identifying the key characteristics that impact structural behavior, (2) altering selected characteristics to account for material availability and accelerated ASR development, and (3) reconciling the test specimen design against the key characteristics to ensure that the representative mechanical behavior is maintained.

This approach is acceptable because the test program focuses on structural performance, which depends on the state of cracking at the time of loading, rather than the rate of ASR. Petrographic examination of cores from the test specimens will provide assurance that cracking in the specimens is representative of the degradation mode at Seabrook Station (e.g., cracking is ASR-induced) and that ASR is occurring through the cross-section of the specimen.

The following specific alterations to the concrete mixture design and special environmental treatments will accelerate ASR-related expansion in the test specimens. These alterations do not compromise the degradation mode and therefore do not compromise the representativeness of the specimens with respect to the reference location.

- Reactive Coarse Aggregate - The test specimens will include reactive coarse aggregate materials that cause ASR. [redacted]

- Reactive Fine Aggregate - The test specimens will include reactive fine aggregate materials that cause ASR. [redacted]

- High Alkali Cement [redacted] - The concrete mixture will include cement with a high concentration of alkaline constituents [redacted], thereby assisting ASR development. [redacted]

- ASR-Accelerating Environmental Conditions - FSEL will store the specimens in an environmental chamber to maintain elevated temperature that will accelerate ASR. [redacted]

[redacted]

- Water-to-Cement Ratio - The water-to-cement ratio in the test specimen may be higher than the value in the reference location. [redacted]

Trial Batching and Expansion Testing

Trial batching and expansion testing has been performed with [redacted] concrete mixture designs with constituents from different sources to provide a basis for selecting a concrete mixture design to fabricate the beams. The constituents used in the trial batching are listed in Table 3-1 and the combinations considered are shown in Table 3-2.

Table 3-1. Trial Batching Constituents

[redacted]

Table 3-2. Trial Batching Combinations

[redacted]

Expansion testing of the candidate mixture designs was performed in accordance with ASTM C1293 (Reference 14), which is an aggregate reactivity test. The normal purpose of the test is to confirm that aggregate is not significantly expansive, and therefore is acceptable for new construction.[6] For evaluation of concrete mixture designs for the beam specimens, the ASTM C1293 test was used to help identify which mixture designs are most reactive, and would therefore yield the fastest expansion. Table 3-2 provides test data for all test mixtures after [redacted] days. Testing continued through [redacted] days on selected specimens; these results are also provided. It is noted that the ASTM C1293 test specimens do not contain reinforcement, so the quantitative expansion rate does not reflect expected expansion on the beam specimens that use the same concrete mixture design. MPR used the results of this trial batching for comparison of the relative expansion among the ASTM C1293 test specimens.

MPR selected Mixture [redacted] for the concrete mixture design of the test specimens based on the favorable expansion test results and [redacted]

[5] Expansion data provided from FSEL to MPR by e-mail on November 30, 2012.

[6] As a point of reference, the acceptance criterion in ASTM C1293 is expansion of less than 0.04% after one year.

[redacted]

Compressive Strength
Compressive strength is a key parameter for structural performance of concrete. The design code (ACI 318) uses compressive strength as the input variable for mechanical properties when evaluating design structural capacity. [redacted]

Cement Type
The concrete mixture used in the test specimens will include Type [redacted] cement prepared from ASTM C150, 2009 Edition, whereas the concrete at Seabrook Station includes Type II cement prepared from ASTM C150, 1976 Edition. The reference location also had additional requirements for several constituents. The differences in chemical constituents are acceptable, as discussed in Reference 10 and summarized below:

- [redacted]
- [redacted]

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[7] ACI defines "high strength" concrete as having a compressive strength greater than 8,000 psi.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Concrete Admixtures

Air-entraining admixtures are used in concrete to minimize the potential for freeze-thaw damage to ensure the long term durability of the concrete. The concrete in the reference location contains air-entraining admixtures. [redacted]

[redacted]

Water-reducing admixtures are used in concrete to increase the workability of the concrete and to keep the water-to-cement ratio low for better mechanical properties of concrete. The concrete in the reference location contains water reducing admixtures. [redacted]

4 Testing Overview

This section provides an overview of the plan for executing the Shear Test Program and the Reinforcement Anchorage Test Program.

4.1 MECHANICAL PROPERTIES OF SPECIMENS

FSEL will measure the mechanical properties of the concrete and reinforcement used to fabricate each specimen.

4.1.1 Evaluation of Specimens

FSEL will determine the compressive strength for the concrete using standard cylinder test methods, and the tensile strength for the reinforcement. This mechanical property testing has two purposes that support evaluation of the specimens, as discussed below.

Establish Representativeness of Specimens
Measurement of the mechanical properties will demonstrate similarity between the test specimens and the reinforced concrete at Seabrook Station. [redacted]

Enable Normalization of Results
The structural performance of each specimen will be intrinsically tied to the mechanical properties of the constitutive concrete and steel materials. [redacted]

4.1.2 Comparison to Structural Performance

In addition, testing to determine the mechanical properties of specimens will enable MPR to calculate structural capacity from design equations and compare the result to the observed structural capacity from beam testing.

[redacted]

[redacted]. The methods for concrete compression and elastic modulus testing are based upon the guidance of ASTM C39 and ASTM C469, respectively.

[redacted] As previously discussed, cores that are removed from reinforced concrete lose the structural context provided by reinforcement; therefore, structural capacity calculated using mechanical properties from cores will not be representative of the performance an ASR-affected specimen.

It is noted that core testing could also be performed for tensile strength of the concrete, which is another parameter that is sensitive to ASR (References 1 and 2). [redacted]

4.2 Assessment of ASR in Specimens

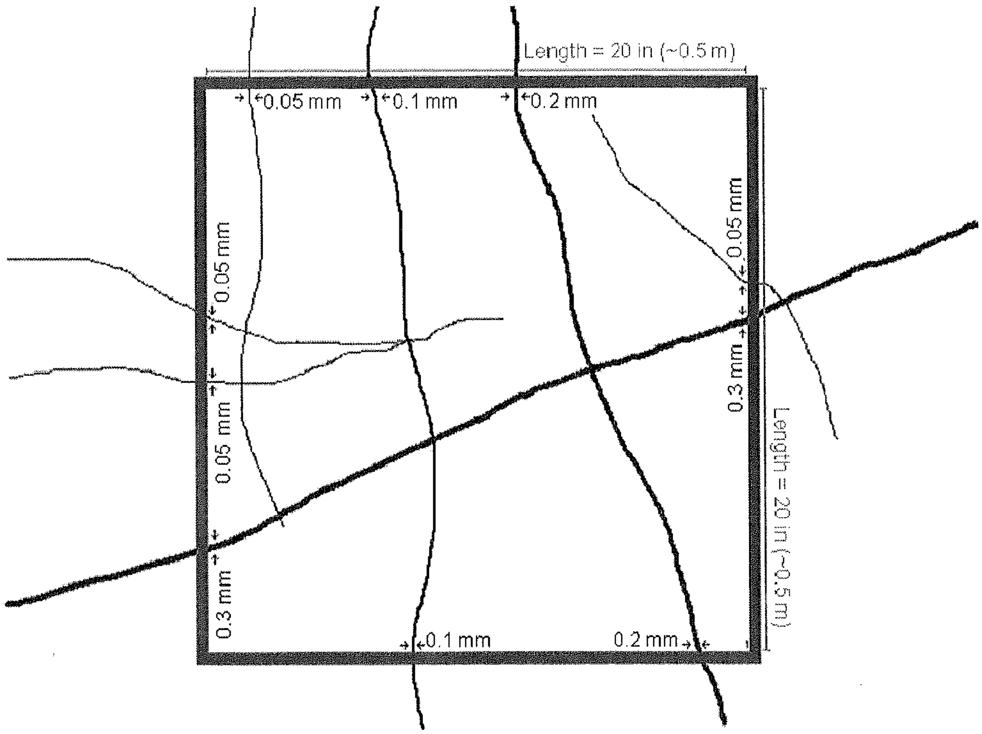
MPR will use multiple methods to confirm the presence of ASR in the beam specimens (crack summation, mechanical expansion, concrete mechanical properties, and petrography). While ASR does result in development of an expansive gel, the chemical change associated with production of the gel does not have a negative impact on concrete chemistry (e.g., by making it softer). MPR will use crack width measurement to assess the degree of ASR degradation and thereby ensure that the condition (and corresponding performance) of each specimen may be associated with a present or future state of ASR-affected structures at Seabrook Station.

Combined Cracking Index

Surface cracking is a direct physical manifestation of the expansion induced by ASR within the core of the structural member. NextEra Energy has obtained a reasonably complete estimate of the effect of ASR at Seabrook Station by summing surface crack widths along horizontal or vertical gridlines of known length. The estimated expansion, referred to as a Cracking Index, is the ratio of the sum of the surface crack widths along the length of the gridline(s) to the length of the gridline(s). The horizontal or vertical Cracking Index is reported in millimeters of total crack width per meter of surface examined (i.e., mm/m). (Reference 1)

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. NextEra Energy is currently using the CCI method to monitor and trend ASR expansion at Seabrook Station. To facilitate application of test program data to field structures, the CCI method will also be used to monitor cracking on the test specimens.

An example of a CCI determination is provided in Figure 4-1 below.



Cracking Index = Sum of Crack Widths (mm) / Sum of Side Lengths (m)
Cracking Index = 1.40 mm / 2.0 m = 0.7 mm/m

Figure 4-1. Example of Cracking Index Measurements

As discussed in Section 3.2.4, MPR selected the concrete mixture design to be used in the test specimens to accelerate expansion relative to expansion rate exhibited in the reference location. These differences in concrete mixture design will also cause the ASR-induced expansion, and hence CCI, to increase more rapidly. [redacted]

[redacted]

[redacted]

The cracking index method is a simple, non-destructive approach that can be used on existing concrete structures like those at Seabrook Station. MPR performed an initial round of CCI measurements as part of the site-wide extent of condition walkdowns (Reference 11) and NextEra Energy will continue to obtain CCI measurements from selected locations as part of the site monitoring program.[9] In the absence of fixed reference points and datum measurements, the cracking index is the most adaptable means for in-situ assessment of the severity of concrete expansion. Alternative approaches that are based on testing cores are less indicative of the global structural condition due to: (1) an unrepresentative sample size and/or (2) an inability to account for structural context.

Mechanical Expansion Measurements

While CCI is expected to be an effective correlating parameter to expansion, MPR will confirm the validity of this relationship using expansion measurements [redacted]

[redacted]

Degradation of Mechanical Properties

In comparison to other measures of mechanical performance, the elastic modulus of concrete is particularly sensitive to the development of ASR (Reference 4). In addition to the elastic modulus testing planned on 28-day concrete cylinders, FSEL will also measure the elastic modulus from a core that is extracted from the specimen at the time of each test. Elastic modulus should decrease as CCI increases, thereby qualitatively corroborating progression of ASR. It is noted that FSEL will also perform compressive strength testing on cores prior to beam testing; compressive strength should also decrease with increasing CCI, although compressive strength is not as sensitive as elastic modulus.

Petrographic Examination

Cores will be obtained from test specimens for petrographic examination. The primary purpose of the petrographic examination is to confirm the presence of ASR. However, qualitative assessments of the severity of ASR will also be performed, including a comparison of the severity of ASR through the depth of the test specimen. These assessments will use the visual

---

[redacted]

[9] It is noted that NextEra Energy plans to install pins in ASR-affected structures to enable measurement of expansion in the future. Pre-ASR reference points are not available, so NextEra Energy will only use this information to monitor expansion from the time that the pins were installed. Because only a partial history of the true expansion at Seabrook Station will be available, direct correlation with the test data will not be possible.

assessment rating and the damage rating index, both of which have been used in evaluation of cores from Seabrook Station.

4.3 Structural Response of Specimens

FSEL will conduct static loading of each specimen in the test laboratory. Hydraulic ram(s), each fixed to a reaction frame, will exert a [redacted] force on the specimen at the desired location(s). When loaded, the base of the specimen will react against a pair of simple supports, positioned toward either end of the beam. [redacted] This test configuration [redacted] is typical for testing used to develop empirical ACI code expressions.

[redacted].

[redacted]

Figure 4-2. Test Setup for Shear Testing

[redacted]

[redacted]

Figure 4-3. Test Setup for Reinforcement Anchorage Testing

[redacted]

[redacted]

[redacted]

[redacted]

4.4 RETROFIT STRATEGY FOR SERIES 2 TESTS

FSEL will prepare beam specimens for both test programs to investigate options for retrofits that would improve structural performance, if capacity is degraded. Based on the results of the Series 1 tests, MPR will evaluate whether observed reductions in capacity necessitate development of retrofits. [redacted]

- [redacted]

- [redacted]

Specific configurations for retrofit methods have not yet been determined because the selected methods may depend on the characteristics of failures observed in testing. Detailed design of the retrofit Series 2 specimens may depart from the strategy outlined above.

5

Application of Results from Shear Test Program

Discussion in this section includes preliminary concepts for how the Shear Test Program results will be applied to an evaluation of structures at Seabrook Station. The methodology used for these evaluations may be modified from that which is presented herein. The following concepts do not include consideration of the structural demands, which MPR will consider after completion of the test programs.

5.1 Overview

The approach for applying the results of the shear test program includes the following steps:

1. Determine the shear capacity of a test specimen that has not been affected by ASR to establish a baseline shear capacity.

2. Determine the shear capacity of test specimens with varying levels of ASR expansion, as quantified by CCI.

3. Develop a relationship between CCI and percentage of baseline shear strength using the experimental results.

4. If necessary, perform additional testing of specimens with retrofits installed.

5. Use the test results as an input for evaluating the shear capacity of selected ASR-affected structures at Seabrook Station. The shear capacity of ASR-affected structures is the nominal capacity reduced by the relative effect of ASR (see Step 3 above). Two options can be used to establish the nominal shear capacity:

   - [redacted]
   - [redacted]

5.2 Calculation of Key Parameters

Following each shear test, FSEL will calculate the true force and deformation demands imposed on the specimen on the basis of the raw data collected by transducers. The structural response of each specimen will be determined when: (1) the forces reported at the critical section have been corrected for the demands imposed by the specimen self-weight and (2) the rigid body motion of the specimen has been factored out of the measured displacements. Figure 5-1 illustrates post-test analysis of the shear data.

[redacted]

Figure 5-1. Post-Test Analysis of Shear Specimen Data

FSEL will present the force-deformation response of each shear specimen in terms of the normalized shear stress at the critical section and the flexural deformation at the load point. The critical section in each shear specimen is defined here as the midpoint of the short (test) shear span.

The shear stress at the critical section may be calculated as the shear force at that section divided by the shear area, $b_w \times d$, where b_w is the web width and d is the effective depth of the cross-section. The shear stress measured at failure of a given specimen depends on the square root of the concrete compressive strength ($\sqrt{f'_c}$). For that reason, meaningful comparisons between the specimen results require that the shear stress be normalized by $\sqrt{f'_c}$. Accordingly, analysis of test data will consider the shear strength of each specimen as the maximum normalized shear stress measured during the course of the test.

The CCI will serve as the primary measure of the concrete expansion as it is the only practical means of in-situ assessment that may be reliably applied in both the laboratory and the field[10]. FSEL will characterize the structural response of each shear specimen by load and deflection measurements at a range of conditions. [redacted]

[redacted]

Figure 5-2. Conceptual Presentation of Shear Testing Results

[10] As previously discussed, MPR will evaluate data from the specimens to characterize the relationship between CCI and true expansion. Conclusions from this effort may be applied for structural evaluations at Seabrook Station.

5.3 Concepts for Evaluation of Shear Strength

5.3.1 ASR Impact on Design Capacity

The ASR-related reduction of shear strength will be determined from a correlation developed using the results of the Shear Test Program (See Figure 5-2). The relative loss of shear strength will be applied to the design shear capacity to obtain a reduced acceptance criterion for allowable shear load to be used in the evaluation of the structure. The correlation developed during the test program should provide a lower bound representation of the expansion effects at Seabrook Station. [redacted]

5.3.2 Redefinition of Design Capacity from Test Results

Instead of using the shear capacity as calculated from ACI 318-71 (the code of record for Seabrook Station), an alternative approach is to redefine the design capacity of the structure being evaluated using the results from the control tests and applying adjustment factors for characteristic parameters that are different than the test specimen. Note that this approach, if implemented, may require a change to the design basis and licensing basis for the structure.

A definitive laboratory assessment of shear strength requires failure of the specimen in shear [redacted]

[redacted]

[redacted]

[redacted] In 1962, ACI-ASCE Committee 326 formally recognized the effect of the longitudinal reinforcement ratio on the shear strength of reinforced concrete members without transverse reinforcement (Reference 7). The [redacted] shear database [redacted] (Reference 18) contains data for normalized shear stress (i.e., $v / \sqrt{f'_c}$) as a function of longitudinal reinforcement ratio. The data show that shear strength increases with reinforcement ratio.

[redacted]

[redacted]

[redacted]

Shear testing of the [redacted]-foot-deep control specimen, in addition to the [redacted]-foot-deep specimens, will quantify the effect of depth on the shear strength of structural elements. The result of the [redacted]-foot-deep shear test is expected to reveal a relatively minor depth effect, consistent with the data from the [redacted] shear database [redacted] (Reference 18).

[redacted]

[redacted]

6 Application of Results from Reinforcement Anchorage Test Program

Discussion in this section includes preliminary concepts for how Reinforcement Anchorage Test Program results will be applied to an evaluation of structures at Seabrook Station. The methodology used for these evaluations may be modified from that which is presented herein.

6.1 Overview

The approach for applying the results of the reinforcement anchorage test program includes the following steps:

1. Determine the load at which a test specimen that has not been affected by ASR fails in flexure. This value is used to establish a minimum bound for reinforcement anchorage capacity.

2. Determine the load at which test specimens with varying levels of ASR expansion, as quantified by CCI, fail in flexure or by reinforcing bar anchorage failure.

3. Develop a relationship between CCI and percentage of baseline reinforcement stress at failure using the experimental results.

4. If necessary, perform additional testing of specimens with retrofits installed to demonstrate that sufficient reinforcement anchorage can be restored.

5. Use the test results as an input for evaluating the reinforcement anchorage capacity of selected ASR-affected structures at Seabrook Station. Specifically, use the empirically-determined correlation to determine whether tensile failure of reinforcement is still expected to be limiting for the observed CCI.

6.2 Calculation of Key Parameters

Following each test, FSEL will calculate the true force and deformation demands imposed on the specimen from the raw data obtained from the collection of transducers. Similar to the Shear Testing Program, the structural response of each specimen will be determined when: (1) the forces reported at the critical section have been corrected for the demands imposed by the specimen weight and (2) the rigid body motion of the specimen has been factored out of the measured displacements. Figure 6-1 illustrates post-test analysis of the reinforcement anchorage test data.

[redacted]

Figure 6-1. Post-Test Analysis of Reinforcement Anchorage Test Data

FSEL will report the force-deformation response of each reinforcement anchorage specimen in terms of the moment and deformation at the midspan of the specimen. FSEL will calculate the midspan moment (M) from the measured support reactions.

The strength of the reinforcement anchorage specimen will be bounded by the yield strength of the longitudinal reinforcement. When the applied load reaches the yield strength of the reinforcement, the specimen will fail by tensile yielding of the reinforcement, rather than inadequate moment transfer at the lap splice. Accordingly, acceptable anchorage performance for this test program would include specimen load capacity that reaches the reinforcement yield strength accompanied by a fairly ductile response. FSEL will calculate the reinforcement stress (f_s) on the basis of the maximum midspan moment measured during each test. Calculation of the reinforcement stress will be completed per the moment-curvature analysis methods referenced within ACI 408R-03, which use the internal moment arm (jd) and the reinforcement area (A_s). FSEL will normalize the reinforcement stress developed during each test by the reinforcement tensile strength.

The CCI will serve as the primary measure of the concrete expansion as it is the only practical means of in-situ assessment that can be reliably applied in both the laboratory and the field[11]. FSEL will characterize the structural response of each reinforcement anchorage specimen by load and deflection measurements at a range of conditions. [redacted]

[redacted]

Figure 6-2. Conceptual Presentation of Reinforcement Anchorage Testing Results

[redacted]

[11] As previously discussed, MPR will evaluate data from the specimens to characterize the relationship between CCI and true expansion. NextEra Energy may apply conclusions from this effort for structural evaluations.

[redacted]

6.3 CONCEPTS FOR EVALUATION OF REINFORCEMENT ANCHORAGE RESULTS

Results from the test specimens for the reinforcement anchorage test program are universally applicable to structures at Seabrook Station, even though there are design differences.

- Reinforcing Bar Diameter - The large diameter reinforcing bars (i.e., No. 7 bars and larger) within wall structures at Seabrook Station are spliced through the use of various lap lengths, most of which are longer than the minimum lap length stipulated by the design code of record (ACI 318-71). [redacted]

- Concrete Cover - Clear concrete cover to flexural reinforcement (including lap splices) in structures at Seabrook Station is a minimum of 2 inches. To ensure applicability of the results to all concrete cover depths, a [redacted]-inch cover depth was conservatively used for the test specimens.

Due to the influence of the cover concrete on the bond and development of reinforcement, the loss of reinforcement anchorage should strongly correlate to surface-based measurements of the CCI. The loss of reinforcement anchorage, as characterized by an inability to yield the flexural reinforcement and attain sufficient ductility, will therefore be defined by a threshold CCI. Universal application of the threshold to the broad range of structural configurations will be technically justified, albeit conservative in locations, [redacted]

[redacted]

[redacted]

7 Flexural Stiffness

Discussion in this section includes preliminary concepts for how test results will be applied to an evaluation of flexural stiffness in structures at Seabrook Station. The methodology used for the long term structural analysis and evaluation may be modified from that which is presented herein.

7.1 Determination of Flexural Stiffness of Test Specimens

FSEL will determine the flexural stiffness of each shear and reinforcement anchorage specimen by a simple linear regression of the elastic portion of the force-deformation response observed during load testing of each specimen. [redacted] The bounds of the regression analysis will be finalized at the end of the test programs and applied consistently across all test results. [redacted] Given the distinct nature of the loading configuration and boundary conditions, it would be inappropriate to report and apply absolute changes in stiffness to structures that are subject to alternate demands.

The impact of the ASR-induced expansion on the elastic response of the shear and reinforcement anchorage test specimens should be similar. MPR will explore consolidation of the results and recommendations from both programs upon completion of the testing.

[redacted]

[redacted]

Figure 7-1. Conceptual Presentation of Stiffness Results

7.2 Application of Results

The relative changes in stiffness measured during each test program, in combination with a comprehensive survey of the plant structures, may provide an opportunity to assess the effect of ASR expansion on the overall response of wall structures to seismic demands. [redacted]

Further details regarding application of the flexural stiffness data will be considered following completion of the test programs.

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Enclosure 7 to SBK-L-13080

Application for Withholding
Proprietary Information from Public Disclosure

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

NextEra Energy Seabrook Application for
Withholding Proprietary Information from Public Disclosure

Subject: 1. Specification for Shear and Reinforcement Anchorage Testing of ASR-Affected Reinforced Concrete (Proprietary);
2. Approach for Shear and Reinforcement Testing of Concrete Affected by Alkali Silica Reaction (Proprietary)

Enclosures 3 and 5 of this letter, MPR 0326-0062-05, Revision 4, and MPR 3848, contain NextEra Energy Seabrook proprietary information. This letter is supported by an affidavit signed by NextEra Energy Seabrook, setting forth the basis on which the information may be withheld from public disclosure by the Commission and addressing the considerations listed in 10 CFR 2.390(b)(4). Accordingly, it is respectfully requested that the information which is proprietary be withheld from public disclosure in accordance 10 CFR 2.390.

Correspondence with respect to this application for withholding or the accompanying affidavit should be addressed to Mr. Michael O'Keefe, Licensing Manager at (603) 773-7745.

NextEra Energy Seabrook, LLC

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

County of Rockingham)
)
State of New Hampshire)

I, Kevin Walsh, being duly sworn according to law, depose and state the following:

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

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

(3) The information sought to be withheld is contained in Enclosures 3 and 5 of NextEra Energy Seabrook's letter SBK-L-13080, Kevin T. Walsh (NextEra Energy Seabrook) to U.S. Nuclear Regulatory Commission, entitled "Seabrook Station Response to Confirmatory Action Letter," dated April 30, 2013. The NextEra Energy Seabrook proprietary information in Enclosures 3 and 5 of SBK-L-13080 is identified by enclosing boxes (▭).

(4) The information sought to be withheld is considered to be proprietary and confidential commercial information because alkali-silica reaction (ASR) is a newly-identified phenomenon at domestic nuclear plants. The information requested to be withheld is the result of several years of intensive NextEra Energy Seabrook effort and the expenditure of a considerable sum of money. This information may be marketable in the event nuclear facilities or other regulated facilities identify the presence of ASR. In order for potential customers to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended. The extent to which this information is available to potential customers diminishes NextEra Energy Seabrook's ability to sell products and services involving the use of the information. Thus, public disclosure of the

information sought to be withheld is likely to cause substantial harm to NextEra Energy Seabrook's competitive position and NextEra Energy Seabrook has a rational basis for considering this information to be confidential commercial information.

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

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

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

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

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

Kevin T. Walsh
Site Vice President
NextEra Energy Seabrook, LLC
626 Lafayette Road
Seabrook, New Hampshire 03874

Subscribed and sworn to before me
this 1st day of ~~April~~ May, 2013.

Notary Public

My commission expires NOV. 18, 2014

SHIRLEY SWEENEY
MY COMMISSION EXPIRES NOV. 18, 2014
NOTARY PUBLIC
NEW HAMPSHIRE