Marshall, Michael

From: Murphy, Martin
Sent: Tuesday, November 20, 2012 8:51 AM
To: Marshall, Michael; Thomas, George; Buford, Angela
Subject: Seabrook Inspection Report
Attachments: Seabrook IR 2012-009 MM Comments.docx

My comments so far. I have public meeting for most of morning and meeting this afternoon so I am not sure how much more I will complete. I think the report potentially creates a lot of questions.

Thoughts?

Marty

B63

UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION I
2100 RENAISSANCE BOULEVARD, SUITE 100
KING OF PRUSSIA, PENNSYLVANIA 19406-2713

Mr. Kevin Walsh
Site Vice President
Seabrook Nuclear Power Plant
NextEra Energy Seabrook, LLC
c/o Mr. Michael O'Keefe
P.O. Box 300
Seabrook, NH 03874

SUBJECT: SEABROOK STATION, UNIT NO. 1 - CONFIMATORY ACTION LETTER FOLLOW-UP INSPECTION - NRC INSPECTION REPORT 05000443/2012009

Dear Mr. Walsh:

On November 2, 2012, the U. S. Nuclear Regulatory Commission (NRC) completed a team inspection at Seabrook Station, Unit No. 1. The enclosed inspection report documents the inspection results, which were discussed on November 2, 2012, with you and other members of your staff.

The team inspection examined activities conducted under your license as they relate to safety and compliance with the Commission's rules and regulations and with the conditions of your license. Specifically, the team reviewed selected procedures and records, observed activities, and interviewed station personnel regarding the adequacy of NextEra's actions to address the impact of Alkali-Silica Reaction (ASR) on reinforced concrete structures. The team reviewed selected Confirmatory Action Letter (CAL) 1-2012-002 commitments for adequacy and closure.

Based upon the inspection team on site and in-office reviews, five CAL items were reviewed and closed, as documented in the enclosed report. The remaining six CAL items will be reviewed during our second planned follow-up inspection scheduled for completion in early 2013.

The inspection team identified NextEra's methods for assessing the impact of ASR on reinforced concrete structures technically sound and generally thorough. The approach of comparing the available design and as-built construction margins to a conservatively established lower bound ASR affect, on these established margins, was appropriate. The team concluded the assumed lower bound values, developed from research data, provide a reasonable interim operability basis until further testing and engineering analysis supports a final operability determination and addresses the uncertainties in identifying the current level and progression of ASR at Seabrook Station.

Comment [M1]: Para is problematic in a number of ways. State C/O based upon only knowing interim information?? How can we be confident to C/O on interim information. Why not C/O based upon satisfactory deliverable per CAL. Margin discussion is challenging and creates questions: Code accepts significant variability in results yet we are claiming that we can assess that variability and quantify it. The lower bound values are actually also unknown (assumed) and may not even be relevant since hard to compare literature data and applicability. Uncertainities will continue to exist; simply we will continue to have a reasonable expectation of safety for these structures. This paragraph should be left more vague to allow maneuverability in the future based upon test results and how licensee chooses to apply, if at all. Detailed discussion with tech staff indicated that the "margin" is exceedingly difficult to explain and even more difficult to quantify. Clear that based upon work to date there is not an immediate safety concern.

In accordance with 10 CFR 2.390 of the NRCs "Rules of Practice," a copy of this letter, its enclosure, and your response (if any) will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of the NRC's document system (ADAMS). ADAMS is accessible from the NRC website at http://www.nrc.gov/reading-rm/adams.html (the Public Electronic Reading Room).

Sincerely,

Christopher G. Miller, Director
Division of Reactor Safety

Docket No. 50-443
License No: NPF-86

Enclosures:
1. Inspection Report No. 05000443/2012009
   w/ Attachment: Supplemental Information
2. Confirmatory Action Letter 1-2012-002

cc w/encl: Distribution via ListServ

In accordance with 10 CFR 2.390 of the NRCs "Rules of Practice," a copy of this letter, its enclosure, and your response (if any) will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of the NRC's document system (ADAMS). ADAMS is accessible from the NRC website at http://www.nrc.gov/reading-rm/adams.html (the Public Electronic Reading Room).

Sincerely,

Christopher G. Miller, Director
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U.S. NUCLEAR REGULATORY COMMISSION

REGION I

Docket No.:	50-443
License No.:	NPF-86
Report No.:	05000443/2012009
Licensee:	NextEra Energy Seabrook, LLC
Facility:	Seabrook Station, Unit No. 1
Location:	Seabrook, New Hampshire 03874
Dates:	June 18, 2012 to November 2, 2012
Inspectors:	W. Cook, Team Leader, Division of Reactor Safety (DRS) S. Chaudhary, Reactor Inspector, DRS W. Raymond, Senior Resident Inspector A. Buford, Structural Engineer, Division of License Renewal, Office of Nuclear Reactor Regulation (NRR) G. Thomas, Structural Engineer, Division of Engineering, NRR
Accompanied by:	Dr. Kent Harries, Professor of Structural Engineering, University of Pittsburg
Approved by:	Richard Conte, ASR Project Manager Division of Reactor Safety

SUMMARY OF FINDINGS

IR 05000443/2012009; 06/18/2012 - 11/02/2012; Seabrook Station, Unit No. 1; Confirmatory Action Letter (CAL) Follow-up Inspection Report.

This report covered three weeks of onsite inspection and four months of in-office review by region based inspectors and headquarters reviewers to assess the adequacy of actions taken by NextEra to address the identification of Alkali-Silica Reaction (ASR) in reinforced concrete structures at Seabrook Station. The NRC's program for overseeing the safe operation of commercial nuclear power reactors is described in NUREG-1649, "Reactor Oversight Process," Revision 4, dated December 2006.

Cornerstone: Mitigating Systems

During this inspection the team examined six of the eleven commitments identified in Confirmatory Action Letter No. 1-2012-002, dated May 16, 2012. These commitments involve actions taken and planned by NextEra to address the degradation of reinforced concrete structures at Seabrook Station due to ASR. Based upon the team's onsite inspection activities and detailed in-office reviews during this inspection of CAL items, the team closed CAL Items #1, #3, #5, #6 and #10. The team reviewed CAL Item #2, but did not close this item based upon additional work needed by NextEra to appropriately address and document this issue. The details of the team's review of each CAL item and the observations pertaining to the adequacy of NextEra's actions to address their commitments to the NRC, to date, are documented in the enclosed report.

The team acknowledged NextEra's plans to conduct performance testing of large scale test specimens (both control and ASR affected) and then apply the data to evaluate the current impact of ASR on Seabrook Station concrete structures and to develop appropriate actions for the continued monitoring of the ASR affected structures. Information from the test program will also be used to make appropriate modifications to the existing structural monitoring program for ASR susceptible structures. The adequacy of NextEra's proposed test program will be evaluated during the second CAL Follow-up inspection, consistent with CAL Item #8. The team verified during this inspection that NextEra's will not finalize their Interim Assessment and Prompt Operability Determinations until: 1) the degree of ASR degradation on station reinforced concrete structures is established within the design and licensing basis; 2) definitive margins are established to the design basis limits; and 3) the progression of ASR is appropriately monitored and demonstrated to ensure adequate margins are maintained for the duration of the current operating license.

The team also clarified NextEra's current position that no structure at Seabrook Station will be precluded from continued monitoring for the affects of ASR until a satisfactory petrographic examination has been completed on that structure to confirm the absence of ASR or that ASR is no longer active. The adequacy of NextEra's Structures Monitoring Program will be evaluated in the second follow-up inspection, consistent with CAL Item #9.

Comment [M2]: We do not know how they "will" apply or use the test results

Comment [M3]: Not sure we can identify what is adequate – what is the metric to determine?

Comment [M4]: There is no way to quantify that the "degree of ASR degradation" is within design and licensing basis. It was never intended to exist, was not designed into the structure and was not captured in licensing basis. Statement makes no sense. Again, margins will never be definitive with the accepted variability in the code also don't need margin to design basis; just need to meet the design basis. Lastly the ASR has to be managed to ensure the design limits are maintained.

Comment [M5]: What is the metric to satisfactory – who is determining, why does it need to be petrographic, industry is OK with visual, too limiting

Comment [M6]: "ASR no longer active" – what does this mean? Has an understanding been proposed and agreed upon?

As highlighted in Section 9.0 of the enclosed report, the team identified additional issues for follow-up during the second inspection. These issues and the remaining CAL Items will be examined and assessed for adequacy prior to the closeout of CAL 1-2012-002.

REPORT DETAILS

1.0 Background

Alkali-Silica Reaction (ASR) is a chemical reaction in concrete that can change the physical properties. In June 2009, NextEra identified potential degradation in below grade concrete structures at Seabrook. In August 2010, NextEra completed petrographic evaluation of concrete core samples which confirmed ASR as the degradation mechanism. The degraded condition in Seabrook Category I structures was evaluated in the Corrective Action Program via a prompt operability determination (POD) in September 2010, and revised in April 2011, September 2011 and May 2012. The initial PODs (Revisions 0 and 1) addressed the B electric tunnel (AR581434) where ASR was first discovered. Five other buildings were identified via the extent of condition (EOC) review and the evaluation of core samples taken from these structures (AR1664399). The PODs were updated as new information became available and revised analytical techniques were incorporated.

NextEra initially used the results of mechanical testing of concrete cores to assess the degree of structural degradation due to ASR. This is the traditional method described in American Concrete Institute (ACI) 228.1R for assessing existing concrete structures. NextEra tested the cores for compressive strength and elastic modulus. NextEra used the methods defined in construction and design code ACI 318-1971 to evaluate the structural capacity (operability) of the ASR affected buildings. However, the mathematical relationships in ACI-318 are based on empirical data from testing of non-degraded concrete and these relationships may not hold true for all stages of ASR affected concrete.

After further review of industry experience and literature pertaining to ASR, NextEra engineering concluded that the core test data was not indicative of structural performance of ASR affected reinforced concrete structures. NextEra's engineering evaluation states that once removed from the structure, concrete cores are no longer subject to the strains imposed by the ASR-related expansion or restraints imposed by the reinforcing cage. Confinement provided by reinforcing steel rebar and other restraints limit ASR expansion of the concrete within the structure, which reduces the extent of deleterious cracking and the resulting reduction of concrete material properties. Therefore, NextEra concluded that the reduction of mechanical properties observed in mechanical testing of cores is not representative of in-situ concrete performance. NextEra's current position is that the mechanical tests are only useful as a diagnostic tool to confirm the presence of ASR. Based on the above, NextEra stopped taking cores to evaluate structures impacted by ASR and revised their approach. NextEra's current approach for assessing structural integrity and operability is to compare available design margins to an assumed reduction in structural capacity due to ASR.

The extent of ASR at Seabrook was documented in a baseline walkdown review of station structures. The review identified the visual signs of ASR through the presence of crack patterns, ASR powder and gel, and/or discoloration/dark staining. The walkdown objectives were to: identify and assess apparent ASR degradation including estimated expansion; identify the condition of concrete in the vicinity of supports that show ASR distress; and, identify the current or past areas of water intrusion. The walkdown results were entered into the corrective action program (AR1757861) and have established NextEra's current baseline condition assessment of Seabrook structures, in conjunction with six-month crack indexing measured on selected structures to trend the progression of ASR and thereby establish a rate of degradation.

As stated above, NextEra's operability evaluations are based upon an examination of available design margins and a presumed ASR reduction in structural design capacity. The details of this methodology and related assumptions are developed in NextEra's Interim Assessment (FP 100716). The assessment assumed lower bound values for potential reductions in concrete material properties based on industry test data of small scale test specimens. The assessment focused on structural design attributes that are the most sensitive to ASR affects (i.e., out-of-plane shear capacity, lap splice development length, and anchorage depth). Compressive strength of concrete is also affected, but less so in the early stages of ASR. The assessment determined the structures were suitable for continued service pending further evaluation of structural performance based on a proposed full-scale testing program representative of Seabrook concrete structures. The test programs have been initiated at the Ferguson Structural Engineering Laboratory at the University of Texas, with testing to be completed in 2013 and the results reported in 2014.

Comment [M7]: I did not review the background section

2.0 Confirmatory Action Letter 1-2012-002

Confirmatory Action Letter (CAL) 1-2012-002, dated May 16, 2012, was written to confirm commitments by NextEra with regard to planned actions to evaluate the degradation of Seabrook reinforced concrete structures due to ASR. In response to the CAL, NextEra committed to provide information to the NRC for the staff to assess the adequacy of NextEra's corrective actions to address this significant condition adverse to quality. CAL 1-2012-002 is provided as an Enclosure to this report. Based on the results of this inspection, CAL Items #1, #3, #5, #6, and #10 are closed; CAL Item #2 is updated; and CAL Items #4, #7, #8, #9, and #11 remain open pending NRC review in Inspection Report 2012-010.

3.0 Review of Operability Determinations and the Interim Assessment (CAL Items #1, #3, and #5)

3.1 Inspection Scope

The team reviewed the PODs for the B Electric Tunnel of the Control Building (POD 581434) and buildings identified in NextEra's extent-of-condition review (PODs 1664399 and 1757861). As discussed in Section 1.0 above, these PODs were revised to reflect a change in the approach taken by NextEra to evaluate the structural integrity of the station reinforced concrete buildings. Revision 2 of the PODs provides the current quantitative and qualitative analyses of the ASR-induced changes in concrete properties, as further detailed in the licensee's Interim Assessment. The team reviewed the supporting documentation for each significant structural design attribute and conducted multiple interviews and discussions with the responsible NextEra engineering staff and consultants. The team used 10 CFR Part 50, Appendix A, and 10 CFR Part 50, Appendix B, Criterion XVI, "Corrective Action," and Criterion XI, "Test Control," as the regulatory basis to assess the adequacy of NextEra's actions to address ASR affects on safety-related Category 1 and in scope Maintenance Rule reinforced concrete structures. The team also used the established code relationships from ACI 318-1971 to independently assess the engineering calculations and analyses performed by NextEra. Lastly, the team used NRC Inspection Manual, "Part 9900 – Operability Determination and Functionality Assessments for Resolution of Degraded or Nonconforming Conditions Adverse to Quality or Safety," to evaluate the licensee's approach to assessing this significant condition adverse to quality.

Comment [M8]: In background section we call these into question, yet we are using these to assess what the licensee did. Do we or don't we agree with the use of these relationships. This seems be an open challenge for questions. Should be an explanation regarding why we found it acceptable to use or take the question out of the background section

The extent-of-condition PODs (Revisions 0 and 1) addressed five buildings (AR 1664399) using the mechanical testing data gathered from concrete core samples. These five structures include the containment enclosure building (CEB), the access tunnel to the radiologically controlled areas (RCAW), the emergency feedwater (EFW) pump house, the residual heat removal (RHR) equipment vault (EV), and the diesel generator building (DGB). During implementation of ASR Structures Walkdown (FP 100705), NextEra identified additional ASR affected concrete in both Category 1 and Maintenance Rule structures including: the condensate storage tank enclosure, the control building air east intake, the service water cooling tower, the A electrical tunnel, the fuel storage building, the east pipe chase, the west pipe chase, the pre-action valve room, the primary auxiliary building, the service water pump house, the mechanical penetration area (which includes portions of the outer containment wall), and the waste processing building (AR1757861).

The team also conducted a detailed review of Foreign Print (FP) 100716, "Seabrook Station: Impact of Alkali-Silica Reaction on Concrete Structures and Attachments," Revision 1, which is the initial evaluation of concrete structures at Seabrook Station and provides the basis for continued operability of affected structures for an interim period. As documented in FP 100716, this interim evaluation will be followed by a second evaluation that "will assess the long-term adequacy of the concrete structures considering the results of the full-scale structural testing program, other in-progress test programs, and results from periodic monitoring of the structures."

3.2 Findings and Observations

The team identified no findings in this area and CAL Items #1, #3 and #5 are closed. Based on a detailed review of the PODs, referenced white papers and associated engineering analyses, including an independent verification of a number of supporting calculations, the team determined NextEra's interim operability bases were appropriate. Given the current extent of ASR, there is reasonable expectation that the affected reinforced concrete structures at Seabrook Station will remain capable of performing their intended functions for an interim period, while NextEra continues to monitor the condition and complete detailed testing and further engineering analyses. Noteworthy observations pertaining to the team's review of the PODs and Interim Assessment follow:

Comment [M9]: Add no value and is an unknown

3.2.1 Operable, but Degraded/Nonconforming

Based upon a detailed review of the quantitative and qualitative analyses documented in the PODs and Interim Assessment, the team determined NextEra had ~~appropriately~~ demonstrated that the ASR impacted structures were operable, but degraded/nonconforming. NextEra demonstrated that the structures maintained structural integrity for design basis loads and load combinations for normal, accident and environmental extreme conditions (including seismic).

The team indentified no inadequacies in the conclusion that ASR impacted structures were currently operable, but degraded or nonconforming.

The team observed that 24 locations (including containment) had been identified via NextEra's ASR Structures Walkdown as having patterned cracking with a combined crack index (CCI) of greater than 1.0 mm/m. Per the Structures Monitoring Program (ES 1807.031), Attachment 3, revised in July 2012, a CCI of >1.0 mm/m requires a structural evaluation. NextEra's Interim Assessment, Section 2.1.2 documents an engineering judgment that biased the performance of detailed structural evaluations to the 11 locations with a CCI > 1.5 mm/m. Although not explicitly stated in Section 2.1.2, the team learned from discussions with NextEra engineers that the locations with a CCI of between 1.0 and 1.5 mm/m (13 locations) were considered bounded by the 11 areas subjected to a detailed evaluation. The lack of a documented structural evaluation for the 13 locations with a CCI of between 1.0 and 1.5 mm/m was considered a minor performance deficiency. NextEra acknowledged this procedural implementation error and entered the issue into their Corrective Action Program (AR 1804477 and AR 1819080). A structural evaluation was completed for containment and reviewed by the team prior to the completion of the inspection period (see Section 3.2.8). However, the evaluations for the remaining locations are yet to be completed. Based upon team review of the competed structural evaluations, to date, there is a reasonable expectation that structural integrity (and operability) of the locations yet to be evaluated by NextEra will be ~~sufficiently~~ demonstrated. Notwithstanding, the team will examine these evaluations in the next CAL follow-up inspection report.

Near the conclusion of this inspection period, NextEra completed the POD for containment (AR 1804477). Preliminary review by the team identified a few areas for follow-up during the second CAL follow-up inspection. Specifically, the team will pursue NextEra's evaluation of the potential for chemical pre-stressing of rebar (reference Section 3.2.8) and review NextEra's future plans for monitoring the localized areas (three) of presumed ASR (not petrographically verified) on the containment outer wall (reference Section 6.0).

3.2.2 Concrete Material Properties - Compressive Strength and Elasticity Modulus

In Revision 2 of POD 581434 for the B Electrical Tunnel, NextEra concluded that there is no loss of concrete compressive strength due to ASR. This conclusion was based on testing of 15 cores (12 ASR-affected concrete and 3 control locations), which showed an average strength of 5143 pounds-per-square-inch (psi) for the ASR affected cores and 4880 psi for the control cores. NextEra concluded that ASR had increased the stiffness of the electric tunnel walls because the compressive strength in the ASR impacted concrete was higher than in the control core samples. Team review of the supporting concrete core data did not validate NextEra's conclusion.

Comment [M10]: Why does this matter as long as the building performs its function and has a reasonable expectation of meeting its safety function

Concrete compressive strength can vary due to variations in in-place concrete strength. The team determined that 12 cores were obtained from six locations in an ASR suspect wall in the B electrical tunnel. Testing produced compressive strength values ranging from a low of 4220 psi to a high of 6610 psi. The mean strength value of these samples is 5143 psi with a standard deviation of 630 psi. The three cores taken from a control area (presumed ASR free) measured 4630, 5350 and 4660 psi. The mean value of these samples was 4880 psi, with a standard deviation of 580 psi. Team review of the B electrical tunnel data determined that the compressive strength measured in 2011 is about 2 percent lower than the measured cylinder strength values from 1979. These values do not show an increase in strength over 25 years, as would be expected as concrete continues to cure. However, given the inherent variability in concrete material properties and the significant variation in the data from the B electric tunnel, the team could not conclude that there was a significant loss of compressive strength or that the affect of the ASR was to increase the compressive strength. In addition, this conclusion is different than the 22 percent measured compressive strength reduction (compared to the 1979 cylinder test results) that had been previously identified by NextEra from initial core sample results and reported in NRC Inspection Report 05000443/2011007. In contrast to the B electric tunnel results, the measured compressive strength values in the other ASR affected buildings suggest a different trend. In general, the measured core sample compressive strengths in the RCA walkway, EFW pump house, RHR EV and EDG buildings in 2011 were higher than the original compressive strength values in 1979 (as expected). This 2011 core sample data shows an average increase of 56 percent.

Comment [M11]: What is this trend? Didn't see a trend in the information identified in this paragraph

Comment [M12]: Information that seems to provide no actual insight and only begs questions. Should be some kind of conclusion regarding meeting or remaining above design values which is why it is ultimately OK.

For modulus of elasticity, although individual cores showed a modulus that was reduced (compared to design), the average modulus value in the RCA walkway, RHR EV, EFW pump house and DGB was within 20 percent of the design modulus value ($\pm$20 percent is acceptable by ACI 318). For the CEB, the average modulus was just beyond (low) the 20 percent allowable. The team noted that modulus values at individual core locations could be lower than design and that NextEra had conservatively used these lower measured modulus values to assess the implications of ASR on structural performance.

Based on the above, the team determined that the core sampling and material property testing completed, to date by NextEra, has not conclusively established the current impact of ASR on concrete material properties (specifically for compressive strength and modulus of elasticity). However, an adverse trend in concrete material properties is indicated and supported by a literature review and available research data. Notwithstanding, review of the core sample data does indicate that the concrete compressive strength remains considerably above the specified design strength value of 3000 psi (or 4000 psi, where used in construction). The team plans to examine this area further in the second follow-up inspection with respect to adequacy of the Structures Monitoring Program.

Comment [M13]: Unnecessary; Literature search indicates a trend, how is this applicable and do we regulate based upon literature searches?

3.2.3 Flexural Capacity and Dynamic Response

NextEra completed a study of the Containment Enclosure Building (CEB) (FP 100714 and FP 100715) which evaluated the effects of varying elastic modulus. Modulus values used in the study were based on field investigation of CEB concrete that correlated a visual rating of ASR with core test results (FP100696 and FP 100700). The CEB study included a parametric analysis that: evaluated the building in a static, three dimensional finite element analysis (FEA) to determine the response (forces and moments) to operating basis earthquake and safe shutdown earthquake seismic loads before and after ASR damage; calculated the section capacities; calculated demand-to-capacity ratios (DCRs); and, compared the DCRs of ASR degraded walls to undamaged walls. The analyses showed that the seismic acceleration profiles, the in-structure response spectrum, and the distribution of forces and moments were not significantly impacted by ASR affected properties. Similarly, the effect of the reduced

Enclosure

modulus on the response of below-grade, ASR-impacted structures was evaluated. For below grade structures, NextEra determined that the structural response remained in the rigid range with no appreciable amplification of the ground response spectra. The seismic response of the structure along with the attached equipment (cable trays and supports) and anchor loads remained unchanged, with no affect on operability due to ASR. The team noted that these studies validated previous analyses that the reduced modulus of elasticity had minimal impact on the seismic response of walls and attached equipment. The team concluded that NextEra's assessment of this ASR affected design attribute was appropriate for the interim operability determination.

3.2.4 Shear Capacity

NextEra analyzed the impact of ASR on the B Electric Tunnel using a FEA to compare the shear capacity versus demand for seismic and hydrodynamic loads. The FEA used the ACI-318 Code, Section 11.4.1 equation for shear stress which relates shear stress to the square root of compressive strength. NextEra assumed a lower bound 25 percent reduction in out-of-plane shear capacity due to the affects of ASR. The team noted that NextEra's design calculation (CD-20, dated 3/28/83) used the average 28-day compressive strength value (5459 psi) to establish the design shear capacity. However, the FEA used the specified design concrete strength of 3000 psi to compare the available design capacity to design load. The use of the 3000 psi vice 5458 psi value in the FEA approximates the assumed 25 percent lower bound value ASR affect on out-of-plane shear capacity. The licensee identified additional conservatism in their analysis based upon the B electrical tunnel average measured core sample compressive strength value of 5140 psi. NextEra's FEA concluded that adequate margin was available. The team acknowledges that: 1) some additional margin may be credited due to the compressive strength of core samples exceeding the design minimum value of 3000 psi; and 2) the assumed 25 percent reduction in shear capacity is conservative because of the uncertainty with respect to the actual impact of ASR on concrete tensile strength during the early stages of ASR. The team viewed the use of a FEA to assess lower bound ASR affects as appropriate and insightful, but not conclusive, pending further testing and engineering analysis planned by NextEra.

Comment [M14]: Equations we question?

Comment [M15]: Paragraph is confusing and unclear. What is the message? 25% where did that come from?

3.2.5 Anchorage

NextEra evaluated the impact of ASR affected concrete on the performance of anchors, including cast in place anchors, drilled in anchors and reinforcing steel anchorage. The potential impact of micro-cracking caused by ASR can impact anchorage capacity by affecting the distribution of shear stresses. Petrographic analysis of Seabrook concrete cores showed that concrete quality was good with relatively small cracks indicating minimal impacts on stress distribution. NextEra's evaluation was supported by anchor performance testing conducted on ASR degraded specimens (FP100718). The tests showed satisfactory performance of the anchors in concrete test specimens, although dissimilar in composition and compressive strength compared to Seabrook structures. NextEra's evaluations illustrated that the assumed reductions in capacity due to ASR degradation were offset by established design margins (FP100716). The team concluded that NextEra's interim anchorage operability assessment was satisfactory. However, based upon the limitations of the testing performed, to date, NextEra plans to conduct further testing. Planned testing involves anchors installed in ASR affected test specimens that more accurately reflect the reinforced concrete structures and anchor configurations at Seabrook.

3.2.6 Review of Finite Element Analysis Modeling

As discussed in Sections 3.2.3 and 3.2.4, NextEra used finite element analysis to evaluate the affects of ASR on certain structures and design attributes. The team noted that the input data for the compressive strength and modulus of elasticity for the CEB model were determined based on a visual examination of CEB walls and only a few directly obtained core sample material properties. The observed crack patterns/dimensions were correlated to a damage rating index (DRI) and associated concrete material properties from test data obtained from core samples taken from several different structures. The input data for poisson ratio was derived exclusively from industry data. NextEra acknowledged the limitations of this input data, but in FP 100696 deemed the approach justified because the analysis was a parametric study of the CEB seismic response, comparing design values to ASR affected values. The team concluded this FEA approach was useful and insightful for providing reasonable expectation of operability for the interim period, but not conclusive with respect to the current or projected state of ASR impact on the CEB. As discussed in Section 9.0, the parametric analysis results will have to be reevaluated following testing and prior to finalizing the PODs.

3.2.7 Lap Splice Strength

Section 6.3 of the Interim Assessment addressed reinforcement lap splice degradation as another design attributed impacted by ASR. In accordance with the licensee's lower bound value of a 40 percent reduction in lap splice strength, NextEra's review of design calculations identified several structures with insufficient margin to accommodate this assumed ASR affect. NextEra was able to recover margin by adjusting the ACI Code 318 prescribed design load factors for predicted dead load and/or hydrostatic loads. The team examined this method for margin recovery and found it satisfactory for the interim operability assessment, but concluded it would not be acceptable for a final operability determination under the current licensing basis.

3.2.8 Concrete Confinement and Rebar Pre-Stressing

Team review of FP 100716, Sections 2.1.2 and 4.1.3, identified that the interim engineering evaluation stated, "since ASR has a negligible impact on structural demand, the impact of ASR on structures and structural attachments can be assessed solely on the basis of changes in capacities." The team observes that restraint to ASR expansion, from concrete confinement by reinforcement and/or other external constraints, causes chemical pre-stress in the structural members. The consequence is increased compressive stresses in concrete and increased tensile stresses in the rebar cage, as long as the restraint is sustained. The team observed that this ASR-induced pre-stress has been addressed only qualitatively in the Interim Assessment and containment structural evaluation (AR 1804477). The team finds this acceptable for interim operability determinations. However, the team's preliminary engineering judgment is that a quantitative evaluation is more appropriate for a final operability assessment of this condition. Further, it should be recognized that the ASR-induced pre-stress varies with time, depending on the degree of restraint and may not be sustained through the service life of the affected structure.

The team concludes that chemical pre-stress, if sustained, may show some beneficial effect in terms of stiffness and gross ultimate structural strength, but it may also result in an increase in structural demand on the concrete and reinforcement. As stated above, the team's judgment is that this structural demand should be quantified (if practicable) and accounted for in the design calculations as a known load. Quantifying, or otherwise approximating the chemical pre-stress, is similar to accounting for (and monitoring for losses) the pre-stress load in pre-stressed concrete design. This issue will be reviewed by the team in the second follow-up inspection.

3.2.9 Condition of Rebar

The team examined information gathered and assessed by NextEra with regards to the condition of rebar and any potential erosion or corrosion due to ASR and water in leakage through below grade reinforced concrete structures. The team observed that NextEra had purposefully removed an area of surface concrete in the B Electrical Tunnel (chronically wet) to examine the condition of the rebar. The engineering staff identified no degradation of the rebar (no oxidation or signs of distress). The team also learned that in the course of removing core samples, in two instances the drill nicked rebar. Examination of the rebar sections removed determined the steel to be in excellent condition (unaffected by ASR or moisture). Preliminarily, the condition of rebar in ASR degraded concrete should be unaffected until the cracking becomes deleterious and exposes the rebar to oxidation mechanisms. Otherwise, the alkaline condition within the concrete should prevent any erosion or corrosion mechanisms. The NRC continues to evaluate the need for any additional rebar intrusive monitoring or testing, and will evaluate this issue in the second CAL follow-up inspection.

4.0 Review of ASR Root Cause Evaluation (CAL Item #2)

4.1 Inspection Scope

The team reviewed NextEra's response to this CAL Item, "Submit the root cause for the organizational causes associated with the occurrence of ASR at Seabrook Station and related corrective actions by May 25, 2012." The licensee submitted their root cause evaluation (RCE) via letter dated May 24, 2012. The purpose of the team's review was to assess the adequacy of the licensee's evaluation of the root cause for the ASR issue at Seabrook and the significant contributing causes. The team also examined the methodology and thoroughness of the licensee's evaluation and associated corrective actions as outlined in 10 CFR Part 50, Appendix B, Criterion XVI, "Corrective Action."

4.2 Findings and Observations

This CAL Item will remain open pending NRC review of NextEra's final RCE. NextEra identified two root causes: 1) ASR developed because the concrete mix design unknowingly utilized an aggregate that was susceptible; and, 2) the monitoring program for plant systems and structures does not contain a process for periodic reassessment of failure modes. A contributing cause identified by NexEra was the failure to prioritize groundwater elimination or mitigation resulting in more concrete areas exposed to moisture. The team made some observations regarding the clarity and completeness of NextEra's root cause evaluation.

The team acknowledges that the first licensee identified root cause involved the use of susceptible aggregate in the concrete mix design that was undetected by the testing specified by ASTM construction standards, at the time (late 1970's). The ASTM standard was subsequently revised to ensure slow reactive aggregates would be properly identified prior to use in construction. The team concluded that this causal factor was beyond the licensee's control.

The team concluded that the second root cause was not adequately characterized in NextEra's May 24, 2012 submittal. Specifically, NextEra did not clearly state the personnel and organizational factors that led to inadequacies in the Structures Monitoring Program (SMP). The team discussed the absence of any human performance aspects in the description of this causal factor and NextEra initiated a revision to the RCE to more appropriately develop and characterize this second root cause and the associated corrective actions. NextEra plans to submit the revised RCE for NRC review, consistent with their CAL Item #2 commitment. The team will review this revision in the next CAL follow-up inspection report.

The team also noted that NextEra excluded a significant contributing cause, identified in the RCE, from the evaluation executive summary and May 24, 2012 letter. As stated in the RCE, this contributing cause involved the longstanding "organizational mindset" that groundwater in-leakage was more of an operational nuisance than a structural integrity concern. This station and engineering staff view prevented a more timely and thorough investigation and examination of the affected concrete reinforced structures on site. NextEra acknowledged this observation.

5.0 Review of Mortar Bar Testing (CAL Item #6)

5.1 Inspection Scope

The team reviewed the results of NextEra recently completed short term expansion testing of mortar bar specimens per test procedures SGH-Z001-12 and SGH-Z002-12. The results of the testing were evaluated per ASTM C1260. The licensee initiated the testing to establish and compare the reaction rates of ASR affected concrete to non-ASR affected concrete on site. The tests were performed by a consultant at an offsite facility. The mortar bar specimens were made using the aggregate extracted from core samples taken from ASR affected structures and non-affected concrete from a slab removed from the waste processing building. NextEra noted that the non-affected concrete slab used for aggregate extraction had shown no visible indications of ASR. The details of the testing are documented in SGH Report 120110-RPY-01 (FP 100734). The team reviewed the SGH report and associated test documents to ascertain the adequacy and technical validity of the testing.

5.2 Findings and Observations

No findings were identified and CAL Item #6 is closed. The test results indicated that both affected and non-affected concrete specimens contained ample reactive aggregate to sustain ASR. The team notes that normal test duration is 14 days and that a specimen expansion of >0.1 percent indicates reactive aggregate, per ASTM C1260. Test results identified that the non-ASR affected specimens exceeded the 0.1 percent threshold in five days and the ASR affected specimens exceeded the 0.1 percent threshold in seven days. NextEra allowed the test to extend to 103 days and both specimen types continued to demonstrate active expansion due to ASR. Accordingly, NextEra concluded that there remains the potential for future volumetric expansion due to ASR in concrete structures at Seabrook.

Based upon the Mortar Bar Testing results, NextEra plans to revise their commitment to conduct Prism Testing. Prism Testing is a similar, but longer term test of the susceptibility to ASR of aggregate used in concrete. NextEra had hoped to establish, via the Mortar Bar Test, a difference in the remaining versus available concrete constituents for ASR in the specimens. The results demonstrated ample reactive materials in both specimen types and NextEra concluded the Prism Test will not provide any additional ASR insights. The team concluded that NextEra's basis to revise their commitment to conduct Prism Testing was reasonable.

6.0 Review of Crack Indexing (CAL Item #10)

6.1 Inspection Scope

The team conducted a review of FP 100647, "Crack Index Determination," Revision 1, to understand the methodology for NextEra's monitoring of ASR progression in selected reinforced concrete structures. NextEra's commitment to this methodology is captured in CAL Item #10. The team used 10 CFR Part 50, Appendix B, Criterion V, "Instructions, Procedures, and Drawings," to evaluate the adequacy of this process. The team's review was limited in scope, in that, the adequacy of this process, as the sole means of monitoring ASR progression in Seabrook structures, is still under NRC review. The team will evaluate this aspect as part of the review of CAL Item #9, the Maintenance Rule Structures Monitoring Program, during the second CAL follow-up inspection.

The team observed field measurements taken on June 20, 2012, by the responsible contractor and discussed the general methodology and procedural guidance with the individuals performing the crack indexing measurements and supervising NextEra staff. The team noted that NextEra found ASR patterned cracking in many areas within Seismic Category I and Maintenance Rule structures, but only a limited number of these areas have sufficient ASR degradation to merit continued monitoring and detailed evaluations. The ASR walkdown identified 131 locations with some level of pattern cracking. Of the 131 locations, 26 exceeded an initial screening criteria of a combined crack index greater that 1.0 mm/m. These 26 areas will continue to be monitored at six-month intervals, per FP 100647.

6.2 Findings and Observations

No findings were identified and CAL Item #10 is closed. The team noted that the periodic crack indexing provides the principle method selected by NextEra to monitor the progression of ASR on reinforced concrete structures. The six-month interval measurements are currently planned until a reliable trend of ASR progression can be established, per Structural Engineering Standard Technical Procedure 36180, "Structures Monitoring Program (SMP)," Attachment 3, Revision 2. As stated above, additional NRC review of the SMP will be conducted in the second CAL follow-up inspection.

The team also reviewed the current methods and terminology used by NextEra to characterize the degree of ASR pattern cracking, previously addressed in NRC Inspection Report 05000443/2011007. When ASR was initially identified in the B electrical tunnel in mid-to-late 2010, the licensee referred to the Federal Highway Administration (FHWA) guidance document FHWA-HIF-09-004 for crack/damage characterization. Three major categories were identified: mild, moderate, and severe, with ratings such as mild to moderate and moderate to severe, also used. Per FHWA-HIF-09-004, these categories were used to define the recommended remedial actions to be taken once ASR was identified. At that time, NextEra labeled the observed cracking as "severe." Per the FHWA guidance, this category requires "further investigation for selecting remedial actions." This characterization was repeated in the above referenced inspection report. The team determined that NextEra revised their crack characterization scheme prior to the implementation of the structures extent-of-condition review. The revised crack rating system was based upon "best practices" taken from the Building Research Establishment (BRE) in the United Kingdom (UK). The revised numeric rating system range is from 0 (no cracking detected) to 6 (heavily fractured ASR-related damage). FP 100636, "Petrographic Examination PE Reports," Revision 0, lists the material property results of all core samples taken and petrographically analyzed. FP 100636 also provides the BRE crack rating for each specimen examined. The crack ratings for the specimens examined range from 0 to 4. A summary table with each numeric rating and its definition is documented in the Supplemental Information attachment to this report.

7.0 Review of Alkali-Silica Reaction Structures Walkdown/Baseline Assessment

7.1 Inspection Scope

The team examined NextEra's program documents FP 100642, "ASR Walkdown Scope," Revision 1, and FP 100705, "Seabrook Station: Summary of Alkali Silica Reaction Walkdown Results," Revision 0. The team reviewed the walkdown scope and examination criteria and the associated field data, photographic evidence, and analysis of NextEra's observations, as documented in FP 100705. The walkdown scope included Seismic Category 1 and some in scope Maintenance Rule structures. NextEra's walkdown is being conducted in three phases. Phase 1 involved examination of readily accessible areas of interest; Phase 2 included examination of coated surfaces identified during Phase 1 inspections (coatings had to be removed to expose the concrete surfaces); and Phase 3 examines normally inaccessible structures/areas (e.g. high radiation, manholes, etc.) which have or will be inspected as the opportunity presents itself (e.g. routine maintenance or outage activities).

The walkdowns assess the extent of ASR throughout the plant with the primary objectives of: identifying and assessing any apparent degradation from ASR, including: estimating in-situ expansion (Crack Indexing); assessing whether concrete in the vicinity of supports for safety-related systems or components show any indications of ASR distress; and documenting and characterizing water intrusion or evidence of previous water intrusion, based upon water being a key contributor to concrete deterioration and distress caused by ASR. The visual criteria for documenting potential ASR indications include: typical patterned surface cracks in concrete; crack dimensions (width, length, orientation); evidence of water ingress/out-seepage (past/present); visual evidence of salt deposit and/or ASR gel; and indications of surface deterioration (i.e., pop-outs and/or spalling). Also, any expansion anchors or structural embodiments located within five feet of the area of interest were examined and documented. The licensee considers their ASR walkdown efforts and observations a baseline condition assessment. This baseline will be used for monitoring the progression of ASR for the duration of the current operating license.

The team performed a number of independent walk-through inspections to verify and assess the thoroughness of the licensee's efforts. The team independently evaluated the extent-of-condition of ASR affected structures that are readily accessible. The team used the expertise of a consulting structural engineer to assist in the team's review of the current condition of ASR affected reinforced concrete structures at Seabrook Station.

7.2 Findings and Observations

The team identified no findings. On a sampling basis, the team's independent walkdown observations were consistent with the licensee's observations and assessments. At Seabrook, the presence of ASR has been conclusively established by petrography in certain buildings (where core samples were obtained) and in other buildings by inference, using visual examination criteria. The team confirmed that NextEra's position is that all reinforced concrete structures on site are susceptible to ASR, dependent upon the exposure to moisture. Therefore, NextEra does not intend to remove any of the identified structures from continued ASR monitoring without confirmation via petrography that ASR is nonexistent or no longer active.

The complete list of structures and localized areas of ASR identified, to date, is documented in FP 100705, Revision 1. The team noted that the results of the walkdown inspection by NextEra were appropriately documented with extensive observation narratives and well supported by clear sketches and photographs. As NextEra completes Phase 3 examinations, the licensee plans to capture the additional observations through revisions to FP 100705. The team noted that the majority of localized areas of ASR are: 1) below grade walls subjected to either ground water intrusion, or particularly high spatial humidity; or, 2) exposure to precipitation and high ambient humidity (some exterior above grade structures).

Based upon the team's review of the Phase 1 and 2 ASR walkdown results and via discussions with responsible engineers overseeing the proposed Phase 3 walkdown areas and tentative schedule, the team identified a minor oversight in the Phase 3 walkdown plan. Specifically, the upper elevations of the containment outer wall were not adequately examined for ASR during the Phase I review and not included in the proposed Phase 3 walkdown schedule. The team identified from discussion with the NextEra engineering staff, that the 2010 IWL examination of containment was being credited for part of the Phase 1 ASR walkdown baseline. The team's detailed review of the 2010 IWL inspection results and associated visual examination attributes (reference implementing procedure, ES 1807.031, "Inservice Inspection Procedure Primary Containment Section XI IWL,") identified that the 2010 IWL exam did not include adequate examination criteria (i.e., active or pattern cracking) for identification of ASR. As evidence of this shortcoming in the IWL examination, during the subsequently performed Phase 1 ASR walkdown by consulting engineers, three locations of ASR related pattern cracking were identified on areas of the containment previously examined by the IWL inspectors. NextEra acknowledged this oversight in crediting the IWL examination and initiated action (AR 1819069) per the Corrective Action Plan, to address the need to revise the Phase 3 plan. In addition to review of the revisions to the Phase 3 walkdown areas during the second CAL follow-up inspection, the NRC plans to examine the adequacy of the proposed Phase 3 implementation schedule.

8.0 Follow-up of Open Items

8.1 (Closed) Unresolved Item 05000443/2011003-03, Open Operability Determinations for Safety-Related Structures Affected by Alkali-Silica Reaction

This item was open pending NRC review of NextEra actions to revise operability determinations for the electric tunnel and other structures addressed in the extent of condition review for ASR. The open aspects were as documented in Inspection Reports 2011-03 and 2011-10 related to: 1) effect of the reduced modulus of elasticity on natural frequency of the structures; 2) the effect of the modulus of elasticity on structure flexural response as related to components attached to the structures, such as pipe and cable supports and their anchor bolts; 3) related effects from increased flexure of building on the loading and seismic effects on safety related pipes and cable tray supports; and, 4) effect of reduced parameters on the whole building (global) response of the CEB structure to seismic loads including further information of the effect on stress and strain in the concrete and rebar system. Following the reviews in Inspection 2011-10, the unresolved item remained open pending NRC review of additional information from NextEra on the effects on cable and pipe support anchors (number 3) and the effects on the CEB response (number 4).

The team reviewed the revised operability determinations for the safety related structures listed below and as described in POD 1664399, Revision 2.

- Control Building – "B" Electrical Tunnel,
- Containment Enclosure Building,
- Diesel Generator Building,
- Residual Heat Removal Equipment Vaults, and
- Emergency Feedwater Pump House

As part of the ASR extent of condition review, NextEra provided structural assessments for the RCA tunnel and other ASR impacted buildings (reference Calculation C-S-1-10168).

The open aspects of numbers 3 and 4 were resolved after NextEra provided additional information. Revision 2 of POD 581434 for the B electric tunnel (ET) provided additional quantitative and qualitative analyses with consideration of ASR-induced changes in concrete properties. The revised POD addressed the changes in modulus on building frequency; flexural response and capacity; shear capacity; and support anchors. The revised POD incorporated the results of the Interim Assessment (FP100716) relative to the performance of reinforcing steel anchorage to show that postulated reductions in capacities were offset by conservatisms in ACI 318 Code and the assumed loads. The revised POD incorporated the testing at the Ferguson Structural Engineering Laboratory (FP 100718) of cast-in-place and drilled-in anchors to assess the impact of anchor performance in ASR affected concrete. The test results showed that the anchor capacities remained above the theoretical capacity at crack indices well above the maximum CI observed in Seabrook structures. Finally, the revised POD for the ET also included consideration of a detailed evaluation of the CEB, chosen for detailed analysis because it conservatively bounds other structures in size and exhibits the highest reduction in modulus of elasticity due to ASR. This included how the induced stresses would shift between the concrete and the steel in adjoining sections of the structure. These issues were factored into the analytical model (finite element analysis) to reanalyze the CEB using the measured elastic modulus applied to ASR impacted sections.

Further NRC review of this area is described in Sections 3.0 and 4.0 of this report. The team concluded that the initial failure of NextEra to adequately consider the ASR impacts on structural performance, relative to support anchors and dynamic response, were examples of minor performance deficiencies, and addressed broadly by the NRC in Finding FIN 05000443/2011-10-02. Unresolved Item 05000443/2011003-03 is closed.

8.2 (Closed) URI 2011-010-01 – Adequacy of Calculation Methods for ASR

NextEra initially pursued mechanical testing of concrete cores because that was the traditional method as described in ACI 228.1R for determining properties of existing concrete structures. Upon further review of industry experience and literature for ASR impacted concrete, NextEra determined that the core test data was not indicative of structural performance of the ASR affected structures. Once removed from the structure, the concrete in the cores is no longer subject to the strains imposed by the ASR-related expansion or restraints imposed by the reinforcing cage. Confinement provided by reinforcing steel and other restraints (e.g., deadweight of the structure) limits ASR expansion of the concrete within the structure, which reduces the extent of deleterious cracking and associated reduction of concrete material properties. NextEra has determined that the structural evaluations based on mechanical properties derived from core samples may under predict structural performance (FP100697, Structural Assessment of ASR-State of the Art). Since the reduction of mechanical properties derived from testing of cores is not necessarily representative of the structural performance, NextEra changed its approach. NextEra no longer relies on further core sampling to characterize the current and future condition of ASR affected structures. Instead, the licensee will monitor structures via Crack Indexing and pursue large scale testing of concrete components more representative of the Seabrook conditions. The testing will be conducted at the Ferguson Structural Engineering Laboratory (FSEL) at the University of Texas Austin (UT-A).

Given the interplay between expansive ASR degradation and structural restraint, NextEra provided an Interim Assessment of the Seabrook structures impacted by ASR which relies on structural proof testing rather than testing of concrete cores removed from the structure. The Interim Assessment was based on available industry data on small scale test specimens having ASR degradation worse than that observed at Seabrook.

NextEra responded to CAL Item #8 by letter dated June 21, 2012, and provided a broad overview of the testing planned at FSEL, which will include a shear test program, a lap splice test program and an anchor test program. The test program will include control specimens that will provide a baseline by which to judge the reductions in capacity due to ASR and to quantify the margins available as calculated using ACI-318. NextEra plans to use the test program to reconcile the ASR condition with the licensing design basis, to inform the structures monitoring program, and to evaluate potential mitigation strategies. NextEra's actions, approach and methods used to resolve the ASR issue, including the test program described in CAL Item #8, is currently under review by the NRC regional and headquarters staffs. Unresolved Item 05000443/2011-010-01 is closed.

9.0 Conclusions and Follow-Up Issues

The team determined, based upon the review of the PODs and supporting engineering analyses documented in the Interim Assessment, that the PODs will not be finalized until: 1) the degree of ASR degradation on station reinforced concrete structures is established within the design and licensing basis; 2) definitive margins are established to the design basis limits; and 3) the progression of ASR is appropriately monitored and demonstrated to ensure adequate margins are maintained for the duration of the current operating license.

The team plans to conduct a second CAL follow-up inspection to review the remaining open CAL items and the open issues documented in this report and listed below:

- Review conservatism of the assumed lower bound affects of ASR (Section 3)
- Review of pending structural evaluations and follow-up on containment POD observations (Section 3.2.1)
- Review of core sample compressive strength and SMP (Section 3.2.2)
- Review quantification of pre-stressing affects of ASR expansion (Section 3.2.8)
- Assess the need for any further rebar examinations or testing (Section 3.2.9)
- Review revised RCE submittal (Section 4.2)
- Confirm revised commitment to CAL Item #7 (Section 5.2)
- Review of Crack Indexing for SMP application (Section 6.2)
- Review the revision to the Phase 3 walkdown plans and schedule (Section 7.2)

10.0 Meetings, Including Exit

On November 2, 2012, the team conducted an exit meeting to discuss the preliminary findings and observations with Mr. Kevin Walsh, Site Vice President, and other members of Seabrook Station staff. The inspectors verified that no proprietary information was retained by the inspectors or documented in this report.

SUPPLEMENTAL INFORMATION

KEY POINTS OF CONTACT

Licensee Personnel

B. Brown, Design Engineering Manager
A. Chesno, Performance Improvement Manager
K. Chew, License Renewal Engineer
R. Cliché, License Renewal Project Manager
M. Collins, Design Engineering Manager
J. Connolly, Site Engineering Director
R. Noble, Project Manager
M. O'Keefe, Licensing Manager
T. Vassallo, Principal Design Engineer
K. Walsh, Site Vice President
P. Willoughby, Licensing Engineer

LIST OF ITEMS OPENED, CLOSED, DISCUSSED, AND UPDATED

Opened/Closed/Update

None

Opened

None

Closed

05000443/2011-010-01	URI	Adequacy of Calculation Methods for ASR
05000443/2011-003-03	URI	Open Operability Determinations for Safety-Related Structures Affected by Alkali-Silica Reaction

LIST OF DOCUMENTS REVIEWED

Procedures

Maintenance Rule Scoping Document, Revision 0
EDS 36180, Structures Monitoring Program, Revision 0, 1, 2

Corrective Action Documents (AR)

1651969, 1629504, 574120, 581434, 1636419, 1673102, 1647722, 1664399, 1677340, 1687932, 1692374, 1698739, 1755727, 1757861, 1819080, 1804477, 1819069

Drawings

Licensing and Design Basis Documents and Calculations

Seabrook Station UFSAR, Revision 14
ACI 318-71
Calculation CD-20
Calculation CD-18
Calculation C-S-1-10168

Miscellaneous Documents

FP100348, Statistical Analysis-Concrete Compression Test Data (PTL)
FP 100642, Scope for Alkali-Silica Reaction Walkdowns
FP 100641, Procedure for ASR Walkdowns and Assessment Checklist
FP100661, Compression Testing Concrete Cores (WJE)
FP100696, Material Properties of ASR-Affected Concrete
FP 100700, Field Investigation
FP100705, Structure ASR Walkdown Report (MPR 0326-0058-58)
FP100714, Three Dimensional Dynamic Analysis of Containment Enclosure Building
FP100715, ASR Impact Study on Containment Enclosure Building
FP100716, Interim Assessment: Impact of ASR on Structures (MPR-3727)
FP100717, ACI 318-71 Perspectives
FP100718, Anchor Test Report (MPR-3722)
FP100720, Crack Index and Expansion Measurement
FP100738, Measurements for ASR Crack Indexing on Concrete Structures
FP 100697, MPR 0326-0058-53, White Paper on Structural Implications of ASR: State of the Art, Revision 1
MPR 0326-0058-83, Shear Screening Criteria Used in MPR-3727
FHWA-HIF-09-004, Federal Highway Administration, "Report on the Diagnosis, Prognosis, and Mitigation of Alkali-Silica Reaction in Transportation Structures."

LIST OF ACRONYMS

ACI	American Concrete Institute
ADAMS	Agencywide Documents Access and Management System
AMP	Aging Management Program
AR	Action Request
ASME	American Society of Mechanical Engineers
ASR	Alkali-Silica Reaction
CCI	Combined Crack Index
CFR	Code of Federal Regulations
CW	Circulating Water
DG	Diesel Generator
DRP	Division of Reactor Projects
DRS	Division of Reactor Safety
EDG	Emergency Diesel Generator
EPRI	Electric Power Research Institute
FEA	Finite Element Analysis
FP	Foreign Print
FPL	Florida Power and Light
FSEL	Franklin Structural Engineering Laboratory
IMC	Inspection Manual Chapter
IP	[NRC] Inspection Procedure
MPR	MPR Associates, Inc.
NRC	Nuclear Regulatory Commission
PARS	Publicly Available Records
P&ID	Piping and Instrument Diagram
PM	Preventative Maintenance
PRA	Probabilistic Risk Assessment
QA	Quality Assurance
RCE	Root Cause Evaluation
RHR	Residual Heat Removal
SDP	Significance Determination Process
SG&H	Simpson, Gumpertz & Heger
SMP	Structures Monitoring Program
SRI	Senior Resident Inspector
UFSAR	Updated Final Safety Analysis Report
UT	Ultrasonic Testing
WO	Work Orders

NextEra Crack Rating Chart

Assessment of Severity of ASR in Hardened Concrete by Petrographic Examination

This rating system is based on a modified "best practice" procedure initially developed at tehe Building Research Establishment (BRE) in the United Kingdom, using ASR identification critieria first set out in the British Concrete Association report titled "The Diagnosis of Alkali-Silica Reaction," (1992).

Rating	Description
0	No cracking detected
1	Very slight cracking (no evidence of deleterious ASR)
2	Slight cracking (minor or trace evidence of deleterious ASR)
3	Moderate cracking (moderate evidence of deleterious ASR)
4	Severe cracking (severe evidence of deleterious ASR)
5	Very severe ASR-related cracking
6	Heavily fractured ASR-related damage

Marshall, Michael

From:	Heater, Keith
Sent:	Monday, November 19, 2012 3:57 PM
To:	RidsEdoMailCenter Resource; RidsNrrOd Resource; RidsNrrDirs Resource; RidsNrrDorl Resource; RidsOgcMailCenter Resource; RidsNrrDorlLpl1-2 Resource; RidsNrrPMSeabrook Resource; ROPreports Resource; R1ORACAL RESOURCE; R1DRSMAIL RESOURCE; R1DRPMAIL RESOURCE; Burritt, Arthur; Cline, Leonard; Turilin, Andrey; Jennerich, Matthew; Raymond, William; Rich, Sarah; Cass, Andrea; Screnci, Diane; Sheehan, Neil; McNamara, Nancy; Tifft, Doug; Santos, Cayetano; Conte, Richard; Trapp, James; Miller, Chris; Matakas, Gina; Haverkamp, Trisha; Larche, Linda; Bearde, Diane; Thompson, Margaret; Cook, William; Evans, Michele; Marshall, Michael; Murphy, Martin
Cc:	Heater, Keith
Subject:	Notice of Public Meeting and Open House with NRC and NextEra Energy, Seabrook, LLC on Dec. 11, 2012. (ML12324A218)
Attachments:	2012 Seabrook ASR public meeting notice .docx

To ALL;

Attached is the Notice of Public Meeting and Open House with NRC and NextEra Energy, Seabrook, LLC on Dec. 11, 2012. (**ML12324A218**)

Licensee:	NextEra Energy, Seabrook, LLC
Facilities:	Seabrook Station
Docket Nos:	50-443
Date/ Time:	December 11, 2012 Open House - 5:30 p.m. to 6:45 p.m. Public Meeting - 7:00 p.m. to 9:00 p.m.
Location:	One Liberty Lane Conference Center 1 Liberty Lane Hampton, NH 03842
Purpose:	The NRC will host an open house and public meeting to discuss the safety implications and status of its review of NextEra's commitment actions related to the Alkali-Silica Reaction (ASR) conditions in safety-related structures at Seabrook Station. The commitments are documented in a May 16, 2012, Confirmatory Action Letter No. 2012-002 (ML12125A172).
Public Participation:	This is a Category 3 Meeting.

View ADAMS P8 Properties ML12324A218
Open ADAMS P8 Document (12/11/2012 - Notice of Public Meeting with NRC and NextEra Energy, Seabrook, LLC, to Discuss the Safety Implications and Status of its Review of Commitment Actions Related to the Alkali-Silica Reaction (ASR) Conditions.)

B/64

- Keith Heater, Lead Admin Asst.
  Region-I, DRP
  610-337-5384

"Mission, Vision, Values
MV^2 – Taking the Right Actions
in the Right Direction
to achieve
Our Shared Goals."

Buford, Angela

From:	Buford, Angela
Sent:	Wednesday, November 21, 2012 2:05 PM
To:	Buford, Angela; Marshall, Michael; Thomas, George; Erickson, Alice; Sheikh, Abdul
Cc:	Murphy, Martin
Subject:	Clarification: RE: Action Requested: Crack Mapping Paper

To clarify, please note that this paper was written to address the following problem statement:

<<Look into available research to assess whether or not using the method crack mapping/indexing alone is sufficient to (1) determine the severity of ASR (2) monitor for ASR progression over time. Also look into the benefits/pitfalls of the Damage Rating Index method>>

So I did not include a review of Seabrook's program/acceptance critera/etc., as I thought NRC review of Seabrook's SMP program and acceptance criteria would be done as part of the CAL inspection and LR review.

Thanks, and enjoy your holiday.

From: Buford, Angela
Sent: Wednesday, November 21, 2012 1:41 PM
To: Marshall, Michael; Thomas, George; Erickson, Alice; Sheikh, Abdul
Cc: Murphy, Martin
Subject: Action Requested: Crack Mapping Paper

All,

Attached is the draft crack mapping position paper. We have been asked to provide this paper to the Region on Wednesday, so there is a quick turnaround to receive any comments from NRR to incorporate.

I have left out the "References" section, as I am still working on the citations. If during the course of your review you would like me to provide you one of the references, please email me.

Please provide your comments to me by Tuesday so that I can incorporate and send to the region. Any feedback would be greatly appreciated.

Angie

From: Angela Buford [mailto:angie.ab@gmail.com]
Sent: Wednesday, November 21, 2012 1:31 PM
To: Buford, Angela
Subject: Crack Mapping Paper

B/65

Buford, Angela

From:	Buford, Angela
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All,

Attached is the draft crack mapping position paper. We have been asked to provide this paper to the Region on Wednesday, so there is a quick turnaround to receive any comments from NRR to incorporate.

I have left out the "References" section, as I am still working on the citations. If during the course of your review you would like me to provide you one of the references, please email me.

Please provide your comments to me by Tuesday so that I can incorporate and send to the region. Any feedback would be greatly appreciated.

Angie

From: Angela Buford [mailto:angie.ab@gmail.com]
Sent: Wednesday, November 21, 2012 1:31 PM
To: Buford, Angela
Subject: Crack Mapping Paper

Marshall, Michael

From: Murphy, Martin
Sent: Monday, November 26, 2012 8:41 AM
To: Cook, William; Conte, Richard
Cc: Marshall, Michael
Subject: IR Comments
Attachments: Seabrook IR 2012-009 MM Comments.docx

Attached are my comments so far. I doubt I will have time today to do additional work on this. I generally agree with Mike's comments and you have a big picture idea regarding where I was after the call on Wed.

I have some additional comments from George which I will look over and forward as appropriate.

Marty

B66

UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION I
2100 RENAISSANCE BOULEVARD, SUITE 100
KING OF PRUSSIA, PENNSYLVANIA 19406-2713

Mr. Kevin Walsh
Site Vice President
Seabrook Nuclear Power Plant
NextEra Energy Seabrook, LLC
c/o Mr. Michael O'Keefe
P.O. Box 300
Seabrook, NH 03874

SUBJECT: SEABROOK STATION, UNIT NO. 1 - CONFIMATORY ACTION LETTER FOLLOW-UP INSPECTION - NRC INSPECTION REPORT 05000443/2012009

Dear Mr. Walsh:

On November 2, 2012, the U. S. Nuclear Regulatory Commission (NRC) completed a team inspection at Seabrook Station, Unit No. 1. The enclosed inspection report documents the inspection results, which were discussed on November 2, 2012, with you and other members of your staff.

The team inspection examined activities conducted under your license as they relate to safety and compliance with the Commission's rules and regulations and with the conditions of your license. Specifically, the team reviewed selected procedures and records, observed activities, and interviewed station personnel regarding the adequacy of NextEra's actions to address the impact of Alkali-Silica Reaction (ASR) on reinforced concrete structures. The team reviewed selected Confirmatory Action Letter (CAL) 1-2012-002 commitments for adequacy and closure.

Based upon the inspection team on site and in-office reviews, five CAL items were reviewed and closed, as documented in the enclosed report. The remaining six CAL items will be reviewed during our second planned follow-up inspection scheduled for completion in early 2013.

The inspection team identified NextEra's methods for assessing the impact of ASR on reinforced concrete structures technically sound and generally thorough. The approach of comparing the available design and as-built construction margins to a conservatively established lower bound ASR affect, on these established margins, was appropriate. The team concluded the assumed lower bound values, developed from research data, provide a reasonable interim operability basis until further testing and engineering analysis supports a final operability determination and addresses the uncertainties in identifying the current level and progression of ASR at Seabrook Station.

Comment [M1]: Para is problematic in a number of ways. State C/O based upon only knowing interim information?? How can we be confident to C/O on interim information. Why not C/O based upon satisfactory deliverable per CAL. Margin discussion is challenging and creates questions: Code accepts significant variability in results yet we are claiming that we can assess that variability and quantify it. The lower bound values are actually also unknown (assumed) and may not even be relevant since hard to compare literature data and applicability. Uncertainities will continue to exist; simply we will continue to have a reasonable expectation of safety for these structures. This paragraph should be left more vague to allow maneuverability in the future based upon test results and how licensee chooses to apply, if at all. Detailed discussion with tech staff indicated that the "margin" is exceedingly difficult to explain and even more difficult to quantify. Clear that based upon work to date there is not an immediate safety concern.

In accordance with 10 CFR 2.390 of the NRCs "Rules of Practice," a copy of this letter, its enclosure, and your response (if any) will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of the NRC's document system (ADAMS). ADAMS is accessible from the NRC website at http://www.nrc.gov/reading-rm/adams.html (the Public Electronic Reading Room).

Sincerely,

Christopher G. Miller, Director
Division of Reactor Safety

Docket No. 50-443
License No: NPF-86

Enclosures:
1. Inspection Report No. 05000443/2012009
   w/ Attachment: Supplemental Information
2. Confirmatory Action Letter 1-2012-002

cc w/encl: Distribution via ListServ

In accordance with 10 CFR 2.390 of the NRCs "Rules of Practice," a copy of this letter, its enclosure, and your response (if any) will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of the NRC's document system (ADAMS). ADAMS is accessible from the NRC website at http://www.nrc.gov/reading-rm/adams.html (the Public Electronic Reading Room).

Sincerely,

Christopher G. Miller, Director
Division of Reactor Safety

Docket No. 50-443
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DATE					

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U.S. NUCLEAR REGULATORY COMMISSION

REGION I

Docket No.:	50-443
License No.:	NPF-86
Report No.:	05000443/2012009
Licensee:	NextEra Energy Seabrook, LLC
Facility:	Seabrook Station, Unit No. 1
Location:	Seabrook, New Hampshire 03874
Dates:	June 18, 2012 to November 2, 2012
Inspectors:	W. Cook, Team Leader, Division of Reactor Safety (DRS) S. Chaudhary, Reactor Inspector, DRS W. Raymond, Senior Resident Inspector A. Buford, Structural Engineer, Division of License Renewal, Office of Nuclear Reactor Regulation (NRR) G. Thomas, Structural Engineer, Division of Engineering, NRR
Accompanied by:	Dr. Kent Harries, Professor of Structural Engineering, University of Pittsburg
Approved by:	Richard Conte, ASR Project Manager Division of Reactor Safety

SUMMARY OF FINDINGS

IR 05000443/2012009; 06/18/2012 - 11/02/2012; Seabrook Station, Unit No. 1; Confirmatory Action Letter (CAL) Follow-up Inspection Report.

This report covered three weeks of onsite inspection and four months of in-office review by region based inspectors and headquarters reviewers to assess the adequacy of actions taken by NextEra to address the identification of Alkali-Silica Reaction (ASR) in reinforced concrete structures at Seabrook Station. The NRC's program for overseeing the safe operation of commercial nuclear power reactors is described in NUREG-1649, "Reactor Oversight Process," Revision 4, dated December 2006.

Cornerstone: Mitigating Systems

During this inspection the team examined six of the eleven commitments identified in Confirmatory Action Letter No. 1-2012-002, dated May 16, 2012. These commitments involve actions taken and planned by NextEra to address the degradation of reinforced concrete structures at Seabrook Station due to ASR. Based upon the team's onsite inspection activities and detailed in-office reviews during this inspection of CAL items, the team closed CAL Items #1, #3, #5, #6 and #10. The team reviewed CAL Item #2, but did not close this item based upon additional work needed by NextEra to appropriately address and document this issue. The details of the team's review of each CAL item and the observations pertaining to the adequacy of NextEra's actions to address their commitments to the NRC, to date, are documented in the enclosed report.

The team acknowledged NextEra's plans to conduct performance testing of large scale test specimens (both control and ASR affected) and then apply the data to evaluate the current impact of ASR on Seabrook Station concrete structures and to develop appropriate actions for the continued monitoring of the ASR affected structures. Information from the test program will also be used to make appropriate modifications to the existing structural monitoring program for ASR susceptible structures. The adequacy of NextEra's proposed test program will be evaluated during the second CAL Follow-up inspection, consistent with CAL Item #8. The team verified during this inspection that NextEra's will not finalize their Interim Assessment and Prompt Operability Determinations until: 1) the degree of ASR degradation on station reinforced concrete structures is established within the design and licensing basis; 2) definitive margins are established to the design basis limits; and 3) the progression of ASR is appropriately monitored and demonstrated to ensure adequate margins are maintained for the duration of the current operating license.

The team also clarified NextEra's current position that no structure at Seabrook Station will be precluded from continued monitoring for the affects of ASR until a satisfactory petrographic examination has been completed on that structure to confirm the absence of ASR or that ASR is no longer active. The adequacy of NextEra's Structures Monitoring Program will be evaluated in the second follow-up inspection, consistent with CAL Item #9.

Comment [M2]: We do not know how they "will" apply or use the test results

Comment [M3]: Not sure we can identify what is adequate – what is the metric to determine?

Comment [M4]: There is no way to quantify that the "degree of ASR degradation" is within design and licensing basis. It was never intended to exist, was not designed into the structure and was not captured in licensing basis. Statement makes no sense. Again, margins will never be definitive with the accepted variability in the code also don't need margin to design basis; just need to meet the design basis. Lastly the ASR has to be managed to ensure the design limits are maintained.

Comment [M5]: What is the metric to satisfactory – who is determining, why does it need to be petrographic, industry is OK with visual, too limiting

Comment [M6]: "ASR no longer active" – what does this mean? Has an understanding been proposed and agreed upon?

As highlighted in Section 9.0 of the enclosed report, the team identified additional issues for follow-up during the second inspection. These issues and the remaining CAL Items will be examined and assessed for adequacy prior to the closeout of CAL 1-2012-002.

REPORT DETAILS

1.0 Background

Alkali-Silica Reaction (ASR) is a chemical reaction in concrete that can change the physical properties. In June 2009, NextEra identified potential degradation in below grade concrete structures at Seabrook. In August 2010, NextEra completed petrographic evaluation of concrete core samples which confirmed ASR as the degradation mechanism. The degraded condition in Seabrook Category I structures was evaluated in the Corrective Action Program via a prompt operability determination (POD) in September 2010, and revised in April 2011, September 2011 and May 2012. The initial PODs (Revisions 0 and 1) addressed the B electric tunnel (AR581434) where ASR was first discovered. Five other buildings were identified via the extent of condition (EOC) review and the evaluation of core samples taken from these structures (AR1664399). The PODs were updated as new information became available and revised analytical techniques were incorporated.

NextEra initially used the results of mechanical testing of concrete cores to assess the degree of structural degradation due to ASR. This is the traditional method described in American Concrete Institute (ACI) 228.1R for assessing existing concrete structures. NextEra tested the cores for compressive strength and elastic modulus. NextEra used the methods defined in construction and design code ACI 318-1971 to evaluate the structural capacity (operability) of the ASR affected buildings. However, the mathematical relationships in ACI-318 are based on empirical data from testing of non-degraded concrete and these relationships may not hold true for all stages of ASR affected concrete.

After further review of industry experience and literature pertaining to ASR, NextEra engineering concluded that the core test data was not indicative of structural performance of ASR affected reinforced concrete structures. NextEra's engineering evaluation states that once removed from the structure, concrete cores are no longer subject to the strains imposed by the ASR-related expansion or restraints imposed by the reinforcing cage. Confinement provided by reinforcing steel rebar and other restraints limit ASR expansion of the concrete within the structure, which reduces the extent of deleterious cracking and the resulting reduction of concrete material properties. Therefore, NextEra concluded that the reduction of mechanical properties observed in mechanical testing of cores is not representative of in-situ concrete performance. NextEra's current position is that the mechanical tests are only useful as a diagnostic tool to confirm the presence of ASR. Based on the above, NextEra stopped taking cores to evaluate structures impacted by ASR and revised their approach. NextEra's current approach for assessing structural integrity and operability is to compare available design margins to an assumed reduction in structural capacity due to ASR.

The extent of ASR at Seabrook was documented in a baseline walkdown review of station structures. The review identified the visual signs of ASR through the presence of crack patterns, ASR powder and gel, and/or discoloration/dark staining. The walkdown objectives were to: identify and assess apparent ASR degradation including estimated expansion; identify the condition of concrete in the vicinity of supports that show ASR distress; and, identify the current or past areas of water intrusion. The walkdown results were entered into the corrective action program (AR1757861) and have established NextEra's current baseline condition assessment of Seabrook structures, in conjunction with six-month crack indexing measured on selected structures to trend the progression of ASR and thereby establish a rate of degradation.

As stated above, NextEra's operability evaluations are based upon an examination of available design margins and a presumed ASR reduction in structural design capacity. The details of this methodology and related assumptions are developed in NextEra's Interim Assessment (FP 100716). The assessment assumed lower bound values for potential reductions in concrete material properties based on industry test data of small scale test specimens. The assessment focused on structural design attributes that are the most sensitive to ASR affects (i.e., out-of-plane shear capacity, lap splice development length, and anchorage depth). Compressive strength of concrete is also affected, but less so in the early stages of ASR. The assessment determined the structures were suitable for continued service pending further evaluation of structural performance based on a proposed full-scale testing program representative of Seabrook concrete structures. .The test programs have been initiated at the Ferguson Structural Engineering Laboratory at the University of Texas, with testing to be completed in 2013 and the results reported in 2014.

Comment [M7]: I did not review the background section

2.0 Confirmatory Action Letter 1-2012-002

Confirmatory Action Letter (CAL) 1-2012-002, dated May 16, 2012, was written to confirm commitments by NextEra with regard to planned actions to evaluate the degradation of Seabrook reinforced concrete structures due to ASR. In response to the CAL, NextEra committed to provide information to the NRC for the staff to assess the adequacy of NextEra's corrective actions to address this significant condition adverse to quality. CAL 1-2012-002 is provided as an Enclosure to this report. Based on the results of this inspection, CAL Items #1, #3, #5, #6, and #10 are closed; CAL Item #2 is updated; and CAL Items #4, #7, #8, #9, and #11 remain open pending NRC review in Inspection Report 2012-010.

3.0 Review of Operability Determinations and the Interim Assessment (CAL Items #1, #3, and #5)

3.1 Inspection Scope

The team reviewed the PODs for the B Electric Tunnel of the Control Building (POD 581434) and buildings identified in NextEra's extent-of-condition review (PODs 1664399 and 1757861). As discussed in Section 1.0 above, these PODs were revised to reflect a change in the approach taken by NextEra to evaluate the structural integrity of the station reinforced concrete buildings. Revision 2 of the PODs provides the current quantitative and qualitative analyses of the ASR-induced changes in concrete properties, as further detailed in the licensee's Interim Assessment. The team reviewed the supporting documentation for each significant structural design attribute and conducted multiple interviews and discussions with the responsible NextEra engineering staff and consultants. The team used 10 CFR Part 50, Appendix A, and 10 CFR Part 50, Appendix B, Criterion XVI, "Corrective Action," and Criterion XI, "Test Control," as the regulatory basis to assess the adequacy of NextEra's actions to address ASR affects on safety-related Category 1 and in scope Maintenance Rule reinforced concrete structures. The team also used the established code relationships from ACI 318-1971 to independently assess the engineering calculations and analyses performed by NextEra. Lastly, the team used NRC Inspection Manual, "Part 9900 – Operability Determination and Functionality Assessments for Resolution of Degraded or Nonconforming Conditions Adverse to Quality or Safety," to evaluate the licensee's approach to assessing this significant condition adverse to quality.

The extent-of-condition PODs (Revisions 0 and 1) addressed five buildings (AR 1664399) using the mechanical testing data gathered from concrete core samples. These five structures include the containment enclosure building (CEB), the access tunnel to the radiologically controlled areas (RCAW), the emergency feedwater (EFW) pump house, the residual heat removal (RHR) equipment vault (EV), and the diesel generator building (DGB). During implementation of ASR Structures Walkdown (FP 100705), NextEra identified additional ASR affected concrete in both Category 1 and Maintenance Rule structures including: the condensate storage tank enclosure, the control building air east intake, the service water cooling tower, the A electrical tunnel, the fuel storage building, the east pipe chase, the west pipe chase, the pre-action valve room, the primary auxiliary building, the service water pump house, the mechanical penetration area (which includes portions of the outer containment wall), and the waste processing building (AR1757861).

The team also conducted a detailed review of Foreign Print (FP) 100716, "Seabrook Station: Impact of Alkali-Silica Reaction on Concrete Structures and Attachments," Revision 1, which is the initial evaluation of concrete structures at Seabrook Station and provides the basis for continued operability of affected structures for an interim period. As documented in FP 100716, this interim evaluation will be followed by a second evaluation that "will assess the long-term adequacy of the concrete structures considering the results of the full-scale structural testing program, other in-progress test programs, and results from periodic monitoring of the structures."

3.2 Findings and Observations

The team identified no findings in this area and CAL Items #1, #3 and #5 are closed. Based on a detailed review of the PODs, referenced white papers and associated engineering analyses, including an independent verification of a number of supporting calculations, the team determined NextEra's interim operability bases were appropriate. Given the current extent of ASR, there is reasonable expectation that the affected reinforced concrete structures at Seabrook Station will remain capable of performing their intended functions for an interim period, while NextEra continues to monitor the condition and complete detailed testing and further engineering analyses. Noteworthy observations pertaining to the team's review of the PODs and Interim Assessment follow:

3.2.1 Operable, but Degraded/Nonconforming

Based upon a detailed review of the quantitative and qualitative analyses documented in the PODs and Interim Assessment, the team determined NextEra had ~~appropriately~~ demonstrated that the ASR impacted structures were operable, but degraded/nonconforming. NextEra demonstrated that the structures maintained structural integrity for design basis loads and load combinations for normal, accident and environmental extreme conditions (including seismic).

Comment [M8]: In background section we call these into question, yet we are using these to assess what the licensee did. Do we or don't we agree with the use of these relationships. This seems be an open challenge for questions. Should be an explanation regarding why we found it acceptable to use or take the question out of the background section

Comment [m9]: Interim? – opens the question of how long. They are operable now this is a slow mechanism & there is an understanding of the rate

Comment [m10]: This implies the staff finds the use of equations acceptable – not consistent with what has been stated

Comment [m11]: Leave it out

Comment [M12]: Add no value and is an unknown

The team indentified no inadequacies in the conclusion that ASR impacted structures were currently operable, but degraded or nonconforming.

The team observed that 24 locations (including containment) had been identified via NextEra's ASR Structures Walkdown as having patterned cracking with a combined crack index (CCI) of greater than 1.0 mm/m. Per the Structures Monitoring Program (ES 1807.031), Attachment 3, revised in July 2012, a CCI of >1.0 mm/m requires a structural evaluation. NextEra's Interim Assessment, Section 2.1.2 documents an engineering judgment that biased the performance of detailed structural evaluations to the 11 locations with a CCI > 1.5 mm/m. Although not explicitly stated in Section 2.1.2, the team learned from discussions with NextEra engineers that the locations with a CCI of between 1.0 and 1.5 mm/m (13 locations) were considered bounded by the 11 areas subjected to a detailed evaluation. The lack of a documented structural evaluation for the 13 locations with a CCI of between 1.0 and 1.5 mm/m was considered a minor performance deficiency. NextEra acknowledged this procedural implementation error and entered the issue into their Corrective Action Program (AR 1804477 and AR 1819080). A structural evaluation was completed for containment and reviewed by the team prior to the completion of the inspection period (see Section 3.2.8). However, the evaluations for the remaining locations are yet to be completed. Based upon team review of the competed structural evaluations, to date, there is a reasonable expectation that structural integrity (and operability) of the locations yet to be evaluated by NextEra will be ~~sufficiently~~ demonstrated. Notwithstanding, the team will examine these evaluations in the next CAL follow-up inspection report.

Near the conclusion of this inspection period, NextEra completed the POD for containment (AR 1804477). Preliminary review by the team identified a few areas for follow-up during the second CAL follow-up inspection. Specifically, the team will pursue NextEra's evaluation of the potential for chemical pre-stressing of rebar (reference Section 3.2.8) and review NextEra's future plans for monitoring the localized areas (three) of presumed ASR (not petrographically verified) on the containment outer wall (reference Section 6.0).

3.2.2 Concrete Material Properties - Compressive Strength and Elasticity Modulus

In Revision 2 of POD 581434 for the B Electrical Tunnel, NextEra concluded that there is no loss of concrete compressive strength due to ASR. This conclusion was based on testing of 15 cores (12 ASR-affected concrete and 3 control locations), which showed an average strength of 5143 pounds-per-square-inch (psi) for the ASR affected cores and 4880 psi for the control cores. NextEra concluded that ASR had increased the stiffness of the electric tunnel walls because the compressive strength in the ASR impacted concrete was higher than in the control core samples. Team review of the supporting concrete core data did not validate NextEra's conclusion.

Comment [M13]: Why does this matter as long as the building performs its function and has a reasonable expectation of meeting its safety function

Concrete compressive strength can vary due to variations in in-place concrete strength. The team determined that 12 cores were obtained from six locations in an ASR suspect wall in the B electrical tunnel. Testing produced compressive strength values ranging from a low of 4220 psi to a high of 6610 psi. The mean strength value of these samples is 5143 psi with a standard deviation of 630 psi. The three cores taken from a control area (presumed ASR free) measured 4630, 5350 and 4660 psi. The mean value of these samples was 4880 psi, with a standard deviation of 580 psi. Team review of the B electrical tunnel data determined that the compressive strength measured in 2011 is about 2 percent lower than the measured cylinder strength values from 1979. These values do not show an increase in strength over 25 years, as would be expected as concrete continues to cure. However, given the inherent variability in concrete material properties and the significant variation in the data from the B electric tunnel, the team could not conclude that there was a significant loss of compressive strength or that the affect of the ASR was to increase the compressive strength. In addition, this conclusion is different than the 22 percent measured compressive strength reduction (compared to the 1979 cylinder test results) that had been previously identified by NextEra from initial core sample results and reported in NRC Inspection Report 05000443/2011007. In contrast to the B electric tunnel results, the measured compressive strength values in the other ASR affected buildings suggest a different trend. In general, the measured core sample compressive strengths in the RCA walkway, EFW pump house, RHR EV and EDG buildings in 2011 were higher than the original compressive strength values in 1979 (as expected). This 2011 core sample data shows an average increase of 56 percent.

Comment [M14]: What is this trend? Didn't see a trend in the information identified in this paragraph

Comment [M15]: Information that seems to provide no actual insight and only begs questions. Should be some kind of conclusion regarding meeting or remaining above design values which is why it is ultimately OK.

For modulus of elasticity, although individual cores showed a modulus that was reduced (compared to design), the average modulus value in the RCA walkway, RHR EV, EFW pump house and DGB was within 20 percent of the design modulus value ($\pm$20 percent is acceptable by ACI 318). For the CEB, the average modulus was just beyond (low) the 20 percent allowable. The team noted that modulus values at individual core locations could be lower than design and that NextEra had conservatively used these lower measured modulus values to assess the implications of ASR on structural performance.

Based on the above, the team determined that the core sampling and material property testing completed, to date by NextEra, has not conclusively established the current impact of ASR on concrete material properties (specifically for compressive strength and modulus of elasticity). However, an adverse trend in concrete material properties is indicated and supported by a literature review and available research data. Notwithstanding, review of the core sample data does indicate that the concrete compressive strength remains considerably above the specified design strength value of 3000 psi (or 4000 psi, where used in construction). The team plans to examine this area further in the second follow-up inspection with respect to adequacy of the Structures Monitoring Program.

Comment [m16]: Stated why? Licensee has stated that the cores will not necessarily provide insight – are you attempting to state that somehow they have to make sure the cores can provide data that is not possible?

Comment [M17]: Unnecessary; Literature search indicates a trend, how is this applicable and do we regulate based upon literature searches?

3.2.3 Flexural Capacity and Dynamic Response

NextEra completed a study of the Containment Enclosure Building (CEB) (FP 100714 and FP 100715) which evaluated the effects of varying elastic modulus. Modulus values used in the study were based on field investigation of CEB concrete that correlated a visual rating of ASR with core test results (FP100696 and FP 100700). The CEB study included a parametric analysis that: evaluated the building in a static, three dimensional finite element analysis (FEA) to determine the response (forces and moments) to operating basis earthquake and safe shutdown earthquake seismic loads before and after ASR damage; calculated the section capacities; calculated demand-to-capacity ratios (DCRs); and, compared the DCRs of ASR degraded walls to undamaged walls. The analyses showed that the seismic acceleration profiles, the in-structure response spectrum, and the distribution of forces and moments were not significantly impacted by ASR affected properties. Similarly, the effect of the reduced

Enclosure

modulus on the response of below-grade, ASR-impacted structures was evaluated. For below grade structures, NextEra determined that the structural response remained in the rigid range with no appreciable amplification of the ground response spectra. The seismic response of the structure along with the attached equipment (cable trays and supports) and anchor loads remained unchanged, with no affect on operability due to ASR. The team noted that these studies validated previous analyses that the reduced modulus of elasticity had minimal impact on the seismic response of walls and attached equipment. The team concluded that NextEra's assessment of this ASR affected design attribute was appropriate for the interim operability determination.

Comment [m18]: Modulus verified? Equation based determination????

3.2.4 Shear Capacity

NextEra analyzed the impact of ASR on the B Electric Tunnel using a FEA to compare the shear capacity versus demand for seismic and hydrodynamic loads. The FEA used the ACI-318 Code, Section 11.4.1 equation for shear stress which relates shear stress to the square root of compressive strength. NextEra assumed a lower bound 25 percent reduction in out-of-plane shear capacity due to the affects of ASR. The team noted that NextEra's design calculation (CD-20, dated 3/28/83) used the average 28-day compressive strength value (5459 psi) to establish the design shear capacity. However, the FEA used the specified design concrete strength of 3000 psi to compare the available design capacity to design load. The use of the 3000 psi vice 5458 psi value in the FEA approximates the assumed 25 percent lower bound value ASR affect on out-of-plane shear capacity. The licensee identified additional conservatism in their analysis based upon the B electrical tunnel average measured core sample compressive strength value of 5140 psi. NextEra's FEA concluded that adequate margin was available. The team acknowledges that: 1) some additional margin may be credited due to the compressive strength of core samples exceeding the design minimum value of 3000 psi; and 2) the assumed 25 percent reduction in shear capacity is conservative because of the uncertainty with respect to the actual impact of ASR on concrete tensile strength during the early stages of ASR. The team viewed the use of a FEA to assess lower bound ASR affects as appropriate and insightful, but not conclusive, pending further testing and engineering analysis planned by NextEra.

Comment [M19]: Equations we question?

Comment [M20]: Paragraph is confusing and unclear. What is the message? 25% where did that come from?

3.2.5 Anchorage

NextEra evaluated the impact of ASR affected concrete on the performance of anchors, including cast in place anchors, drilled in anchors and reinforcing steel anchorage. The potential impact of micro-cracking caused by ASR can impact anchorage capacity by affecting the distribution of shear stresses. Petrographic analysis of Seabrook concrete cores showed that concrete quality was good with relatively small cracks indicating minimal impacts on stress distribution. NextEra's evaluation was supported by anchor performance testing conducted on ASR degraded specimens (FP100718). The tests showed satisfactory performance of the anchors in concrete test specimens, although dissimilar in composition and compressive strength compared to Seabrook structures. NextEra's evaluations illustrated that the assumed reductions in capacity due to ASR degradation were offset by established design margins (FP100716). The team concluded that NextEra's interim anchorage operability assessment was satisfactory. However, based upon the limitations of the testing performed, to date, NextEra plans to conduct further testing. Planned testing involves anchors installed in ASR affected test

Comment [m21]: Value?

specimens that more accurately reflect the reinforced concrete structures and anchor configurations at Seabrook.

3.2.6 Review of Finite Element Analysis Modeling

As discussed in Sections 3.2.3 and 3.2.4, NextEra used finite element analysis to evaluate the affects of ASR on certain structures and design attributes. The team noted that the input data for the compressive strength and modulus of elasticity for the CEB model were determined based on a visual examination of CEB walls and only a few directly obtained core sample material properties. The observed crack patterns/dimensions were correlated to a damage rating index (DRI) and associated concrete material properties from test data obtained from core samples taken from several different structures. The input data for poisson ratio was derived exclusively from industry data. NextEra acknowledged the limitations of this input data, but in FP 100696 deemed the approach justified because the analysis was a parametric study of the CEB seismic response, comparing design values to ASR affected values. The team concluded this FEA approach was useful and insightful for providing reasonable expectation of operability for the interim period, but not conclusive with respect to the current or projected state of ASR impact on the CEB. As discussed in Section 9.0, the parametric analysis results will have to be reevaluated following testing and prior to finalizing the PODs.

3.2.7 Lap Splice Strength

Section 6.3 of the Interim Assessment addressed reinforcement lap splice degradation as another design attributed impacted by ASR. In accordance with the licensee's lower bound value of a 40 percent reduction in lap splice strength, NextEra's review of design calculations identified several structures with insufficient margin to accommodate this assumed ASR affect. NextEra was able to recover margin by adjusting the ACI Code 318 prescribed design load factors for predicted dead load and/or hydrostatic loads. The team examined this method for margin recovery and found it satisfactory for the interim operability assessment, but concluded it would not be acceptable for a final operability determination under the current licensing basis.

3.2.8 Concrete Confinement and Rebar Pre-Stressing

Team review of FP 100716, Sections 2.1.2 and 4.1.3, identified that the interim engineering evaluation stated, "since ASR has a negligible impact on structural demand, the impact of ASR on structures and structural attachments can be assessed solely on the basis of changes in capacities." The team observes that restraint to ASR expansion, from concrete confinement by reinforcement and/or other external constraints, causes chemical pre-stress in the structural members. The consequence is increased compressive stresses in concrete and increased tensile stresses in the rebar cage, as long as the restraint is sustained. The team observed that this ASR-induced pre-stress has been addressed only qualitatively in the Interim Assessment and containment structural evaluation (AR 1804477). The team finds this acceptable for interim operability determinations. However, the team's preliminary engineering judgment is that a quantitative evaluation is more appropriate for a final operability assessment of this condition. Further, it should be recognized that the ASR-induced pre-stress varies with time, depending on the degree of restraint and may not be sustained through the service life of the affected structure.

The team concludes that chemical pre-stress, if sustained, may show some beneficial effect in terms of stiffness and gross ultimate structural strength, but it may also result in an increase in structural demand on the concrete and reinforcement. As stated above, the team's judgment is that this structural demand should be quantified (if practicable) and accounted for in the design calculations as a known load. Quantifying, or otherwise approximating the chemical pre-stress, is similar to accounting for (and monitoring for losses) the pre-stress load in pre-stressed concrete design. This issue will be reviewed by the team in the second follow-up inspection.

3.2.9 Condition of Rebar

The team examined information gathered and assessed by NextEra with regards to the condition of rebar and any potential erosion or corrosion due to ASR and water in leakage through below grade reinforced concrete structures. The team observed that NextEra had purposefully removed an area of surface concrete in the B Electrical Tunnel (chronically wet) to examine the condition of the rebar. The engineering staff identified no degradation of the rebar (no oxidation or signs of distress). The team also learned that in the course of removing core samples, in two instances the drill nicked rebar. Examination of the rebar sections removed determined the steel to be in excellent condition (unaffected by ASR or moisture). Preliminarily, the condition of rebar in ASR degraded concrete should be unaffected until the cracking becomes deleterious and exposes the rebar to oxidation mechanisms. Otherwise, the alkaline condition within the concrete should prevent any erosion or corrosion mechanisms. The NRC continues to evaluate the need for any additional rebar intrusive monitoring or testing, and will evaluate this issue in the second CAL follow-up inspection.

4.0 Review of ASR Root Cause Evaluation (CAL Item #2)

4.1 Inspection Scope

The team reviewed NextEra's response to this CAL Item, "Submit the root cause for the organizational causes associated with the occurrence of ASR at Seabrook Station and related corrective actions by May 25, 2012." The licensee submitted their root cause evaluation (RCE) via letter dated May 24, 2012. The purpose of the team's review was to assess the adequacy of the licensee's evaluation of the root cause for the ASR issue at Seabrook and the significant contributing causes. The team also examined the methodology and thoroughness of the licensee's evaluation and associated corrective actions as outlined in 10 CFR Part 50, Appendix B, Criterion XVI, "Corrective Action."

4.2 Findings and Observations

This CAL Item will remain open pending NRC review of NextEra's final RCE. NextEra identified two root causes: 1) ASR developed because the concrete mix design unknowingly utilized an aggregate that was susceptible; and, 2) the monitoring program for plant systems and structures does not contain a process for periodic reassessment of failure modes. A contributing cause identified by NexEra was the failure to prioritize groundwater elimination or mitigation resulting in more concrete areas exposed to moisture. The team made some observations regarding the clarity and completeness of NextEra's root cause evaluation.

The team acknowledges that the first licensee identified root cause involved the use of susceptible aggregate in the concrete mix design that was undetected by the testing specified by ASTM construction standards, at the time (late 1970's). The ASTM standard was subsequently revised to ensure slow reactive aggregates would be properly identified prior to use in construction. The team concluded that this causal factor was beyond the licensee's control.

The team concluded that the second root cause was not adequately characterized in NextEra's May 24, 2012 submittal. Specifically, NextEra did not clearly state the personnel and organizational factors that led to inadequacies in the Structures Monitoring Program (SMP). The team discussed the absence of any human performance aspects in the description of this causal factor and NextEra initiated a revision to the RCE to more appropriately develop and characterize this second root cause and the associated corrective actions. NextEra plans to submit the revised RCE for NRC review, consistent with their CAL Item #2 commitment. The team will review this revision in the next CAL follow-up inspection report.

The team also noted that NextEra excluded a significant contributing cause, identified in the RCE, from the evaluation executive summary and May 24, 2012 letter. As stated in the RCE, this contributing cause involved the longstanding "organizational mindset" that groundwater in-leakage was more of an operational nuisance than a structural integrity concern. This station and engineering staff view prevented a more timely and thorough investigation and examination of the affected concrete reinforced structures on site. NextEra acknowledged this observation.

5.0 Review of Mortar Bar Testing (CAL Item #6)

5.1 Inspection Scope

The team reviewed the results of NextEra recently completed short term expansion testing of mortar bar specimens per test procedures SGH-Z001-12 and SGH-Z002-12. The results of the testing were evaluated per ASTM C1260. The licensee initiated the testing to establish and compare the reaction rates of ASR affected concrete to non-ASR affected concrete on site. The tests were performed by a consultant at an offsite facility. The mortar bar specimens were made using the aggregate extracted from core samples taken from ASR affected structures and non-affected concrete from a slab removed from the waste processing building. NextEra noted that the non-affected concrete slab used for aggregate extraction had shown no visible indications of ASR. The details of the testing are documented in SGH Report 120110-RPY-01 (FP 100734). The team reviewed the SGH report and associated test documents to ascertain the adequacy and technical validity of the testing.

5.2 Findings and Observations

No findings were identified and CAL Item #6 is closed. The test results indicated that both affected and non-affected concrete specimens contained ample reactive aggregate to sustain ASR. The team notes that normal test duration is 14 days and that a specimen expansion of >0.1 percent indicates reactive aggregate, per ASTM C1260. Test results identified that the non-ASR affected specimens exceeded the 0.1 percent threshold in five days and the ASR affected specimens exceeded the 0.1 percent threshold in seven days. NextEra allowed the test to extend to 103 days and both specimen types continued to demonstrate active expansion due to ASR. Accordingly, NextEra concluded that there remains the potential for future volumetric expansion due to ASR in concrete structures at Seabrook.

Based upon the Mortar Bar Testing results, NextEra plans to revise their commitment to conduct Prism Testing. Prism Testing is a similar, but longer term test of the susceptibility to ASR of aggregate used in concrete. NextEra had hoped to establish, via the Mortar Bar Test, a difference in the remaining versus available concrete constituents for ASR in the specimens. The results demonstrated ample reactive materials in both specimen types and NextEra concluded the Prism Test will not provide any additional ASR insights. The team concluded that NextEra's basis to revise their commitment to conduct Prism Testing was reasonable.

6.0 Review of Crack Indexing (CAL Item #10)

6.1 Inspection Scope

The team conducted a review of FP 100647, "Crack Index Determination," Revision 1, to understand the methodology for NextEra's monitoring of ASR progression in selected reinforced concrete structures. NextEra's commitment to this methodology is captured in CAL Item #10. The team used 10 CFR Part 50, Appendix B, Criterion V, "Instructions, Procedures, and Drawings," to evaluate the adequacy of this process. The team's review was limited in scope, in that, the adequacy of this process, as the sole means of monitoring ASR progression in Seabrook structures, is still under NRC review. The team will evaluate this aspect as part of the review of CAL Item #9, the Maintenance Rule Structures Monitoring Program, during the second CAL follow-up inspection.

The team observed field measurements taken on June 20, 2012, by the responsible contractor and discussed the general methodology and procedural guidance with the individuals performing the crack indexing measurements and supervising NextEra staff. The team noted that NextEra found ASR patterned cracking in many areas within Seismic Category I and Maintenance Rule structures, but only a limited number of these areas have sufficient ASR degradation to merit continued monitoring and detailed evaluations. The ASR walkdown identified 131 locations with some level of pattern cracking. Of the 131 locations, 26 exceeded an initial screening criteria of a combined crack index greater that 1.0 mm/m. These 26 areas will continue to be monitored at six-month intervals, per FP 100647.

6.2 Findings and Observations

No findings were identified and CAL Item #10 is closed. The team noted that the periodic crack indexing provides the principle method selected by NextEra to monitor the progression of ASR on reinforced concrete structures. The six-month interval measurements are currently planned until a reliable trend of ASR progression can be established, per Structural Engineering Standard Technical Procedure 36180, "Structures Monitoring Program (SMP)," Attachment 3, Revision 2. As stated above, additional NRC review of the SMP will be conducted in the second CAL follow-up inspection.

The team also reviewed the current methods and terminology used by NextEra to characterize the degree of ASR pattern cracking, previously addressed in NRC Inspection Report 05000443/2011007. When ASR was initially identified in the B electrical tunnel in mid-to-late 2010, the licensee referred to the Federal Highway Administration (FHWA) guidance document FHWA-HIF-09-004 for crack/damage characterization. Three major categories were identified: mild, moderate, and severe, with ratings such as mild to moderate and moderate to severe, also used. Per FHWA-HIF-09-004, these categories were used to define the recommended remedial actions to be taken once ASR was identified. At that time, NextEra labeled the observed cracking as "severe." Per the FHWA guidance, this category requires "further investigation for selecting remedial actions." This characterization was repeated in the above referenced inspection report. The team determined that NextEra revised their crack characterization scheme prior to the implementation of the structures extent-of-condition review. The revised crack rating system was based upon "best practices" taken from the Building Research Establishment (BRE) in the United Kingdom (UK). The revised numeric rating system range is from 0 (no cracking detected) to 6 (heavily fractured ASR-related damage). FP 100636, "Petrographic Examination PE Reports," Revision 0, lists the material property results of all core samples taken and petrographically analyzed. FP 100636 also provides the BRE crack rating for each specimen examined. The crack ratings for the specimens examined range from 0 to 4. A summary table with each numeric rating and its definition is documented in the Supplemental Information attachment to this report.

7.0 Review of Alkali-Silica Reaction Structures Walkdown/Baseline Assessment

7.1 Inspection Scope

The team examined NextEra's program documents FP 100642, "ASR Walkdown Scope," Revision 1, and FP 100705, "Seabrook Station: Summary of Alkali Silica Reaction Walkdown Results," Revision 0. The team reviewed the walkdown scope and examination criteria and the associated field data, photographic evidence, and analysis of NextEra's observations, as documented in FP 100705. The walkdown scope included Seismic Category 1 and some in scope Maintenance Rule structures. NextEra's walkdown is being conducted in three phases. Phase 1 involved examination of readily accessible areas of interest; Phase 2 included examination of coated surfaces identified during Phase 1 inspections (coatings had to be removed to expose the concrete surfaces); and Phase 3 examines normally inaccessible structures/areas (e.g. high radiation, manholes, etc.) which have or will be inspected as the opportunity presents itself (e.g. routine maintenance or outage activities).

The walkdowns assess the extent of ASR throughout the plant with the primary objectives of: identifying and assessing any apparent degradation from ASR, including: estimating in-situ expansion (Crack Indexing); assessing whether concrete in the vicinity of supports for safety-related systems or components show any indications of ASR distress; and documenting and characterizing water intrusion or evidence of previous water intrusion, based upon water being a key contributor to concrete deterioration and distress caused by ASR. The visual criteria for documenting potential ASR indications include: typical patterned surface cracks in concrete; crack dimensions (width, length, orientation); evidence of water ingress/out-seepage (past/present); visual evidence of salt deposit and/or ASR gel; and indications of surface deterioration (i.e., pop-outs and/or spalling). Also, any expansion anchors or structural embodiments located within five feet of the area of interest were examined and documented. The licensee considers their ASR walkdown efforts and observations a baseline condition assessment. This baseline will be used for monitoring the progression of ASR for the duration of the current operating license.

The team performed a number of independent walk-through inspections to verify and assess the thoroughness of the licensee's efforts. The team independently evaluated the extent-of-condition of ASR affected structures that are readily accessible. The team used the expertise of a consulting structural engineer to assist in the team's review of the current condition of ASR affected reinforced concrete structures at Seabrook Station.

7.2 Findings and Observations

The team identified no findings. On a sampling basis, the team's independent walkdown observations were consistent with the licensee's observations and assessments. At Seabrook, the presence of ASR has been conclusively established by petrography in certain buildings (where core samples were obtained) and in other buildings by inference, using visual examination criteria. The team confirmed that NextEra's position is that all reinforced concrete structures on site are susceptible to ASR, dependent upon the exposure to moisture. Therefore, NextEra does not intend to remove any of the identified structures from continued ASR monitoring without confirmation via petrography that ASR is nonexistent or no longer active.

The complete list of structures and localized areas of ASR identified, to date, is documented in FP 100705, Revision 1. The team noted that the results of the walkdown inspection by NextEra were appropriately documented with extensive observation narratives and well supported by clear sketches and photographs. As NextEra completes Phase 3 examinations, the licensee plans to capture the additional observations through revisions to FP 100705. The team noted that the majority of localized areas of ASR are: 1) below grade walls subjected to either ground water intrusion, or particularly high spatial humidity; or, 2) exposure to precipitation and high ambient humidity (some exterior above grade structures).

Based upon the team's review of the Phase 1 and 2 ASR walkdown results and via discussions with responsible engineers overseeing the proposed Phase 3 walkdown areas and tentative schedule, the team identified a minor oversight in the Phase 3 walkdown plan. Specifically, the upper elevations of the containment outer wall were not adequately examined for ASR during the Phase I review and not included in the proposed Phase 3 walkdown schedule. The team identified from discussion with the NextEra engineering staff, that the 2010 IWL examination of containment was being credited for part of the Phase 1 ASR walkdown baseline. The team's detailed review of the 2010 IWL inspection results and associated visual examination attributes (reference implementing procedure, ES 1807.031, "Inservice Inspection Procedure Primary Containment Section XI IWL,") identified that the 2010 IWL exam did not include adequate examination criteria (i.e., active or pattern cracking) for identification of ASR. As evidence of this shortcoming in the IWL examination, during the subsequently performed Phase 1 ASR walkdown by consulting engineers, three locations of ASR related pattern cracking were identified on areas of the containment previously examined by the IWL inspectors. NextEra acknowledged this oversight in crediting the IWL examination and initiated action (AR 1819069) per the Corrective Action Plan, to address the need to revise the Phase 3 plan. In addition to review of the revisions to the Phase 3 walkdown areas during the second CAL follow-up inspection, the NRC plans to examine the adequacy of the proposed Phase 3 implementation schedule.

8.0 Follow-up of Open Items

8.1 (Closed) Unresolved Item 05000443/2011003-03, Open Operability Determinations for Safety-Related Structures Affected by Alkali-Silica Reaction

This item was open pending NRC review of NextEra actions to revise operability determinations for the electric tunnel and other structures addressed in the extent of condition review for ASR. The open aspects were as documented in Inspection Reports 2011-03 and 2011-10 related to: 1) effect of the reduced modulus of elasticity on natural frequency of the structures; 2) the effect of the modulus of elasticity on structure flexural response as related to components attached to the structures, such as pipe and cable supports and their anchor bolts; 3) related effects from increased flexure of building on the loading and seismic effects on safety related pipes and cable tray supports; and, 4) effect of reduced parameters on the whole building (global) response of the CEB structure to seismic loads including further information of the effect on stress and strain in the concrete and rebar system. Following the reviews in Inspection 2011-10, the unresolved item remained open pending NRC review of additional information from NextEra on the effects on cable and pipe support anchors (number 3) and the effects on the CEB response (number 4).

The team reviewed the revised operability determinations for the safety related structures listed below and as described in POD 1664399, Revision 2.

- Control Building – "B" Electrical Tunnel,
- Containment Enclosure Building,
- Diesel Generator Building,
- Residual Heat Removal Equipment Vaults, and
- Emergency Feedwater Pump House

As part of the ASR extent of condition review, NextEra provided structural assessments for the RCA tunnel and other ASR impacted buildings (reference Calculation C-S-1-10168).

The open aspects of numbers 3 and 4 were resolved after NextEra provided additional information. Revision 2 of POD 581434 for the B electric tunnel (ET) provided additional quantitative and qualitative analyses with consideration of ASR-induced changes in concrete properties. The revised POD addressed the changes in modulus on building frequency; flexural response and capacity; shear capacity; and support anchors. The revised POD incorporated the results of the Interim Assessment (FP100716) relative to the performance of reinforcing steel anchorage to show that postulated reductions in capacities were offset by conservatisms in ACI 318 Code and the assumed loads. The revised POD incorporated the testing at the Ferguson Structural Engineering Laboratory (FP 100718) of cast-in-place and drilled-in anchors to assess the impact of anchor performance in ASR affected concrete. The test results showed that the anchor capacities remained above the theoretical capacity at crack indices well above the maximum CI observed in Seabrook structures. Finally, the revised POD for the ET also included consideration of a detailed evaluation of the CEB, chosen for detailed analysis because it conservatively bounds other structures in size and exhibits the highest reduction in modulus of elasticity due to ASR. This included how the induced stresses would shift between the concrete and the steel in adjoining sections of the structure. These issues were factored into the analytical model (finite element analysis) to reanalyze the CEB using the measured elastic modulus applied to ASR impacted sections.

Further NRC review of this area is described in Sections 3.0 and 4.0 of this report. The team concluded that the initial failure of NextEra to adequately consider the ASR impacts on structural performance, relative to support anchors and dynamic response, were examples of minor performance deficiencies, and addressed broadly by the NRC in Finding FIN 05000443/2011-10-02. Unresolved Item 05000443/2011003-03 is closed.

8.2 (Closed) URI 2011-010-01 – Adequacy of Calculation Methods for ASR

NextEra initially pursued mechanical testing of concrete cores because that was the traditional method as described in ACI 228.1R for determining properties of existing concrete structures. Upon further review of industry experience and literature for ASR impacted concrete, NextEra determined that the core test data was not indicative of structural performance of the ASR affected structures. Once removed from the structure, the concrete in the cores is no longer subject to the strains imposed by the ASR-related expansion or restraints imposed by the reinforcing cage. Confinement provided by reinforcing steel and other restraints (e.g., deadweight of the structure) limits ASR expansion of the concrete within the structure, which reduces the extent of deleterious cracking and associated reduction of concrete material properties. NextEra has determined that the structural evaluations based on mechanical properties derived from core samples may under predict structural performance (FP100697, Structural Assessment of ASR-State of the Art). Since the reduction of mechanical properties derived from testing of cores is not necessarily representative of the structural performance, NextEra changed its approach. NextEra no longer relies on further core sampling to characterize the current and future condition of ASR affected structures. Instead, the licensee will monitor structures via Crack Indexing and pursue large scale testing of concrete components more representative of the Seabrook conditions. The testing will be conducted at the Ferguson Structural Engineering Laboratory (FSEL) at the University of Texas Austin (UT-A).

Given the interplay between expansive ASR degradation and structural restraint, NextEra provided an Interim Assessment of the Seabrook structures impacted by ASR which relies on structural proof testing rather than testing of concrete cores removed from the structure. The Interim Assessment was based on available industry data on small scale test specimens having ASR degradation worse than that observed at Seabrook.

NextEra responded to CAL Item #8 by letter dated June 21, 2012, and provided a broad overview of the testing planned at FSEL, which will include a shear test program, a lap splice test program and an anchor test program. The test program will include control specimens that will provide a baseline by which to judge the reductions in capacity due to ASR and to quantify the margins available as calculated using ACI-318. NextEra plans to use the test program to reconcile the ASR condition with the licensing design basis, to inform the structures monitoring program, and to evaluate potential mitigation strategies. NextEra's actions, approach and methods used to resolve the ASR issue, including the test program described in CAL Item #8, is currently under review by the NRC regional and headquarters staffs. Unresolved Item 05000443/2011-010-01 is closed.

9.0 Conclusions and Follow-Up Issues

The team determined, based upon the review of the PODs and supporting engineering analyses documented in the Interim Assessment, that the PODs will not be finalized until: 1) the degree of ASR degradation on station reinforced concrete structures is established within the design and licensing basis; 2) definitive margins are established to the design basis limits; and 3) the progression of ASR is appropriately monitored and demonstrated to ensure adequate margins are maintained for the duration of the current operating license.

The team plans to conduct a second CAL follow-up inspection to review the remaining open CAL items and the open issues documented in this report and listed below:

- Review conservatism of the assumed lower bound affects of ASR (Section 3)
- Review of pending structural evaluations and follow-up on containment POD observations (Section 3.2.1)
- Review of core sample compressive strength and SMP (Section 3.2.2)
- Review quantification of pre-stressing affects of ASR expansion (Section 3.2.8)
- Assess the need for any further rebar examinations or testing (Section 3.2.9)
- Review revised RCE submittal (Section 4.2)
- Confirm revised commitment to CAL Item #7 (Section 5.2)
- Review of Crack Indexing for SMP application (Section 6.2)
- Review the revision to the Phase 3 walkdown plans and schedule (Section 7.2)

10.0 Meetings, Including Exit

On November 2, 2012, the team conducted an exit meeting to discuss the preliminary findings and observations with Mr. Kevin Walsh, Site Vice President, and other members of Seabrook Station staff. The inspectors verified that no proprietary information was retained by the inspectors or documented in this report.

SUPPLEMENTAL INFORMATION

KEY POINTS OF CONTACT

Licensee Personnel

B. Brown, Design Engineering Manager
A. Chesno, Performance Improvement Manager
K. Chew, License Renewal Engineer
R. Cliché, License Renewal Project Manager
M. Collins, Design Engineering Manager
J. Connolly, Site Engineering Director
R. Noble, Project Manager
M. O'Keefe, Licensing Manager
T. Vassallo, Principal Design Engineer
K. Walsh, Site Vice President
P. Willoughby, Licensing Engineer

LIST OF ITEMS OPENED, CLOSED, DISCUSSED, AND UPDATED

Opened/Closed/Update

None

Opened

None

Closed

05000443/2011-010-01	URI	Adequacy of Calculation Methods for ASR
05000443/2011-003-03	URI	Open Operability Determinations for Safety-Related Structures Affected by Alkali-Silica Reaction

LIST OF DOCUMENTS REVIEWED

Procedures

Maintenance Rule Scoping Document, Revision 0
EDS 36180, Structures Monitoring Program, Revision 0, 1, 2

Corrective Action Documents (AR)

1651969, 1629504, 574120, 581434, 1636419, 1673102, 1647722, 1664399, 1677340, 1687932, 1692374, 1698739, 1755727, 1757861, 1819080, 1804477, 1819069

Drawings

Licensing and Design Basis Documents and Calculations

Seabrook Station UFSAR, Revision 14
ACI 318-71
Calculation CD-20
Calculation CD-18
Calculation C-S-1-10168

Miscellaneous Documents

FP100348, Statistical Analysis-Concrete Compression Test Data (PTL)
FP 100642, Scope for Alkali-Silica Reaction Walkdowns
FP 100641, Procedure for ASR Walkdowns and Assessment Checklist
FP100661, Compression Testing Concrete Cores (WJE)
FP100696, Material Properties of ASR-Affected Concrete
FP 100700, Field Investigation
FP100705, Structure ASR Walkdown Report (MPR 0326-0058-58)
FP100714, Three Dimensional Dynamic Analysis of Containment Enclosure Building
FP100715, ASR Impact Study on Containment Enclosure Building
FP100716, Interim Assessment: Impact of ASR on Structures (MPR-3727)
FP100717, ACI 318-71 Perspectives
FP100718, Anchor Test Report (MPR-3722)
FP100720, Crack Index and Expansion Measurement
FP100738, Measurements for ASR Crack Indexing on Concrete Structures
FP 100697, MPR 0326-0058-53, White Paper on Structural Implications of ASR: State of the Art, Revision 1
MPR 0326-0058-83, Shear Screening Criteria Used in MPR-3727
FHWA-HIF-09-004, Federal Highway Administration, "Report on the Diagnosis, Prognosis, and Mitigation of Alkali-Silica Reaction in Transportation Structures."

LIST OF ACRONYMS

ACI	American Concrete Institute
ADAMS	Agencywide Documents Access and Management System
AMP	Aging Management Program
AR	Action Request
ASME	American Society of Mechanical Engineers
ASR	Alkali-Silica Reaction
CCI	Combined Crack Index
CFR	Code of Federal Regulations
CW	Circulating Water
DG	Diesel Generator
DRP	Division of Reactor Projects
DRS	Division of Reactor Safety
EDG	Emergency Diesel Generator
EPRI	Electric Power Research Institute
FEA	Finite Element Analysis
FP	Foreign Print
FPL	Florida Power and Light
FSEL	Franklin Structural Engineering Laboratory
IMC	Inspection Manual Chapter
IP	[NRC] Inspection Procedure
MPR	MPR Associates, Inc.
NRC	Nuclear Regulatory Commission
PARS	Publicly Available Records
P&ID	Piping and Instrument Diagram
PM	Preventative Maintenance
PRA	Probabilistic Risk Assessment
QA	Quality Assurance
RCE	Root Cause Evaluation
RHR	Residual Heat Removal
SDP	Significance Determination Process
SG&H	Simpson, Gumpertz & Heger
SMP	Structures Monitoring Program
SRI	Senior Resident Inspector
UFSAR	Updated Final Safety Analysis Report
UT	Ultrasonic Testing
WO	Work Orders

NextEra Crack Rating Chart

Assessment of Severity of ASR in Hardened Concrete by Petrographic Examination

This rating system is based on a modified "best practice" procedure initially developed at tehe Building Research Establishment (BRE) in the United Kingdom, using ASR identification critieria first set out in the British Concrete Association report titled "The Diagnosis of Alkali-Silica Reaction," (1992).

Rating	Description
0	No cracking detected
1	Very slight cracking (no evidence of deleterious ASR)
2	Slight cracking (minor or trace evidence of deleterious ASR)
3	Moderate cracking (moderate evidence of deleterious ASR)
4	Severe cracking (severe evidence of deleterious ASR)
5	Very severe ASR-related cracking
6	Heavily fractured ASR-related damage

Marshall, Michael

From:	Sheikh, Abdul
Sent:	Tuesday, November 27, 2012 10:48 AM
To:	Buford, Angela
Cc:	Erickson, Alice; Marshall, Michael; Thomas, George
Subject:	RE: Action Requested: Crack Mapping Paper
Attachments:	Crack Mapping and DRI 11-21-12 abdul input.docx

Please see the attached file. This is based on a quick review.

In a previous email you stated that, "My understanding of the scope of this paper was not to relate the Seabrook program and criteria within, but to assess whether using crack mapping alone is sufficient to (1) determine the severity of ASR (2) monitor for ASR progression over time.

Assessing the licensee's structures monitoring program (including the adequacy of the tier 1,2, and 3 values and what to be done for each tier) in my mind falls under the umbrella of the inspection CAL item for structures monitoring and staff review of the Structures Monitoring AMP. I believe we will review the adequacy of the acceptance criteria and associated actions during the LR review and CAL inspection."

I think the team should consider enlarging the scope of the paper to include an assessment of the three tier cracking criteria provided by the applicant. Thru a review of this paper, DLR, NRR, and Region should be able to reach a consensus on acceptability of this criteria that can be used for evaluation of both Part 50 and 54 issues. The applicant has to use an interim criteria for cracking extent and width until additional tests are performed to correlate mechanical properties to the cracking index and crack width.

From: Buford, Angela
Sent: Wednesday, November 21, 2012 1:41 PM
To: Marshall, Michael; Thomas, George; Erickson, Alice; Sheikh, Abdul
Cc: Murphy, Martin
Subject: Action Requested: Crack Mapping Paper

All,

Attached is the draft crack mapping position paper. We have been asked to provide this paper to the Region on Wednesday, so there is a quick turnaround to receive any comments from NRR to incorporate.

I have left out the "References" section, as I am still working on the citations. If during the course of your review you would like me to provide you one of the references, please email me.

Please provide your comments to me by Tuesday so that I can incorporate and send to the region. Any feedback would be greatly appreciated.

Angie

From: Angela Buford [mailto:angie.ab@gmail.com]
Sent: Wednesday, November 21, 2012 1:31 PM
To: Buford, Angela
Subject: Crack Mapping Paper

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USNRC

In situ Monitoring of ASR-affected Concrete

A study on crack indexing and damage rating index to assess the severity of ASR and to monitor ASR progression

Angela Buford
11/21/2012

Key Messages:

1. Three or four pronged surface cracking (map cracking) in concrete structures may be indicative of ASR .
2. Presence of ASR in concrete structures can only be confirmed or ruled out by petrographic examination of concrete cores extracted from affected structure.
3. The width and extent of surface cracking (crack mapping) cannot by itself used to determine the degradation and loss of strength in concrete structures.
4. ~~1.~~ Laboratory and in-situ testing must be performed to correlate Surface cracking with loss of mechanical properties because cracking patterns may vary for different structural geometry and/or design, apparent concreting sequence, localized detailing (especially where cracking may be coincident with water leakage) and both environmental and in-service conditions." ~~may not be indicative of the conditions of the concrete through the section, and crack indexing measurements may not consistently indicate the level of ASR severity from one structure to another. For each group of similar (i.e., reinforcement detail, size, environmental conditions) structures, additional examinations are necessary to correlate crack measurements to severity of ASR degradation.~~

~~2. Crack mapping results should be correlated to actual strains (and therefore stresses) in the concrete and rebar in order to accurately represent the effect of ASR-induced stresses in engineering evaluations for structural behavior.~~

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~~3.~~4. Damage Rating Index (DRI) is a more accurate measure of ASR severity than crack indexing, and alleviates many of the pitfalls of the crack indexing method. DRI should be considered as a method to assess damage related to ASR.

Alkali-Silica Reaction (ASR)

ASR is a chemical reaction that occurs in concrete between alkali hydroxides dissolved in the cement pore solution and reactive silica phases in the aggregates. The product of the reaction is an expansive gel around the aggregate particles, which imbibes water from the pore fluid, and, having much larger volume than the reacting components, triggers a progressive damage of the material (Winnicki and Pietruszczak 2008). The pressures imparted by the gel onto the concrete can exceed the tensile strength of the aggregates and the cement paste and cause microcracking and macrocracking in the aggregate and surrounding paste. With the presence of moisture, the gel expands and can cause destructive cracking and deleterious expansion of the concrete. The extent of the concrete deterioration depends on aggregate reactivity, high levels of alkalinity, availability of moisture, temperature, and structural restraint (Williams, Choudhuri, and Perez 2009). Concrete expansion and cracking can lead to serious operational and serviceability problems in concrete structures (Rivard et al. 2002).

Surface Cracking and Expansion

The Federal Highway Administration (FHWA) Report on the Diagnosis, Prognosis, and Mitigation of Alkali-Silica Reaction in Transportation Structures states that "in concrete members undergoing internal expansion due to ASR and subject to wetting and drying cycles (cyclic exposure to sun, rain, wind, etc.), the concrete often shows surface cracking because of induced tension cracking in the 'less expansive' surface layer (because of variable humidity conditions and leaching of alkalis) under the expansive thrust of the inner concrete core (with more constant humidity and pH conditions)." Cracks first form as three or four-pronged star patterns resulting from expansion of the gel reacting with the aggregate. If the concrete is not subject to directional stress, the crack pattern developed forms irregular polygons, commonly referred to as map cracking (Swamy 1992). This cracking is usually enough to relieve the pressure and accommodate the resulting volume increase (Figg 1987; reported by Famy et. Al. 2007).

Map cracking is one of the most commonly reported visual signs associated with ASR. The pattern and severity of cracking vary depending on the type and quantity of reactive aggregate used, the alkali content of the concrete, exposure conditions, distribution of stresses, and degree of confinement in the concrete (Smaoui et al. 2004). ASR can also be characterized by longitudinal cracking, surface discoloration, aggregate pop-out, and surface deposits (gel or efflorescence) (Williams, Choudhuri, and Perez 2009). Although pattern cracking is a characteristic visual indication that ASR may be present in the concrete, ASR can exist in concrete without indications of pattern cracking. Newman (2003) noted that "while superficial cracking patterns can often be reminiscent of ASR, it is important to be aware that reliable diagnosis can never be adequately based on the appearance of surface cracking alone." This consideration is also emphasized by Barnes (2001), whose research cites examples where cracking was thought to be and diagnosed as ASR, and also examples in which ASR gel and associated cracked aggregate particles were found in concrete that was uncracked. In addition, in ASR-affected structures with reinforcement close to the surface or in heavily reinforced structures, surface cracking may be suppressed while internal damage exists throughout the section. The presence and extent of surface cracking is not a conclusive indication that ASR is present or measure of concrete degradation due to ASR.

Crack Mapping/Indexing

In order to determine the effect of ASR on the performance of a concrete structure, it is important that there be an understanding of current concrete condition (ASR damage reached to-date) and the rate of expansion. Crack indexing is a method that is proposed to measure crack widths and expansion of cracks over time. For this visual examination individual crack widths are measured over a defined grid and the total amount of cracking is quantified. The examination is repeated over regular intervals and the results are compared over time, with a goal of establishing a rate of ASR progression. The Institute of Structural Engineers (ISE 1992) proposed a method for crack mapping that consists of measuring the ASR crack widths along five parallel lines that are each 1 m long. Lines are traced directly onto the concrete structure. The total width of intersecting cracks along each line is summed and divided by the length of the line to determine the severity of ASR cracking, and then over time to determine the rate of expansion. Another method, suggested by Laboratoire Central des Ponts et Chaussees (LCPC 1997) consists of measuring the widths of all cracks intersecting two perpendicular 1m lines originating from the same point and their two diagonals 1.4 m long. The total crack index is determined as a value in millimeters per meter and compared to criteria that correspond to action levels.

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It is stated throughout ASR research that crack mapping is somewhat limited in its applicability. Saint-Pierre et al. (2007) note that compared to other non-destructive methods developed for assessing the damage induced by ASR, the semi-quantitative surface methods like crack mapping appear to be less effective. It is generally agreed that while results of crack indexing can potentially give some indication of how ASR is progressing over time, establishing an absolute trend that directly correlates expansion levels to ASR progression may not be a reliable practice. ASR research also indicates that using crack measurement alone to characterize the current state of ASR degradation would not be advised, since the practice relies on the assumption that the surface cracking on the face of a structure is wholly congruent to ASR severity. In the 2010 Addendum to its report titled "Structural Effects of Alkali-Silica Reaction - Technical guidance on the Appraisal of Existing Structures," ISE stated that the crack summation procedures for estimating expansion to date work well in directions where there is little restraint from structural stress, reinforcement, or prestress. This suggests that in structures with higher restraint, this would not be the case. In addition, crack mapping is limited in that it can only give data on two-way crack measurements and does not capture cracking in the out-of-plane direction. It is suggested that further activities be carried out for assessing current condition of the concrete and current expansion rate, as well as correlating the expansion to structural integrity.

In addition, crack indexing evaluation criteria should not be universally applied to all structures because surface cracking may not give a reliable indication of the ASR degradation to the structure. Due to variability in size, location, environment, reinforcement detailing, and relative severity of ASR damage, it may be necessary to obtain an understanding of the ASR effects for each individual structure or group of structures with similar physical properties and environments. Indeed, Newman (2003) stated "it is important to relate cracking patterns variously to structural geometry and/or design, apparent concreting sequence, localized detailing (especially where cracking may be coincident with water leakage) and both environmental and in-service conditions."

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The correlation between surface cracking and ASR deterioration may be closer to unity for specimens used in the laboratory that are only allowed to deteriorate due to ASR conditions. However, for concrete in the field, the surface indications sometimes poorly correlate to the extent of ASR degradation within the concrete. Since conditions are so variable from one region to another, and even from one place to another in the same structure, poor correlations are often observed between the severity of surface cracking and the presence of the internal signs of ASR (i.e., reaction products, micro-cracking, and expansion) (Nishibayashi et al. 1989 and Stark 1990 reported by Smaoui et al. 2002). Development of cracking on the surface depends strongly on the amount of reinforcement close to the surface (Smaoui et al. 2002) and also depends on external environmental conditions such as wetting-drying, freezing-thawing, and exposure to saline solutions (Smaoui et al. 2002). Two examples of situations in which external conditions can affect the surface cover concrete such that the surface features are not indicative of the actual ASR degradation of the structure are presented here for consideration. In one case, presence and extent of surface cracking can depend on the pH of the surface which can be affected by leaching and carbonation. As such, wetting-drying cycles can affect the features of ASR, as conditions at the surface layer could be less favorable to the development of ASR, due to the [lower] humidity during the drying periods and the leaching of alkalis during the wetting periods (Poitevin 1983 and Swamy 1995, reported by Smaoui et al. 2004). In other words, if the outer surface layer of concrete is exposed to conditions that would cause the ASR severity or development to be lower, but conditions inside the concrete remain conducive to ASR development (i.e., high relative humidity); surface conditions would not be representative of the ASR within the concrete section. Crack indexing efforts would incorrectly characterize the level of ASR degradation as minor, when within the section the ASR degradation might be more severe.

Another example in which environmental conditions have caused surface conditions to be different than conditions within the concrete is the subject of a study done by Berube et al (2002). In this study, an attempt was made to correlate ASR expansion with type of exposure to moisture. Results showed that in specimens exposed to wetting-drying cycles saw more surface cracking but less actual expansion than specimens that were always exposed to humidity. In this case, the larger amount of surface cracking evident in the specimens exposed to wetting-drying cycles did not show to correlate well to the actual expansion due to ASR, with the ASR expansion being less severe than the cracking would indicate. Conversely (and perhaps more ominously), the specimens that showed less surface cracking saw a greater expansion due to ASR, which shows that visual examination of surface cracking alone may not be adequate.

Smaoui et al. (2004) state that although the intensity of surface cracking on ASR-affected concrete in service can help to assess the severity of ASR, quantitative measurement of this intensity [i.e., crack mapping] [could] lead to values that generally underestimate the true expansion attained, except maybe when the surface concrete layer does not suffer any ASR expansion at all. If the concrete surface layer undergoes ASR expansion that is less than that of the inner concrete, according to Smaoui et al. (2004), "the measurement of surface cracking will tend to give expansion values lower than the overall expansion of the concrete element under study." This research indicates that the degree of correlation between surface cracking and actual ASR expansion or degradation tends to vary with the level of exposure, which means that crack indexing over a number of structures with varying environmental conditions may not conclusively measure the extent or severity of ASR degradation. It should also be noted here that periodic crack indexing measurements also have the potential to be misleading since crack sizes can vary seasonally.

ASR-induced Stresses

The ISE (2010) noted that for some structures exposed to ASR, internal damage occurs through the depth [of the section] but visible cracking is suppressed by heavy reinforcement. In reinforced concrete structures, expansion of ASR cracks generates tensile stresses in the reinforcing steel while also causing compressive stresses in the concrete surrounding the rebar (this phenomenon is often likened to prestress in the concrete and noted to temporarily improve structural behavior). According to Smaoui et al., 2004, the most useful information in the structural evaluation of an ASR-affected concrete member is the state of the stresses in the concrete, but more importantly in the steel reinforcement. The ASR-induced stresses increase the structural demand on the steel and concrete, but this new design load has likely not been accounted for in the original design or in further structural evaluations. According to Multon et al. (2005), "assessment models have to take into consideration the property of stresses to modify ASR-induced expansions and their effect on the mechanical response of ASR-damaged structures..." Crack mapping alone to determine ASR effects on the structure does not allow for the consideration of rebar stresses. Visual examination and measurement of crack growth should be correlated to strain measurements taken of ASR-affected concrete and the reinforcing steel. In similar structures, then, the visual indications of expansion due to ASR can relate to stresses in the concrete and reinforcing steel in order to apply ASR-induced stress as an additional load in structural evaluations. Smaoui et al., 2004 propose that if it is not possible to do a destructive examination (i.e., exposing the rebar or taking deep cores) of the structure in question, "an indirect method is based on the expansion accumulated to date...Assuming that this expansion corresponds to that of the reinforcement steel, the stresses within the reinforcement and the concrete could thus be determined from the modulus of elasticity of the steel and the corresponding sections of the concrete elements under investigation." For determining added stresses in in situ structures, once correlation has been made with respect to size and rebar configuration between the in situ structure and a test specimen, it would be appropriate to use crack mapping as a measure of ASR degradation when introducing the additional ASR-induced stresses on concrete and reinforcing steel in structural evaluations.

Discussion on Applicability of Crack Indexing

This report is not intended to present the position that crack indexing and resulting data should not be part of a structural monitoring program to assess the ongoing effects of ASR in concrete. In fact, crack indexing is recommended by the Federal Highway Administration (FHWA 2010) "to obtain a quantitative rating of the 'surface' deterioration of the structure as a whole" (it should be noted that in the FHWA document, the word "surface" is emphasized with quotation marks, which implies recognition that crack indexing measurements alone provide information limited only to what is occurring at the concrete surface). This report's position is that crack mapping can only be useful once there is an understanding of how the conditions inside the concrete, (i.e., relative humidity, presence and severity of cracking, and added stresses in the concrete, reinforcing detail) correlate to the cracking observed at the surface. The FHWA (2010) document agrees, indicating that to obtain an understanding of the current state of ASR degradation and in order to correlate the surface cracking to the actual effects of ASR-induced expansion on the structure, other investigations of the in-situ structure are necessary. In addition to crack indexing, FHWA recommendations that apply to nuclear structures include taking stress [strain] measurements in reinforcing steel, obtaining temperature and humidity readings, and performing non-destructive testing such as pulse velocity measurements (the recommendation to use pulse velocity measurements is in agreement with the experimental findings of Saint-Pierre et al. 2007). The Institution of Structural Engineers (ISE 2010) suggests that expansion to date and severity of ASR should be evaluated using examination and testing of cores for changes in modulus of elasticity and development of hysteresis (stiffness deterioration). It is also proposed that strain sensors be used as a method of monitoring ASR progression (Harries 2012) in order to monitor and quantify out-of-plane expansion.

In addition to provisions for monitoring (or predicting) progression of ASR, it is recommended that each structure or group of similar structures undergo petrographic analysis to determine the current state of ASR damage, in order to provide an accurate baseline from which to understand the current severity level and monitor ASR progression. A discussion of the Damage Rating Index method for assessing ASR severity is discussed in Appendix A of this report.

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Comment [AHS1]: I do not understand how DRI can be used as a baseline if additional cores are not taken on a periodic basis to determine the rate of degradation. You cannot monitor with one test result.

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Appendix A: Damage Rating Index

The damage rating index (DRI) was developed by Grattan-Bellew and Danay in 1992 (Reported by Smaoui et al. 2004) as a method to determine the extent of internal damage in concrete affected by ASR (Rivard et al. 2002). The DRI is a method for quantifying both qualitative and quantitative observations and determining severity of ASR using petrographic analysis of polished sections of concrete. It is based on the recognition of a series of petrographic features that are commonly associated with ASR (Rivard et al. 2002). The DRI accounts for defects observed in the concrete, such as the presence and distribution of reaction products, existence of internal microcracking, and location of microcracking (within the aggregate vs. through the cement paste) by assigning a weighting factor to each and quantifying overall damage. When the factors are normalized to an area of 100 cm^2, the resulting number is the DRI. Rivard et. Al. (2000) noted that the abundance of individual defects and the overall DRI values increased with regularity with increased ASR expansion. It should be noted that the specimens used by Rivard et. Al. were comprised of reactive aggregates with different reaction mechanisms, but ASR expansion indeed correlated with DRI measures of ASR severity. Rivard et al. noted a possible limitation of the DRI method: that weighting factors assigned to each defect may not universally apply to all types of reactive aggregates (reported by Smaoui et al. 2004) and that weighting factor adjustments may be appropriate depending on the aggregate being examined. Other than that, research supports that this method is a more effective way to assess severity of ASR than crack indexing.

Smaoui et al. (2004) performed damage rating indexing on specimens from five concrete mixes using different reactive aggregates to determine if there was a reliable and accurate correlation between ASR damage determined by DRI and ASR expansion measurements. They noted that there exists a potential error in estimating expansion of ASR concrete in the field and establishing a DRI-expansion relationship with laboratory testing. In some of the lab specimens, relatively similar DRI values were obtained for very different expansion levels for cylinders which had been cast with the same concrete mix (and progressed ASR over time). The tests indicated that expansion levels (of in situ structures compared to laboratory specimens) may not be the best indication of ASR degradation. For example, the presence of air bubbles in the proximity of reactive aggregates [in field concrete] usually has the effect of reducing the expansion due to ASR (Landry 1994, Reported by Smaoui et al. 2004). In other words, air bubbles that exist in the in situ concrete structure could result in a smaller expansion of the structure as concluded under crack mapping activities while more severe ASR damage could be present in the structure because ASR features have "room" to grow inside the existing structure before extensive cracking is notable on the concrete surface. Smaoui et al. (2004) concluded that "for evaluating the expansion attained to date by ASR-affected concrete, it may be necessary to reconsider the relevant defects and their respective weighting factors and take into account a certain number of factors such as the presence or absence of entrained air and preexisting cracks and alteration rims" to assess the severity of ASR in structures. It is notable that the research done by Rivard et al. (2000) showed that DRI correlated well with actual ASR expansion, while subsequent work done by Smaoui et al. (2004) proposed that in some cases lack of gross expansion did not correlate to low ASR degradation, and that air bubbles prevented macro-level expansion even though ASR effects were severe. Crack indexing would not have identified this severe ASR progression since that method only measures expansion of cracks.

The DRI has been shown to be a relatively inexpensive and effective method for assessing the damage level of ASR-affected structures.

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Comment [AHS2]: Please verify this statement. Also NRC is not usually concerned with cost.

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References

(coming soon)

Buford, Angela

From: Buford, Angela
Sent: Wednesday, November 28, 2012 1:13 PM
To: Galloway, Melanie
Subject: RE: Status: Discussion on Inspection Report
Attachments: 11-28-12 revision ABIR 2012-009 11-26-12.docx

As far as Michael's outstanding comments I had identified in yesterday afternoon's call with the region as possibly not having been adequately addressed, I thought everything had been changed satisfactorily except for two areas: "Interim" language, and the explanation for closing the OD items without the containment OD completed.

I have 3 comments: see the attached document, which was sent by Bill Cook this morning at 10:30am. Unfortunately he did not use track changes so it has not been readily identifiable which areas changed without going back through Michael's original comments and the earlier revised report.

1) Cover report (regarding "interim operability" explanation)
2) pg 4 (regarding Operability Determination item being open or closed)
3) pg 11 (regarding closure of crack mapping item)

Call me if you want to discuss.

Angie

From: Galloway, Melanie
Sent: Wednesday, November 28, 2012 12:50 PM
To: Buford, Angela
Subject: RE: Status: Discussion on Inspection Report

I have not gotten the new report.

From: Buford, Angela
Sent: Wednesday, November 28, 2012 12:24 PM
To: Galloway, Melanie
Subject: RE: Status: Discussion on Inspection Report

I have received an updated version of the report (did you? If not I can forward it)

1. If you would like to share any further thoughts you had on the way they dispositioned Michael's comments, please do
2. Having gone through the updated (as of 10:30am this morning) report, I have some general follow-up comments.

If you would like to touch base, feel free to give me a call.

Angie

From: Galloway, Melanie
Sent: Wednesday, November 28, 2012 7:16 AM
To: Buford, Angela
Subject: RE: Status: Discussion on Inspection Report

THanks. I'll call you about 8 am in your office.

From: Buford, Angela
Sent: Wednesday, November 28, 2012 7:08 AM
To: Galloway, Melanie
Subject: Status: Discussion on Inspection Report

Melanie, I'm still waiting to hear from Marty to meet with him this morning regarding the disposition of his comments, and have yet to, so I'm not sure whether or not you'd like to have our discussion prior to that.

I plan to be in the office until about 9:30am and then will be working at home from 11-4:30 and can be reached either way through the NRC operator.

Angie

Angela R. Buford | Structural Engineer
Division of License Renewal
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852
t: 301.415.3166
angela.buford@nrc.gov

Buford, Angela

From: Raymond, William NRO
Sent: Thursday, November 29, 2012 1:30 PM
To: Buford, Angela; Cook, William
Subject: RE: IR 2012-009 11-28-12 DLR Comments.docx

yes

From: Buford, Angela NRR
Sent: Thursday, November 29, 2012 1:16 PM
To: Cook, William; Raymond, William
Subject: RE: IR 2012-009 11-28-12 DLR Comments.docx

Is 2pm okay? I'll set up a bridge. Rich is out pretty much the rest of the afternoon

---

From: Cook, William R1
Sent: Thursday, November 29, 2012 1:14 PM
To: Raymond, William; Buford, Angela; Conte, Richard
Subject: RE: IR 2012-009 11-28-12 DLR Comments.docx

Me too.

From: Raymond, William
Sent: Thursday, November 29, 2012 1:06 PM
To: Buford, Angela; Conte, Richard; Cook, William
Subject: RE: IR 2012-009 11-28-12 DLR Comments.docx

Hey Messenger,
I can be available whenever you set up with the rest....
Bill

From: Buford, Angela
Sent: Thursday, November 29, 2012 11:52 AM
To: Conte, Richard; Cook, William; Raymond, William
Subject: IR 2012-009 11-28-12 DLR Comments.docx

These are Melanie's comments that she has shared with Chris Miller. There are three "issues" she has identified, and all of the comments bin into one of the issues. I characterized all of the comments and added them to the report. They are:

1. Operability (use of the term Interim operability and justification for why the NRC accepted things)
2. License Renewal Alignment (she has some concerns with the way crack indexing was closed out, she thinks it should either remain open or be worded differently)
3. Clarity (she had thoughts on how the Report could be organized more clearly for a member of the public or someone unfamiliar with the history to read)

This is a complete listing of her comments, and I (know the answers to some and) can help with sorting these out. There are also some minor track changes revisions.

Rich I know you're busy most of the afternoon, but Bill and Bill, if you'd like we should have a call once you've read the comments.

Thanks,

Angie [the messenger]

Marshall, Michael

From:	Thomas, George
Sent:	Thursday, November 29, 2012 10:21 AM
To:	Buford, Angela
Cc:	Murphy, Martin; Marshall, Michael; Erickson, Alice; Sheikh, Abdul
Subject:	RE: Action Requested: Crack Mapping Paper
Attachments:	Crack Mapping and DRI 11-21-12 gt.docx

Angie,
Attached are some brief comments on the paper for your consideration.
Thanks.
George

From: Buford, Angela
Sent: Wednesday, November 21, 2012 1:41 PM
To: Marshall, Michael; Thomas, George; Erickson, Alice; Sheikh, Abdul
Cc: Murphy, Martin
Subject: Action Requested: Crack Mapping Paper

All,

Attached is the draft crack mapping position paper. We have been asked to provide this paper to the Region on Wednesday, so there is a quick turnaround to receive any comments from NRR to incorporate.

I have left out the "References" section, as I am still working on the citations. If during the course of your review you would like me to provide you one of the references, please email me.

Please provide your comments to me by Tuesday so that I can incorporate and send to the region. Any feedback would be greatly appreciated.

Angie

From: Angela Buford [mailto:angie.ab@gmail.com]
Sent: Wednesday, November 21, 2012 1:31 PM
To: Buford, Angela
Subject: Crack Mapping Paper

B70

USNRC

In situ Monitoring of ASR-affected Concrete

A study on crack indexing and damage rating index to assess the severity of ASR and to monitor ASR progression

Angela Buford
11/21/2012

Key Messages:

1. Surface cracking may not be indicative of the conditions of the concrete through the section, and crack indexing measurements may not consistently indicate the level of ASR severity from one structure to another. For each group of similar (i.e., reinforcement detail, size, environmental conditions) structures, additional examinations are necessary to correlate crack measurements to severity of ASR degradation.

2. Crack mapping results should be correlated to actual strains (and therefore stresses) in the concrete and rebàr in order to accurately represent the effect of ASR-induced stresses in engineering evaluations for structural behavior.

3. Damage Rating Index (DRI) is a more accurate measure of ASR severity than crack indexing, and alleviates many of the pitfalls of the crack indexing method. DRI should be considered as a method to assess damage related to ASR.

Alkali-Silica Reaction (ASR)

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Crack Mapping/Indexing

Comment [g1]: The FHWA report has aanother scheme of crack indexing described in Section 4.2 and App B, which is what the licensee has adapted. Maybe that scheme should also be briefly described in this section.

In order to determine the effect of ASR on the performance of a concrete structure, it is important that there be an understanding of current concrete condition (ASR damage reached to-date) and the rate of expansion. Crack indexing is a method that is proposed to measure crack widths and expansion of cracks over time. For this visual examination individual crack widths are measured over a defined grid and the total amount of cracking is quantified. The examination is repeated over regular intervals and the results are compared over time, with a goal of establishing a rate of ASR progression. The Institute of Structural Engineers (ISE 1992) proposed a method for crack mapping that consists of measuring the ASR crack widths along five parallel lines that are each 1 m long. Lines are traced directly onto the concrete structure. The total width of intersecting cracks along each line is summed and divided by the length of the line to determine the severity of ASR cracking, and then over time to determine the rate of expansion. Another method, suggested by Laboratoire Central des Ponts et Chaussees (LCPC 1997) consists of measuring the widths of all cracks intersecting two perpendicular 1m lines originating from the same point and their two diagonals 1.4 m long. The total crack index is determined as a value in millimeters per meter and compared to criteria that correspond to action levels.

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In addition, crack indexing evaluation criteria should not be universally applied to all structures because surface cracking may not give a reliable indication of the ASR degradation to the structure. Due to variability in size, location, environment, reinforcement detailing, and relative severity of ASR damage, it may be necessary to obtain an understanding of the ASR effects for each individual structure or group of structures with similar physical properties and environments. Indeed, Newman (2003) stated "it is important to relate cracking patterns variously to structural geometry and/or design, apparent concreting sequence, localized detailing (especially where cracking may be coincident with water leakage) and both environmental and in-service conditions."

Surface Cracking vs. Internal ASR Damage

The correlation between surface cracking and ASR deterioration may be closer to unity for specimens used in the laboratory that are only allowed to deteriorate due to ASR conditions. However, for concrete in the field, the surface indications sometimes poorly correlate to the extent of ASR degradation within the concrete. Since conditions are so variable from one region to another, and even from one place to another in the same structure, poor correlations are often observed between the severity of surface cracking and the presence of the internal signs of ASR (i.e., reaction products, micro-cracking, and expansion) (Nishibayashi et al. 1989 and Stark 1990 reported by Smaoui et al. 2002). Development of cracking on the surface depends strongly on the amount of reinforcement close to the surface (Smaoui et al. 2002) and also depends on external environmental conditions such as wetting-drying, freezing-thawing, and exposure to saline solutions (Smaoui et al. 2002). Two examples of situations in which external conditions can affect the surface cover concrete such that the surface features are not indicative of the actual ASR degradation of the structure are presented here for consideration. In one case, presence and extent of surface cracking can depend on the pH of the surface which can be affected by leaching and carbonation. As such, wetting-drying cycles can affect the features of ASR, as conditions at the surface layer could be less favorable to the development of ASR, due to the [lower] humidity during the drying periods and the leaching of alkalis during the wetting periods (Poitevin 1983 and Swamy 1995, reported by Smaoui et al. 2004). In other words, if the outer surface layer of concrete is exposed to conditions that would cause the ASR severity or development to be lower, but conditions inside the concrete remain conducive to ASR development (i.e., high relative humidity); surface conditions would not be representative of the ASR within the concrete section. Crack indexing efforts would incorrectly characterize the level of ASR degradation as minor, when within the section the ASR degradation might be more severe.

Another example in which environmental conditions have caused surface conditions to be different than conditions within the concrete is the subject of a study done by Berube et al (2002). In this study, an attempt was made to correlate ASR expansion with type of exposure to moisture. Results showed that in specimens exposed to wetting-drying cycles saw more surface cracking but less actual expansion than specimens that were always exposed to humidity. In this case, the larger amount of surface cracking evident in the specimens exposed to wetting-drying cycles did not show to correlate well to the actual expansion due to ASR, with the ASR expansion being less severe than the cracking would indicate. Conversely (and perhaps more ominously), the specimens that showed less surface cracking saw a greater expansion due to ASR, which shows that visual examination of surface cracking alone may not be adequate.

Smaoui et al. (2004) state that although the intensity of surface cracking on ASR-affected concrete in service can help to assess the severity of ASR, quantitative measurement of this intensity [i.e., crack mapping] [could] lead to values that generally underestimate the true expansion attained, except maybe when the surface concrete layer does not suffer any ASR expansion at all. If the concrete surface layer undergoes ASR expansion that is less than that of the inner concrete, according to Smaoui et al. (2004), "the measurement of surface cracking will tend to give expansion values lower than the overall expansion of the concrete element under study." This research indicates that the degree of correlation between surface cracking and actual ASR expansion or degradation tends to vary with the level of exposure, which means that crack indexing over a number of structures with varying environmental conditions may not conclusively measure the extent or severity of ASR degradation. It should also be noted here that periodic crack indexing measurements also have the potential to be misleading since crack sizes can vary seasonally.

ASR-induced Stresses

The ISE (2010) noted that for some structures exposed to ASR, internal damage occurs through the depth [of the section] but visible cracking is suppressed by heavy reinforcement. In reinforced concrete structures, expansion of ASR cracks generates tensile stresses in the reinforcing steel while also causing compressive stresses in the concrete surrounding the rebar (this phenomenon is often likened to prestress in the concrete and noted to temporarily improve structural behavior). According to Smaoui et al., 2004, the most useful information in the structural evaluation of an ASR-affected concrete member is the state of the stresses in the concrete, but more importantly in the steel reinforcement. The ASR-induced stresses increase the structural demand on the steel and concrete, but this new design load has likely not been accounted for in the original design or in further structural evaluations. According to Multon et al. (2005), "assessment models have to take into consideration the property of stresses to modify ASR-induced expansions and their effect on the mechanical response of ASR-damaged structures..." Crack mapping alone to determine ASR effects on the structure does not allow for the consideration of rebar stresses. Visual examination and measurement of crack growth should be correlated to strain measurements taken of ASR-affected concrete and the reinforcing steel. In similar structures, then, the visual indications of expansion due to ASR can relate to stresses in the concrete and reinforcing steel in order to apply ASR-induced stress as an additional load in structural evaluations. Smaoui et al., 2004 propose that if it is not possible to do a destructive examination (i.e., exposing the rebar or taking deep cores) of the structure in question, "an indirect method is based on the expansion accumulated to date...Assuming that this expansion corresponds to that of the reinforcement steel, the stresses within the reinforcement and the concrete could thus be determined from the modulus of elasticity of the steel and the corresponding sections of the concrete elements under investigation." For determining added stresses in in situ structures, once correlation has been made with respect to size and rebar configuration between the in situ structure and a test specimen, it would be appropriate to use crack mapping as a measure of ASR degradation when introducing the additional ASR-induced stresses on concrete and reinforcing steel in structural evaluations. Establishing a measured displacement field of selected points on the surface, such as the reference pins used for crack indexing, could also help find the stress field within the structure.

Discussion on Applicability of Crack Indexing

This report is not intended to present the position that crack indexing and resulting data should not be part of a structural monitoring program to assess the ongoing effects of ASR in concrete. In fact, crack indexing is recommended by the Federal Highway Administration (FHWA 2010) "to obtain a quantitative rating of the 'surface' deterioration of the structure as a whole" (it should be noted that in the FHWA document, the word "surface" is emphasized with quotation marks, which implies recognition that crack indexing measurements alone provide information limited only to what is occurring at the concrete surface). This report's position is that crack mapping can only be useful once there is an understanding of how the conditions inside the concrete, (i.e., relative humidity, presence and severity of cracking, and added stresses in the concrete, reinforcing detail) correlate to the cracking observed at the surface. The FHWA (2010) document agrees, indicating that to obtain an understanding of the current state of ASR degradation and in order to correlate the surface cracking to the actual effects of ASR-induced expansion on the structure, other investigations of the in-situ structure are necessary. In addition to crack indexing, FHWA recommendations that apply to nuclear structures include installing demec points to take displacement and relative movement measurements, taking stress [strain] measurements in reinforcing steel, obtaining temperature and humidity readings, and performing non-destructive testing such as pulse velocity measurements (the recommendation to use pulse velocity measurements is in agreement with the experimental findings of Saint-Pierre et al. 2007). The Institution of Structural Engineers (ISE 2010) suggests that expansion to date and severity of ASR should be evaluated using examination and testing of cores for changes in modulus of elasticity and development of hysteresis (stiffness deterioration). It is also proposed that strain sensors be used as a method of monitoring ASR progression (Harries 2012) in order to monitor and quantify out-of-plane expansion.

In addition to provisions for monitoring (or predicting) progression of ASR, it is recommended that each structure or group of similar structures undergo petrographic analysis to determine the current state of ASR damage, in order to provide an accurate baseline from which to understand the current severity level and monitor ASR progression. A discussion of the Damage Rating Index method for assessing ASR severity is discussed in Appendix A of this report.

Appendix A: Damage Rating Index

The damage rating index (DRI) was developed by Grattan-Bellew and Danay in 1992 (Reported by Smaoui et al. 2004) as a method to determine the extent of internal damage in concrete affected by ASR (Rivard et al. 2002). The DRI is a method for quantifying both qualitative and quantitative observations and determining severity of ASR using petrographic analysis of polished sections of concrete. It is based on the recognition of a series of petrographic features that are commonly associated with ASR (Rivard et al. 2002). The DRI accounts for defects observed in the concrete, such as the presence and distribution of reaction products, existence of internal microcracking, and location of microcracking (within the aggregate vs. through the cement paste) by assigning a weighting factor to each and quantifying overall damage. When the factors are normalized to an area of 100 cm^2, the resulting number is the DRI. Rivard et. Al. (2000) noted that the abundance of individual defects and the overall DRI values increased with regularity with increased ASR expansion. It should be noted that the specimens used by Rivard et. Al. were comprised of reactive aggregates with different reaction mechanisms, but ASR expansion indeed correlated with DRI measures of ASR severity. Rivard et al. noted a possible limitation of the DRI method: that weighting factors assigned to each defect may not universally apply to all types of reactive aggregates (reported by Smaoui et al. 2004) and that weighting factor adjustments may be appropriate depending on the aggregate being examined. Other than that, research supports that this method is a more effective way to assess severity of ASR than crack indexing.

Smaoui et al. (2004) performed damage rating indexing on specimens from five concrete mixes using different reactive aggregates to determine if there was a reliable and accurate correlation between ASR damage determined by DRI and ASR expansion measurements. They noted that there exists a potential error in estimating expansion of ASR concrete in the field and establishing a DRI-expansion relationship with laboratory testing. In some of the lab specimens, relatively similar DRI values were obtained for very different expansion levels for cylinders which had been cast with the same concrete mix (and progressed ASR over time). The tests indicated that expansion levels (of in situ structures compared to laboratory specimens) may not be the best indication of ASR degradation. For example, the presence of air bubbles in the proximity of reactive aggregates [in field concrete] usually has the effect of reducing the expansion due to ASR (Landry 1994, Reported by Smaoui et al. 2004). In other words, air bubbles that exist in the in situ concrete structure could result in a smaller expansion of the structure as concluded under crack mapping activities while more severe ASR damage could be present in the structure because ASR features have "room" to grow inside the existing structure before extensive cracking is notable on the concrete surface. Smaoui et al. (2004) concluded that "for evaluating the expansion attained to date by ASR-affected concrete, it may be necessary to reconsider the relevant defects and their respective weighting factors and take into account a certain number of factors such as the presence or absence of entrained air and preexisting cracks and alteration rims" to assess the severity of ASR in structures. It is notable that the research done by Rivard et al. (2000) showed that DRI correlated well with actual ASR expansion, while subsequent work done by Smaoui et al. (2004) proposed that in some cases lack of gross expansion did not correlate to low ASR degradation, and that air bubbles prevented macro-level expansion even though ASR effects were severe. Crack indexing would not have identified this severe ASR progression since that method only measures expansion of cracks.

The DRI has been shown to be a relatively inexpensive and effective method for assessing the damage level of ASR-affected structures.

References

(coming soon)

Buford, Angela

From: Buford, Angela
Sent: Thursday, November 29, 2012 11:52 AM
To: Conte, Richard; Cook, William; Raymond, William
Subject: IR 2012-009 11-28-12 DLR Comments.docx
Attachments: IR 2012-009 11-28-12 DLR Comments.docx

These are Melanie's comments that she has shared with Chris Miller. There are three "issues" she has identified, and all of the comments bin into one of the issues. I characterized all of the comments and added them to the report. They are:

1. Operability (use of the term Interim operability and justification for why the NRC accepted things)
2. License Renewal Alignment (she has some concerns with the way crack indexing was closed out, she thinks it should either remain open or be worded differently)
3. Clarity (she had thoughts on how the Report could be organized more clearly for a member of the public or someone unfamiliar with the history to read)

This is a complete listing of her comments, and I (know the answers to some and) can help with sorting these out. There are also some minor track changes revisions.

Rich I know you're busy most of the afternoon, but Bill and Bill, if you'd like we should have a call once you've read the comments.

Thanks,

Angie [the messenger]

B7

Buford, Angela

From: Buford, Angela
Sent: Thursday, November 29, 2012 6:44 AM
To: Cook, William; Raymond, William; Conte, Richard; Chaudhary, Suresh
Cc: Graves, Herman
Subject: In-situ Monitoring of ASR 11-27-12.docx
Attachments: In-situ Monitoring of ASR 11-27-12.docx

Please find attached the crack mapping paper. Consider this a draft, because I'd like to get your comments and incorporate them before the paper is final.

I realize it's an extremely quick turnaround, but if there are any pressing or substantive comments/concerns, please provide them to me by COB today (Thursday). If not possible today, then tomorrow at the latest.

Thanks a lot!

Angie

UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION I
2100 RENAISSANCE BOULEVARD, SUITE 100
KING OF PRUSSIA, PENNSYLVANIA 19406-2713

Mr. Kevin Walsh
Site Vice President
Seabrook Nuclear Power Plant
NextEra Energy Seabrook, LLC
c/o Mr. Michael O'Keefe
P.O. Box 300
Seabrook, NH 03874

SUBJECT: SEABROOK STATION, UNIT NO. 1 - CONFIRMATORY ACTION LETTER FOLLOW-UP INSPECTION - NRC INSPECTION REPORT 05000443/2012009

Dear Mr. Walsh:

On November 2, 2012, the U. S. Nuclear Regulatory Commission (NRC) completed a team inspection at Seabrook Station, Unit No. 1. The enclosed inspection report documents the inspection results, which were discussed on November 2, 2012, with you and other members of your staff.

The team inspection examined activities conducted under your license as they relate to safety and compliance with the Commission's rules and regulations and with the conditions of your license. Specifically, the team reviewed selected procedures and records, observed activities, and interviewed station personnel regarding the adequacy of NextEra's actions to address the impact of Alkali-Silica Reaction (ASR) on reinforced concrete structures. The team reviewed selected Confirmatory Action Letter (CAL) 1-2012-002 commitments for adequacy and closure.

Based upon the inspection team on site and in-office reviews, five CAL items were reviewed and closed, as documented in the enclosed report. The remaining six CAL items will be reviewed during our second planned follow-up inspection scheduled for completion in early 2013.

The inspection team determined that NextEra's methods for assessing operability of ASR-affected reinforced concrete structures were technically sound and generally comprehensive. NextEra compared the available design and as-built construction margins to lower bound ASR effects on selected structural design attributes. The team concluded this margins assessment provided a reasonable interim operability basis, until further testing and engineering analysis supports a final operability determination, expected to be completed by mid-2014. The team will review NextEra's proposed testing to address the uncertainties in evaluating the current level and progression of ASR on Seabrook Station reinforced concrete structures in the second follow-up inspection.

Comment [A1]: Comments are of 3 types:

(A)**OPERABILITY** DISCUSSION - Problem with characterizing as "Interim Operability Assessment":
a.Operability is not usually characterized as acceptable for an interim period and the Agency does not have an "interim operability" process and it appears this is a licensee phrase we should consider not using.
b.Justification for why the staff concluded an assessment or evaluation was appropriate or acceptable is not readily identifiable to the reader
(B) - **LR** ALIGNMENT License renewal alignment: In some areas, DLR is concerned that the statement may send a wrong message in terms of an Agency position
(C) - OVERALL **CLARITY**:
a.In some areas, the "story" is not clear (how the NRC arrived at a conclusion...is there background information that would help the reader to understand xyz).
b. The use of the terms "Lower bound" and "upper bound" are unclear. Consider using plainer language

Deleted: interim

Comment [A2]: OPERABILITY: Need to explain what this means. Suggested wording might be "The inspetion team determined that NextEra's methods for assessing operability of ASR-affected reinforced concrete structures were was appropriately bounding based on limited available information and conservative assumptions of ASR effect"

In accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) 2.390 of the NRCs "Rules of Practice," a copy of this letter, its enclosure, and your response (if any) will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of the NRC's document system (ADAMS). ADAMS is accessible from the NRC website at http://www.nrc.gov/reading-rm/adams.html (the Public Electronic Reading Room).

Sincerely,

Christopher G. Miller, Director
Division of Reactor Safety

Docket No. 50-443
License No: NPF-86

Enclosures:
1. Inspection Report No. 05000443/2012009
   w/ Attachment: Supplemental Information
2. Confirmatory Action Letter 1-2012-002

cc w/encl: Distribution via ListServ

In accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) 2.390 of the NRCs "Rules of Practice," a copy of this letter, its enclosure, and your response (if any) will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of the NRC's document system (ADAMS). ADAMS is accessible from the NRC website at http://www.nrc.gov/reading-rm/adams.html (the Public Electronic Reading Room).

Sincerely,

Christopher G. Miller, Director
Division of Reactor Safety

Docket No. 50-443
License No: NPF-86

Enclosures:
1. Inspection Report No. 05000443/2012009
   w/ Attachment: Supplemental Information
2. Confirmatory Action Letter 1-2012-002

cc w/encl: Distribution via ListServ

Distribution w/encl:
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S. Kennedy, RI, OEDO
RidsNrrPMSeabrook Resource
RidsNrrDorlLpl1-2 Resource
ROPreports Resource

DOCUMENT NAME: G:\DRS\Seabrook Concrete\Oper-funct - TIAs\CAL FU 92702 Report 1\IR 2012-009 11-13-12.docx
ADAMS Accession No.: ML

☑ SUNSI Review		☑ Non-Sensitive ☐ Sensitive		☑ Publicly Available ☐ Non-Publicly Available	
OFFICE *mmt*	RI/DRS	RI/DRP	RI/DRS	RI/DRS	RI/DRS
NAME	WCook/	ABurritt/	RConte/	JTrapp/	CMiller/
DATE					

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U.S. NUCLEAR REGULATORY COMMISSION

REGION I

Docket No.:	50-443
License No.:	NPF-86
Report No.:	05000443/2012009
Licensee:	NextEra Energy Seabrook, LLC
Facility:	Seabrook Station, Unit No. 1
Location:	Seabrook, New Hampshire 03874
Dates:	June 18, 2012 to November 2, 2012
Inspectors:	W. Cook, Team Leader, Division of Reactor Safety (DRS) S. Chaudhary, Reactor Inspector, DRS W. Raymond, Senior Resident Inspector A. Buford, Structural Engineer, Division of License Renewal, Office of Nuclear Reactor Regulation (NRR) G. Thomas, Structural Engineer, Division of Engineering, NRR
Accompanied by:	Dr. Kent Harries, Associate Professor of Structural Engineering and Mechanics, University of Pittsburgh
Approved by:	Richard Conte, ASR Project Manager Division of Reactor Safety

SUMMARY OF FINDINGS

IR 05000443/2012009; 06/18/2012 - 11/02/2012; Seabrook Station, Unit No. 1; Confirmatory Action Letter (CAL) Follow-up Inspection Report.

This report covered three weeks of onsite inspection and four months of in-office review by region based inspectors and headquarters reviewers to assess the adequacy of actions taken by NextEra to address the identification of Alkali-Silica Reaction (ASR) in reinforced concrete structures at Seabrook Station. The NRC's program for overseeing the safe operation of commercial nuclear power reactors is described in NUREG-1649, "Reactor Oversight Process," Revision 4, dated December 2006.

Cornerstone: Mitigating Systems

During this inspection the team examined six of the 11 commitments identified in CAL No. 1-2012-002, dated May 16, 2012. These commitments involve actions taken and planned by NextEra to address the degradation of reinforced concrete structures at Seabrook Station due to ASR. Based upon the team's onsite inspection activities and detailed in-office reviews, the team closed CAL Items #1, #3, #5, #6, and #10. The team reviewed CAL Item #2, but did not close this item based upon additional actions needed by NextEra to appropriately address and document this issue. The details of the team's review of each CAL item and the observations pertaining to the adequacy of NextEra's actions to address their commitments to the NRC, to date, are documented in the enclosed report.

The team determined during this inspection that NextEra does not plan to finalize their structural evaluations and operability assessments until: 1) the degree of ASR degradation on station reinforced concrete structures is appropriately reconciled with the station design and licensing basis; and 2) the progression of ASR is appropriately monitored to ensure structural integrity and operability is maintained for the duration of the current operating license. Further, the team determined that NextEra's current position is that no reinforced concrete structure at Seabrook Station will be precluded from monitoring for the affects of ASR until a satisfactory petrographic examination has been completed on that structure to confirm the absence of ASR.

The team acknowledged NextEra's plans to conduct structural performance testing of large scale test specimens (both control and ASR-affected) and then apply the test data to evaluate the current impact of ASR on Seabrook Station concrete structures and to develop appropriate actions for the continued monitoring of the ASR-affected structures. The adequacy of NextEra's proposed test program will be evaluated during the second CAL follow-up inspection, in accordance with CAL Item #8. The adequacy of NextEra's current Structures Monitoring Program will be evaluated coincident with the team's review of CAL Item #9.

As discussed in Section 9.0 of the enclosed report, the team identified additional issues for follow-up during the second inspection. These issues and the remaining CAL items will be examined and assessed for adequacy prior to the closeout of CAL 1-2012-002.

REPORT DETAILS

1.0 Background

Alkali-Silica Reaction (ASR) is a chemical reaction occurring in hardened concrete that can change the physical properties of the concrete and potentially affect structural performance. In June 2009, NextEra identified potential degradation in below grade concrete structures at Seabrook. In August 2010, NextEra completed petrographic evaluation of concrete core samples which confirmed ASR as the degradation mechanism. The degraded condition in Seabrook Category I structures was evaluated in the Corrective Action Program via a prompt operability determination (POD) in September 2010, and revised in April 2011, September 2011 and May 2012. The initial PODs (Revisions 0 and 1) addressed the B electric tunnel (AR 581434) where ASR was first discovered. Five other buildings were identified as part of the extent-of-condition (EOC) review and the evaluation of core samples taken from these structures (AR 1664399). The PODs were updated as new information became available and revised analytical techniques were incorporated.

NextEra initially used the results of mechanical testing of concrete cores to assess the degree of structural degradation due to ASR. This is the traditional method described in American Concrete Institute (ACI) 228.1R for assessing existing concrete structures. NextEra tested the cores for compressive strength and elastic modulus. NextEra used the methods defined in construction and design code ACI 318-1971 to evaluate the structural capacity (operability) of the ASR-affected buildings. However, the mathematical relationships in ACI-318 are based on empirical data from testing of non-degraded concrete and these relationships may not hold true for all stages of ASR-affected concrete.

After further review of industry experience and literature pertaining to ASR, NextEra engineering concluded that the core test data was not indicative of structural performance of ASR-affected reinforced concrete structures. NextEra's engineering evaluation stated that once the cores are removed from the structure, concrete core samples are no longer subject to the strains imposed by the ASR-related expansion or restraints imposed by the steel reinforcing cage. The engineering evaluation also stated that confinement provided by steel reinforcing bars (rebar) and other restraints limit ASR expansion of the concrete within the structure and thereby limit the adverse impact on structural performance. Therefore, NextEra engineering concluded that the reduction of mechanical properties observed in mechanical testing of cores was not representative of in-situ concrete performance. NextEra's current position is that the testing of core is only useful as a diagnostic tool to confirm the presence of ASR. Based on this engineering judgment, NextEra stopped taking cores to evaluate the concrete mechanical properties of structures impacted by ASR and revised the operability assessment approach. NextEra's current approach for assessing structural integrity and operability is to compare available design margins to an assumed reduction in structural capacity due to ASR.

The extent of ASR at Seabrook was documented in a baseline walkdown review of station structures. The review identified the visual signs of ASR through the presence of crack patterns, ASR gel in wet and powder forms, and/or discoloration/dark staining. NextEra's walkdown objectives were to: identify and assess apparent ASR degradation including estimated expansion; identify the condition of concrete in the vicinity of supports that show ASR

distress; and identify the current or past areas of water intrusion. The walkdown results were entered into the corrective action program (AR 1757861) and have established NextEra's current baseline condition assessment of Seabrook structures, in conjunction with six-month crack indexing measurements on selected structures to trend the progression of ASR and possibly establish a rate of expansion.

NextEra's operability evaluations were based upon an examination of available design margins and a presumed ASR reduction in structural design capacity for critical limit states. The details of this methodology and related assumptions were developed in NextEra's Interim Assessment (FP 100716). The assessment assumed lower bound values for potential reductions in structural design properties (limit states) based on research test data from primarily small scale test specimens. The assessment focused on the structural design properties that are the most sensitive to ASR effects (i.e., out-of-plane shear capacity, lap splice development length, and anchorage capacity). The assessment determined the structures were suitable for continued service pending further evaluation of structural performance based on a proposed large scale testing program of beam specimens representative of Seabrook reinforced concrete structures. The test program has been initiated at the Ferguson Structural Engineering Laboratory at the University of Texas at Austin (UT-A), with testing targeted to be completed in 2013 and the results reported in 2014.

2.0 Confirmatory Action Letter 1-2012-002

Confirmatory Action Letter (CAL) 1-2012-002, dated May 16, 2012, was written to confirm commitments by NextEra (established during a meeting with NRC management and staff on April 23, 2012) with regard to planned actions to evaluate ASR-affected reinforced concrete structures at Seabrook Station. In response to the CAL, NextEra committed to provide information to the NRC staff to assess the adequacy of NextEra's corrective actions to address this significant condition adverse to quality. CAL 1-2012-002 is provided as an Enclosure to this report. The NRC staff also formed a working group to provide appropriate oversight of NextEra's activities to address ASR and to coordinate NRC inspection and review activities. The ASR Working Group Charter (ML121250588) outlines the regulatory framework and general acceptance criterion for NRC oversight and review of this issue.

Based on the results of this inspection, CAL Items #1, #3, #5, #6, and #10 are closed; CAL Item #2 is updated; and CAL Items #4, #7, #8, #9, and #11 remain open pending NRC review in the second CAL follow-up inspection (Report No. 05000443/2012010).

3.0 Review of Operability Determinations and the Interim Assessment (CAL Items #1, #3, and #5)

Comment [A3]: CLARITY: consider putting the CAL # in parentheses next to the titles in this subsection. It is not readily apparent to the reader which CAL item is being referenced, especially in the paragraphs such as "shear strength" and "anchorage"

Also – consider adding the actual CAL language at the beginning of each of the sections that refer to CAL item.

3.1 Inspection Scope

The team reviewed the PODs for the B Electric Tunnel of the Control Building (POD 581434) and buildings identified in NextEra's extent-of-condition review (PODs 1664399 and 1757861). As discussed in Section 1.0 above, these PODs were revised to reflect a change in the approach taken by NextEra to evaluate the structural integrity of the station reinforced concrete buildings. Revision 2 of the PODs provides the current quantitative and qualitative analyses of

the ASR-induced changes in structural performance, as further detailed in the licensee's Interim Assessment. The team reviewed the supporting documentation for each significant structural design attribute and conducted multiple interviews and discussions with the responsible NextEra engineering staff and consultants. The team used 10 CFR Part 50, Appendix A (General Design Criteria 1, 2, and 4), and 10 CFR Part 50, Appendix B, Criterion XVI, "Corrective Action," and Criterion XI, "Test Control," as the regulatory basis to assess the adequacy of NextEra's actions to address ASR effects on safety-related Category I and in scope Maintenance Rule reinforced concrete structures. The team used NRC Inspection Manual, "Part 9900 – Operability Determination and Functionality Assessments for Resolution of Degraded or Nonconforming Conditions Adverse to Quality or Safety," to evaluate the licensee's approach to assessing this significant condition adverse to quality.

The extent-of-condition POD (Revisions 0 and 1) initially addressed five structures (AR 1664399). These five structures included the containment enclosure building (CEB), the access tunnel to the radiologically controlled areas (RCAW), the emergency feedwater (EFW) pump house, the residual heat removal (RHR) equipment vault (EV), and the diesel generator building (DGB). During implementation of ASR Structures Walkdown (FP 100705), NextEra identified additional structures with localized areas of patterned cracking, including: the condensate storage tank enclosure, the control building air east intake, the service water cooling tower, the A electrical tunnel, the fuel storage building, the east pipe chase, the west pipe chase, the pre-action valve room, the primary auxiliary building, the service water pump house, the mechanical penetration area (which includes portions of the outer containment wall, AR 1804477), and the waste processing building (AR 1757861).

The team conducted a detailed review of Foreign Print (FP) 100716, "Seabrook Station: Impact of Alkali-Silica Reaction on Concrete Structures and Attachments," Revision 1, which is the initial evaluation of concrete structures at Seabrook Station and provides the basis for continued operability of affected structures for an interim period. As documented in FP 100716, NextEra's interim evaluation will be followed by a second evaluation that "will assess the long-term adequacy of the concrete structures considering the results of the full-scale structural testing program, other in-progress test programs, and results from periodic monitoring of the structures."

3.2 Findings and Observations

The team identified no findings in this area and CAL Items #1, #3 and #5 are closed. Based on a detailed review of the PODs, referenced white papers and associated engineering analyses, including an independent verification by the team of a number of supporting calculations, the team determined NextEra's interim operability bases were appropriate. Given the current known extent of ASR, there is reasonable expectation that the affected reinforced concrete structures at Seabrook Station will remain capable of performing their intended functions for an interim period, while NextEra continues to monitor the condition and complete detailed testing and further engineering analyses (expected to be completed by mid-2014).

The team noted that the areas identified by NextEra to be affected by ASR are generally localized (i.e., part of a wall, not the entire wall or structural member exhibits evidence of ASR). Even though the identified ASR areas are localized, NextEra's engineering evaluations

conservatively assume the entire structure or structural member (wall) is adversely affected. Assuming an entire structural member is affected allows for a direct comparison to the original design calculations of record. Noteworthy observations pertaining to the team's review of the PODs and Interim Assessment follow:

3.2.1 Operable, but Degraded (Below Full Qualification)

Based upon a detailed review of the quantitative and qualitative analyses documented in the PODs and Interim Assessment, the team determined NextEra had appropriately demonstrated that the ASR impacted structures were operable, but degraded and below full qualification. NextEra demonstrated that the structures would maintain structural integrity for design basis loads and load combinations for normal, accident and environmental extreme conditions (including seismic) for an interim period.

The team observed that 26 locations (including containment) had been identified via NextEra's ASR Structures Walkdown as having patterned cracking with a combined crack index (CCI) of greater than 1.0 mm/m. Per the Structures Monitoring Program (EDS 36180, Revision 2), Attachment 3, revised in July 2012, a CCI of >1.0 mm/m requires a structural evaluation. NextEra's Interim Assessment, Section 2.1.2 documents an engineering judgment that biased the performance of detailed structural evaluations to the 11 locations with a CCI > 1.5 mm/m. Although not explicitly stated in Section 2.1.2, the team learned from discussions with NextEra engineers that the locations with a CCI of between 1.0 and 1.5 mm/m (13 locations) were considered bounded by the 11 areas subjected to a detailed evaluation. The lack of a documented structural evaluation for the 13 locations with a CCI of between 1.0 and 1.5 mm/m was considered a minor performance deficiency. NextEra acknowledged this procedural implementation error and entered the issue into their Corrective Action Program (AR 1804477 and AR 1819080). A structural evaluation was completed for containment and reviewed by the team prior to the completion of the inspection period (see Section 3.2.8). However, the evaluations for the remaining locations are yet to be completed by NextEra. The team will examine these evaluations in the next CAL follow-up inspection report.

Near the conclusion of this inspection, NextEra completed a POD for containment (AR 1804477). Preliminary review by the team identified areas for follow-up during the second CAL follow-up inspection. Specifically, the team plans to assess NextEra's evaluation of the potential for ASR-induced pre-stressing of rebar (reference Section 3.2.8) and to review NextEra's future plans for monitoring the localized areas (three) of presumed ASR (not verified by a petrographic exam) on the containment outer wall. NextEra's current monitoring plans for the containment wall areas are documented in FP 100647, "Crack Index Determination." (See Section 6.0 of this report for additional information and team observations concerning Crack Indexing.)

3.2.2 Concrete Material Properties - Compressive Strength and Elasticity Modulus

As discussed in Section 1.0, NextEra stopped taking core samples to evaluate ASR-affected structures. Notwithstanding, Revision 2 of POD 581434 for the B electrical tunnel, concluded that there is no loss of concrete compressive strength due to ASR. This conclusion was based on testing of 15 cores (12 ASR-affected concrete and 3 control locations). NextEra concluded

that ASR had increased the stiffness of the electric tunnel walls because the compressive strength in the ASR impacted concrete was higher than in the control core samples. [The team notes that this conclusion is different than the 22 percent measured compressive strength reduction (compared to the 1979 cylinder test results) that had been previously identified by NextEra from initial core sample results and reported in NRC Inspection Report 05000443/2011007.] Team review of the available supporting concrete core data during this inspection did not validate NextEra's current conclusion.

Comment [A4]: CLARITY: This appears to disagree with the statement in the cover letter that the methods were "technically sound and generally comprehensive". To the reader, the statement seems to "hang" without further discussion following an unfavorable-seeming conclusion. Consider adding a qualifying follow-up statement. How does this lack of agreement from the staff result in a conclusion that the methods were technically sound?

As-built concrete compressive strength can vary due to variations in the mixture (aggregate, sand, cement, and water) and the curing process. Consequently, design and construction specifications were developed to ensure, in spite of this variability, that concrete specified and used in reinforced concrete structures meets acceptable standards of performance. In addition, concrete strength is expected to increase with age and curing. The team also notes that additional inaccuracies are introduced via the core sampling process and associated testing methods. Accordingly, team examination of the 2011 core sample compressive strength values and measured cylinder strength values from 1979 (two percent lower), lead the team to conclude there is neither a significant loss or increase in compressive strength in the ASR-affected B electrical tunnel concrete material properties. Team review of core sample measured modulus of elasticity values identified that although individual cores showed a modulus that was reduced (compared to design), the average modulus value in the RCA walkway, RHR equipment vault, EFW pump house and DGB was within 20 percent of the design modulus value ($\pm$20 percent is acceptable by ACI 318). For the CEB, the average modulus was just beyond (low) the 20 percent allowable. Based upon available core sample results, the team considered the ASR effect on elasticity modulus inconclusive, also.

Comment [A5]: CLARITY: not clear to the reader - two percent lower than what?

Comment [A6]: CLARITY: significant loss or increase in compressive strength - from what starting point?

Overall, the team concluded that the core sampling and associated mechanical testing completed, to date, has not conclusively established the current impact of ASR on concrete material properties. While the team acknowledges that the core sample results may not represent in-situ concrete structural performance, as NextEra has concluded, the core samples and test results (mechanical and petrography) may still provide valuable information and insights relative to the impact (relative degree and progression) of ASR on reinforced concrete structures. Consequently, the team plans to examine core sampling in the second CAL follow-up inspection, with respect to core sample test results being used to understand ASR effects on ACI Code relationships and the overall adequacy of the Structures Monitoring Program. .

3.2.3 Flexural Capacity and Dynamic Response

NextEra completed a comparative study of the Containment Enclosure Building (CEB) (FP 100714 and FP 100715) which evaluated the effects of reduced elastic modulus on seismic response. The CEB was chosen for detailed analysis because it conservatively bounds other site structures due to its relative size and dynamic loading. The CEB parametric study included: an evaluation of the building in a static, three-dimensional finite element analysis (FEA) to determine the response (forces and moments) to operating basis earthquake and safe shutdown earthquake seismic loads before and after ASR damage; a calculation of the wall section capacities; a calculation of demand-to-capacity ratios (DCR); and, a comparison of the DCRs of ASR-affected walls to unaffected walls. Based upon assumed bounding conditions and the assumed state of ASR degradation used in the FEA model, the analyses showed that the seismic acceleration profiles, in-structure response spectrum, and distribution of forces and moments were not significantly impacted. The effect of the lower modulus values on the response of below-grade, ASR-impacted structures was evaluated in Calculation C-S-1-10163. For these below grade structures, NextEra determined that the dynamic structural response remained in the rigid range with no appreciable amplification of the ground response spectra.

Based upon the above, NextEra concluded that the seismic response of the CEB, along with the attached equipment (cable trays and supports) and anchor loads remained practically unchanged due to the assumed ASR effects. The team concluded that NextEra's assessment of this ASR-affected structural design attribute was appropriate for an interim operability determination.

Comment [A7]: OPERABILITY: No discussion of the staff's opinion on what NextEra did. If we found it accebptable, why? Is it only okay on an interim basis? Will the applicability or appropriateness expire?

3.2.4 Shear Capacity

NextEra analyzed the impact of ASR on the B electric tunnel using an FEA in calculation FP 100730 to determine refined structural demand and to compare the shear capacity versus demand for seismic and hydrodynamic loads. NextEra assumed a lower bound 25 percent reduction in out-of-plane concrete shear capacity due to the effects of ASR on walls without shear reinforcement. The team noted that NextEra's design calculation (CD-20, dated 3/28/83) used the average 28-day compressive strength value (5459 psi) to establish that the design shear capacity exceeded the design load/demand. However, the FEA-based calculation used the specified design concrete strength of 3000 psi to compare the available design capacity to design load. The use of the 3000 psi vice 5458 psi value in the FEA identified that adequate margin was available using the as-built specified concrete compressive strength. The team notes that the FEA is a more precise computational design method than the manual methods used in the 1983 design calculation. The team notes that NextEra identified, but did not credit, additional conservatism in their margins analysis based upon the B electrical tunnel average measured core sample compressive strength value of 5140 psi. NextEra's FEA-based evaluation concluded that adequate margin was available to account for the lower bound ASR effect on out-of-plane concrete shear capacity. The team acknowledges that: 1) some additional margin may be credited due to the compressive strength of core samples exceeding the design minimum value of 3000 psi; and 2) the use of a 25 percent reduction in shear capacity, as a lower bound ASR effect, was appropriate for the assessment of this limit state. The team viewed the use of an FEA to assess shear capacity and the lower bound ASR effects as appropriate for the interim operability assessment.

Comment [A8]: CLARITY: Consider plainer language, as "lower bound" and "upper bound" are confusing, to explain the rationale for using a 25% reduction

Comment [A9]: OPERABILITY: Same as comment above.

3.2.5 Review of Finite Element Analysis Modeling

As discussed in Sections 3.2.3 and 3.2.4 above, NextEra used a linear elastic FEA to evaluate the effects of ASR on certain structures and design attributes. The team noted that the input data for the compressive strength and modulus of elasticity for the CEB model were determined based on a visual examination of CEB walls and only a few directly obtained core sample material properties. The observed crack patterns/dimensions on the CEB were correlated by NextEra to a damage rating index (DRI) and associated concrete material properties from test data obtained from core samples taken from several different structures. The input data for poisson ratio was derived exclusively from research data. NextEra acknowledged the limitations of this input data, but in FP 100696 deemed the approach justified because the analysis was a parametric study of the CEB seismic response, comparing design values to ASR-affected values. The team concluded the application of the FEA to a parametric analysis was useful for providing a reasonable expectation of operability for the interim period, but not conclusive with respect to identifying a current or projected state of ASR impact. For example, the team noted that the boundary conditions used at and below elevation zero-foot of the CEB FEA model may need to be re-evaluated and better justified, considering the seismic isolation of the structure wall (separated from the concrete backfill by the waterproofing membrane). The team concluded that the use of a FEA model with more accurate concrete material property data and more representative boundary conditions may be appropriate for a final operability assessment.

Comment [A10]: OPERABILITY: Why was it useful and reasonable but not conclusive?

Comment [A11]: OPERABILITY: Why does this need to be re-evaluated or better justified?

Comment [A12]: OPERABILITY: interim operability vs. final operability vs. Operable. Why is it okay now?

3.2.6 Anchorage

NextEra evaluated the impact of ASR-affected concrete on the performance of anchorage, including both expansion and undercut post-installed anchors. The potential impact of micro-cracking caused by ASR can negatively impact the structural capacity of anchorages and embedments supporting safety-related components. NextEra's interim operability evaluation was supported by anchor performance testing conducted on ASR degraded UT-A test specimens (FP 100718). The tests showed satisfactory performance of the anchors in ASR-affected concrete. NextEra's evaluation illustrated that the assumed lower bound reduction in capacity due to ASR was offset by established anchor manufacturer's design margins (FP 100716). The team concluded that NextEra's interim anchorage operability assessment was satisfactory. However, based upon the limitations of the testing performed, to date, (on ASR-affected test specimens of different composition and compressive strength than Seabrook structures) NextEra plans to conduct further testing. Planned testing involves anchors installed in ASR-affected test specimens that more closely reflect the reinforced concrete structures and anchor configurations at Seabrook.

Comment [A13]: CLARITY: Same comment: Consider plainer language, as "lower bound" and "upper bound" are confusing

Comment [A14]: OPERABILITY: Same Comment as above: No discussion of the staff's opinion on what NextEra did or on the results. If we found it accebptable, why? Is it only okay on an interim basis? Will the applicability or appropriateness expire?

Comment [A15]: OPERABILITY: What is the NRC's position on this testing? Do we agree with the licensee?

3.2.7 Lap Splice Strength

Section 6.3 of NextEra's Interim Assessment addressed reinforcement lap splice degradation as another design attribute impacted by ASR. In accordance with the licensee's lower bound value of a 40 percent reduction in lap splice strength, NextEra's review of design calculations identified several structures with insufficient margin to accommodate this assumed ASR affect. NextEra was able to "recover" margin by adjusting the ACI 318 prescribed design load factors for predicted dead load and/or hydrostatic load. NextEra's term "recover" represents examining the design calculations and determining the accuracy of the predicted loads; if the predicted load can be more accurately quantified, then it is appropriate to remove the load factor (LF) from the associated load/demand calculation. By ACI 318, the LFs account for the uncertainty in accurately predicting the structural loads. The team examined this method and found it satisfactory for the interim operability assessment, but concluded it would not be acceptable for a final operability determination under the current licensing basis. The final operability assessment requires full conformance with the ACI design methodology or revision to the licensing basis.

Comment [A16]: CLARITY: Same comment as above: Consider plainer language, as "lower bound" and "upper bound" are confusing, to explain the rationale for using a 40% reduction

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Comment [A17]: OPERABILITY: Same Comment as above: No discussion of the staff's opinion on what NextEra did or on the results. If we found it accebptable, why? Is it only okay on an interim basis? Will the applicability or appropriateness expire?

Comment [A18]: OPERABILITY: Why is it okay now?

3.2.8 Concrete Confinement and Rebar Pre-Stressing

Team review of FP 100716, Sections 2.1.2 and 4.1.3, identified that the Interim Assessment stated, "Since ASR has a negligible impact on structural demand, the impact of ASR on structures and structural attachments can be assessed solely on the basis of changes in capacities." The team observed that restraint to ASR expansion, from concrete confinement by reinforcement (in two or three dimensions) and/or other external constraints, may cause internal pre-stress in the structural member. The consequence may increase compressive stresses in concrete and increase tensile stresses in the rebar, as long as the restraint is sustained. The team observed that NextEra has only addressed this ASR-induced pre-stress qualitatively in FP 100716 and in the containment structural evaluation (AR 1804477). The team's preliminary engineering judgment is that a quantitative evaluation is more appropriate for a final operability assessment of this condition. Further, it should be recognized that the ASR-induced pre-stress varies with time, depending on the degree of restraint and may not be sustained throughout the service life of an affected structure. Accordingly, any potential beneficial effect should not be relied upon or credited in design.

Comment [A19]: OPERABILITY: Why?

The team acknowledges NextEra's conclusion that ASR-induced pre-stress may result in some beneficial effects in terms of structural stiffness. However, the team's judgment is that this structural demand should be quantified (if practicable) and accounted for in the design calculations as a known load. Quantifying, or otherwise approximating the ASR-induced pre-stress, is similar to accounting for the pre-stress load in pre-stressed concrete design. This issue will be reviewed by the team in the second CAL follow-up inspection.

Comment [A20]: OPERABILITY/CLARITY: How does this relate to operability?

3.2.9 Condition of Rebar

The team examined information gathered and assessed by NextEra with regards to the condition of rebar and any potential erosion or corrosion due to ASR and water in leakage through below grade reinforced concrete structures. The team observed that NextEra had purposefully removed an area of surface concrete in the B electrical tunnel (chronically wet) to examine the condition of the rebar. The engineering staff identified no degradation of the rebar (no oxidation or signs of distress). The team also learned that in the course of removing core samples, in two instances the drill nicked rebar. Examination of the rebar sections removed determined the steel to be in excellent condition (unaffected by ASR or moisture).

Preliminarily, NextEra has concluded that the condition of rebar in ASR degraded concrete should be unaffected unless the cracking becomes deleterious and exposes the rebar to oxidation mechanisms. Otherwise, the alkaline condition within the concrete should prevent any corrosion mechanisms. The NRC continues to evaluate the need for any additional rebar intrusive monitoring or testing, and will evaluate this issue in the second CAL follow-up inspection.

Comment [A21]: OPERABILITY/CLARITY: Same comment as above: How does this relate to operability?

4.0 Review of Alkali-Silicon Reaction Root Cause Evaluation (CAL Item #2)

4.1 Inspection Scope

The team reviewed NextEra's response to this CAL Item, "Submit the root cause for the organizational causes associated with the occurrence of ASR at Seabrook Station and related corrective actions by May 25, 2012." The licensee submitted their root cause evaluation (RCE) via letter dated May 24, 2012. The purpose of the team's review was to assess the adequacy of the licensee's evaluation of the root cause for the ASR issue at Seabrook and the significant contributing causes. The team also examined the methodology and thoroughness of the licensee's evaluation and associated corrective actions as outlined in 10 CFR Part 50, Appendix B, Criterion XVI, "Corrective Action."

4.2 Findings and Observations

This CAL Item will remain open pending NRC review of NextEra's final RCE. NextEra identified two root causes: 1) ASR developed because the concrete mix design unknowingly utilized an aggregate that was susceptible; and 2) the monitoring program for plant systems and structures does not contain a process for periodic reassessment of failure modes. A contributing cause identified by NexEra was the failure to prioritize groundwater elimination or mitigation resulting in more concrete areas exposed to moisture. The team made observations regarding the level of detail and clarity of NextEra's root cause evaluation.

The team acknowledges that the first licensee identified root cause involved the use of susceptible aggregate in the concrete mix design that was undetected by the testing specified by American Society for Testing and Materials (ASTM) construction standards, at the time (late 1970's). Since this time, the role of slow reacting aggregate in ASR has been identified in the construction industry and standard tests are now available to ensure slow reactive aggregates would be properly identified prior to use in construction. The team concluded that this causal factor was beyond the licensee's control.

The team concluded that the second root cause was not adequately characterized in NextEra's May 24, 2012, submittal. Specifically, NextEra did not clearly state the personnel and organizational factors that led to inadequacies in the Structures Monitoring Program (SMP). The team discussed the absence of any human performance aspects in the description of this causal factor and NextEra initiated a revision to the RCE to more appropriately develop and characterize this second root cause and the associated corrective actions. NextEra plans to submit the revised RCE for NRC review. The team will review this revision in the next CAL follow-up inspection report.

The team also noted that NextEra excluded a contributing cause, identified in the RCE, from the evaluation executive summary and May 24, 2012, letter. As stated in the RCE, this contributing cause involved the longstanding "organizational mindset" that groundwater infiltration was more of an "operational nuisance" than a structural integrity concern. This station and engineering staff view prevented a more timely and thorough investigation and examination of the affected concrete reinforced structures on site. NextEra acknowledged this observation.

5.0 Review of Mortar Bar Testing (CAL Item #6)

5.1 Inspection Scope

The team reviewed the results of NextEra recently completed short term expansion testing of mortar bar specimens per test procedures SGH-Z001-12 and SGH-Z002-12. The results of the testing were evaluated per ASTM C1260. The licensee initiated the testing to establish and compare the reaction rates of ASR-affected concrete to non-ASR-affected concrete on site. The tests were performed by a consultant at an offsite facility. The mortar bar specimens were made using the aggregate extracted from core samples taken from ASR-affected structures and non-affected concrete from a slab removed from the waste processing building. NextEra noted that the non-affected concrete slab used for aggregate extraction had shown no visible indications of ASR and was not petrographically examined. The details of the testing are documented in SGH Report 120110-RPY-01 (FP 100734). The team reviewed the SGH report and associated test documents to ascertain the adequacy and technical validity of the testing.

5.2 Findings and Observations

No findings were identified and CAL Item #6 is closed. The test results indicated that both affected and non-affected concrete specimens contained ample reactive aggregate to sustain ASR. The team notes that normal test duration is 14 days and that a specimen expansion of >0.1 percent indicates reactive aggregate, per ASTM C1260. Test results identified that the non-ASR-affected specimens exceeded the 0.1 percent threshold in 5 days and the ASR-affected specimens exceeded the 0.1 percent threshold in 7 days. NextEra allowed the test to extend to 103 days and both specimen types continued to demonstrate active expansion due to ASR. Accordingly, NextEra concluded that there remains the potential for future volumetric expansion due to ASR in concrete structures at Seabrook.

Based upon the Mortar Bar Testing results, NextEra plans to revise their commitment to conduct Prism Testing. Prism Testing is similar to Mortar Bar Testing, but a longer term test of the susceptibility to ASR of aggregate used in concrete. NextEra had hoped to establish, via the Mortar Bar Test, a difference in the remaining versus available concrete constituents for ASR in the specimens. The results demonstrated ample reactive materials in both specimen types and NextEra concluded the Prism Test will not provide any additional ASR insights. The team had no additional observations and will review the revised Prism Testing commitment when it is submitted.

6.0 Review of Crack Indexing (CAL Item #10)

6.1 Inspection Scope

The team conducted a review of FP 100647, "Crack Index Determination," Revision 1, to understand the methodology for NextEra's monitoring of ASR progression in selected reinforced concrete structures. NextEra's commitment to this methodology is documented in CAL Item #10. The team used 10 CFR Part 50, Appendix B, Criterion V, "Instructions, Procedures, and Drawings," to evaluate the implementation and adequacy of the procedural guidance. The team's review was limited in scope, in that, the adequacy of this process, as the sole means of monitoring ASR progression in Seabrook structures, is still under NRC review. The team will evaluate this aspect as part of the review of CAL Item #9, the Maintenance Rule Structures Monitoring Program, during the second CAL follow-up inspection.

The team observed field measurements taken on June 20, 2012, by the responsible contractor and discussed the general methodology and procedural guidance with the individuals performing the crack indexing measurements and supervising NextEra staff. The team noted that NextEra found ASR patterned cracking in many areas within Seismic Category I and Maintenance Rule structures, but only a limited number of these areas have sufficient ASR degradation to merit continued monitoring and detailed evaluations. The ASR walkdowns identified 131 locations with some level of pattern cracking. Of the 131 localized areas, 26 exceeded the initial screening criteria of a combined crack index greater than 1.0 millimeter per meter (mm/m). The 1.0 mm/m threshold was established in the Structures Monitoring Program, Attachment 3, for conducting a structural evaluation. These 26 areas will continue to be monitored at six-month intervals, per FP 100647.

6.2 Findings and Observations

No findings were identified and CAL Item #10 is closed. The team noted that the periodic crack indexing provides the principle method selected by NextEra to monitor the progression of ASR on reinforced concrete structures. The six-month interval measurements are currently planned until a reliable trend of ASR progression can be established, per Structural Engineering Standard Technical Procedure 36180, "Structures Monitoring Program," Attachment 3, Revision 2. As stated above, additional NRC review of the SMP will be conducted in the second CAL follow-up inspection.

Comment [A22]: LR: This section poses some concerns for license renewal. It is not clear to the reader that the NRC may not find crack mapping acceptable, and re-statement of the licensee's approach here appears to imply endorsement

The team also reviewed the current methods and terminology used by NextEra to characterize the degree of ASR pattern cracking, previously addressed in NRC Inspection Report 05000443/2011007. When ASR was initially identified in the B electrical tunnel in mid-to-late 2010, the licensee referred to the Federal Highway Administration (FHWA) guidance document FHWA-HIF-09-004 for crack/damage characterization. Three major categories were identified: mild, moderate, and severe, with ratings such as mild to moderate and moderate to severe, also used. Per FHWA-HIF-09-004, these categories were used to define the recommended remedial actions to be taken once ASR was identified. At that time, NextEra labeled the observed cracking as "severe." Per the FHWA guidance, this category requires "further investigation for selecting remedial actions." This characterization was repeated in the above referenced inspection report. The team determined that NextEra revised their crack

characterization scheme prior to the implementation of the structures extent-of-condition review. The revised crack rating system was based upon "best practices" taken from the Building Research Establishment (BRE) in the United Kingdom (UK). The revised numeric rating system range is from 0 (no cracking detected) to 6 (heavily fractured ASR-related damage).
FP 100636, "Petrographic Examination PE Reports," Revision 0, lists the material property results of all core samples taken and petrographically analyzed. FP 100636 also provides the BRE crack rating for each specimen examined. The crack ratings for the specimens examined range from 0 to 4 (a rating of 4 represents severe cracking). A summary table with each numeric rating and its definition is documented in the Supplemental Information attachment to this report.

Comment [A23]: LR: Same comment as above. It appears as though we are closing out the item with the understanding that Crack Mapping will be used by the applicant and accepted by the NRC. Problems could arise for license renewal if DLR does not accept crack mapping, consider leaving this item Open (Also DLR does not understand why it is being closed when there is ongoing review)

7.0 Review of Alkali-Silica Reaction Structures Walkdown/Baseline Assessment

7.1 Inspection Scope

The team examined NextEra's program documents FP 100642, "ASR Walkdown Scope," Revision 1, and FP 100705, "Seabrook Station: Summary of Alkali Silica Reaction Walkdown Results," Revision 0. The team reviewed the walkdown scope and examination criteria and the associated field data, photographic evidence, and analysis of NextEra's observations, as documented in FP 100705. The walkdown scope included Seismic Category I and some in scope Maintenance Rule structures. NextEra's walkdown is being conducted in three phases. Phase 1 involved examination of readily accessible areas of interest; Phase 2 included examination of coated surfaces identified during Phase 1 inspections (coatings had to be removed to expose the concrete surfaces); and Phase 3 examines normally inaccessible structures/areas (e.g. high radiation, manholes, etc.) which have or will be inspected as the opportunity presents itself (e.g. routine maintenance or outage activities).

The walkdowns assess the extent of ASR throughout the plant with the primary objectives of: identifying and assessing any apparent degradation from ASR, including: estimating in-situ expansion (Crack Indexing); assessing whether concrete in the vicinity of supports for safety-related systems or components show any indications of ASR distress; and documenting and characterizing water intrusion or evidence of previous water intrusion, based upon water being a key contributor to concrete deterioration and distress caused by ASR. The visual criteria for documenting potential ASR indications include: typical patterned surface cracks in concrete; crack dimensions (width, length, orientation); evidence of water ingress/out-seepage (past/present); visual evidence of salt deposit and/or ASR gel; and indications of surface deterioration (i.e., pop-outs and/or spalling). Also, any expansion anchors or structural embedments located within 5 feet of the area of interest were examined and documented. The licensee considers their ASR walkdown efforts and observations a baseline condition assessment. This baseline will be used for monitoring the progression of ASR for the duration of the current operating license.

The team performed a number of independent walk-through inspections to verify and assess the thoroughness of the licensee's efforts. The team independently evaluated the extent-of-condition of ASR-affected structures that are readily accessible. The team used the expertise of a consulting structural engineer to assist in the team's review of the current condition of ASR-affected reinforced concrete structures at Seabrook Station.

Comment [A24]: LR: Potential impact on license renewal, and our implied endorsement to let the licensee use this as their extent of condition or baseline walkdown in LR space.

7.2 Findings and Observations

The team identified no findings. On a sampling basis, the team's independent walkdown observations were consistent with the licensee's observations and assessments. At Seabrook, the presence of ASR has been conclusively established by petrography in certain buildings (where core samples were obtained) and in other buildings by inference, using visual examination criteria. The team confirmed that NextEra's position is that all reinforced concrete structures on site are susceptible to ASR, dependent upon the exposure to moisture. Therefore, NextEra does not intend to exclude any structures from ASR monitoring without confirmation via petrography that ASR is nonexistent.

The complete list of structures and localized areas of ASR identified, to date, is documented in FP 100705, Revision 1. The team noted that the results of the walkdown inspection by NextEra were appropriately documented with extensive observation narratives and well supported by clear sketches and photographs. As NextEra completes Phase 3 examinations, the licensee plans to capture the additional observations through revisions to FP 100705. The team noted that the majority of localized areas of ASR are: 1) below grade walls subjected to either ground water intrusion, or particularly high spatial humidity; or 2) exposure to precipitation and high ambient humidity (some exterior above grade structures).

Based upon the team's review of the Phase 1 and 2 ASR walkdown results and via discussions with responsible engineers overseeing the proposed Phase 3 walkdown areas and tentative schedule, the team identified a minor oversight in the Phase 3 walkdown plan. Specifically, the upper elevations of the containment outer wall were not adequately examined for ASR during the Phase I review and not included in the proposed Phase 3 walkdown schedule. The team identified from discussion with the NextEra engineering staff, that the 2010 IWL examination of containment was being credited for part of the Phase 1 ASR walkdown baseline. The team's detailed review of the 2010 IWL inspection results and associated visual examination attributes (reference implementing procedure, ES 1807.031, "Inservice Inspection Procedure Primary Containment Section XI IWL,") identified that the 2010 IWL exam did not include sufficient examination criteria (i.e., active or pattern cracking) for identification of ASR. As evidence of the absence of ASR identification criteria in the IWL examination, during the subsequently performed Phase 1 ASR walkdown by consulting engineers, three locations of ASR related pattern cracking were identified on areas of the containment previously examined by the IWL inspectors. NextEra acknowledged this oversight in crediting the IWL examination and initiated action (AR 1819069) per the Corrective Action Plan. NextEra plans to revise the Phase 3 plan to address this concern. The team plans to examine the adequacy of the proposed Phase 3 changes and implementation schedule during the second CAL follow-up inspection.

8.0 Follow-up of Open Items

Comment [A25]: CLARITY: The information presented in this section provides much detail that would be useful in previous sections, to understand what the initial NRC concerns were, and how they have been addressed in the CAL. To a new reader unfamiliar with the background, this section provides context to other sections. Consider moving or stating some of this information earlier.

8.1 (Closed) Unresolved Item 05000443/2011003-03, Open Operability Determinations for Safety-Related Structures Affected by Alkali-Silica Reaction

This item was open pending NRC review of NextEra actions to revise operability determinations for the electric tunnel and other structures addressed in the extent of condition review for ASR.

The open aspects were as documented in Inspection Reports 2011-03 and 2011-10 related to: 1) effect of the reduced modulus of elasticity on natural frequency of the structures; 2) the effect of the modulus of elasticity on structure flexural response as related to components attached to the structures, such as pipe and cable supports and their anchor bolts; 3) related effects from increased flexure of building on the loading and seismic effects on safety-related pipes and cable tray supports; and, 4) effect of reduced parameters on the whole building (global) response of the CEB structure to seismic loads including further information of the effect on stress and strain in the concrete and rebar system. Following the reviews in Inspection 2011-10, the unresolved item remained open pending NRC review of additional information from NextEra on the effects on cable and pipe support anchors (number 3) and the effects on the CEB response (number 4).

The team reviewed the revised operability determinations for the safety related structures listed below and as described in POD 1664399, Revision 2.

- Control Building – "B" Electrical Tunnel,
- Containment Enclosure Building,
- Diesel Generator Building,
- Residual Heat Removal Equipment Vaults, and
- Emergency Feedwater Pump House

As part of the ASR extent of condition review, NextEra provided structural assessments for the RCA tunnel and other ASR impacted buildings (reference Calculation C-S-1-10168).

The open aspects of numbers 3 and 4 were resolved after NextEra provided additional information. Revision 2 of POD 581434 for the B electric tunnel (ET) provided additional quantitative and qualitative analyses with consideration of ASR-induced changes in concrete properties. The revised POD addressed the changes in modulus on building frequency; flexural response and capacity; shear capacity; and support anchors. The revised POD incorporated the results of the Interim Assessment (FP 100716) relative to the performance of reinforcing steel anchorage to show that postulated reductions in capacities were offset by conservatisms in ACI 318 Code and the assumed loads. The revised POD incorporated the testing at the Ferguson Structural Engineering Laboratory (FP 100718) of cast-in-place and drilled-in anchors to assess the impact of anchor performance in ASR-affected concrete. The test results showed that the anchor capacities remained above the theoretical capacity at crack indices well above the maximum CI observed in Seabrook structures. Finally, the revised POD for the ET also included consideration of a detailed evaluation of the CEB, chosen for detailed analysis because it conservatively bounds other structures in size and exhibits the highest reduction in modulus of elasticity due to ASR.

Further NRC review of this area is described in Sections 3.0 and 4.0 of this report. The team concluded that the initial failure of NextEra to adequately consider the ASR impacts on structural performance, relative to support anchors and dynamic response, were examples of minor performance deficiencies, in that, upon further evaluation these issues were determined to be acceptable as part of the interim operability assessment. This issue was also addressed broadly by the NRC in Finding FIN 05000443/2011-10-02. Unresolved Item 05000443/2011003-03 is closed.

Comment [A26]: LR: Comment (not necessarily suggest report change): "The issues were determined to be acceptable..." By whom? Why is this item closed? Justification for NRC closure of this item is unclear.

8.2 (Closed) URI 2011-010-01 – Adequacy of Calculation Methods for ASR

NextEra initially pursued mechanical testing of concrete cores because that was the traditional method as described in ACI 228.1R for determining properties of existing concrete structures. Upon further review of industry experience and literature for ASR-affected concrete, NextEra determined that the core test data was not indicative of structural performance of the ASR-affected structures. Once removed from the structure, the concrete in the cores is no longer subject to the strains imposed by the ASR-related expansion or restraints imposed by the reinforcing cage. Confinement provided by reinforcing steel and other restraints (e.g., deadweight of the structure) limits ASR expansion of the concrete within the structure, which reduces the extent of deleterious cracking and associated reduction of concrete material properties. NextEra has determined that the structural evaluations based on mechanical properties derived from core samples may under predict structural performance (FP 100697, Structural Assessment of ASR-State of the Art). Since the reduction of mechanical properties derived from testing of cores is not necessarily representative of the structural performance, NextEra changed its approach. For the interim operability assessment, NextEra compared the structural design capacities to design loads/demands and an assumed lower bound ASR effects. This interim operability assessment was based on available industry data from small scale test specimens having ASR degradation worse than that observed at Seabrook. For the final operability assessment, NextEra plans to monitor structures via Crack Indexing and pursue large scale testing of concrete components that are representative of the Seabrook ASR conditions to demonstrate overall structural performance and operability. The large scale testing will be conducted at the Ferguson Structural Engineering Laboratory (FSEL) at the University of Texas, Austin (UT-A).

NextEra responded to CAL Item #8 by letter dated June 21, 2012, and provided a broad overview of the testing planned at FSEL, which will include a shear test program, a lap splice test program, and an anchor test program. The test program will include control specimens that will provide a baseline by which to determine the reductions in capacity due to ASR and to quantify the margins available as calculated using ACI-318. NextEra plans to use the test program to reconcile the ASR condition with the licensing design basis, to inform the structures monitoring program, and to evaluate potential mitigation strategies. NextEra's actions, approach and methods used to resolve the ASR issue, including the proposed test program, will be evaluated by the team in the second CAL follow-up inspection. Unresolved Item 05000443/2011-010-01 is closed.

9.0 Conclusions and Follow-Up Issues

The team determined during this inspection that NextEra does not plan to finalize their structural evaluations and operability assessments until: 1) the degree of ASR degradation on station reinforced concrete structures is appropriately reconciled with the station design and licensing bases; and 2) the progression of ASR is appropriately monitored to ensure structural integrity and operability is maintained for the duration of the current operating license. Further, the team determined that NextEra's current position is that no reinforced concrete structure at Seabrook Station will be precluded from monitoring for the affects of ASR until a satisfactory petrographic examination has been completed on that structure to confirm the absence of ASR. As

discussed in the above sections, NextEra plans to complete performance testing of large scale test specimens and use the test results to finalize the structural operability assessments and modify the Structures Monitoring Program.

The team plans to conduct a second CAL follow-up inspection to review the remaining open CAL items and the open issues documented in this report and listed below:

- Review of pending structural evaluations, including follow-up of the containment POD observations (Section 3.2.1)
- Review of core sample material property testing and SMP (Section 3.2.2)
- Review quantification of pre-stressing effects of ASR expansion (Section 3.2.8)
- Assess the need for any further rebar examinations or testing (Section 3.2.9)
- Review revised RCE submittal (Section 4.2)
- Confirm revised commitment to CAL Item #7 (Section 5.2)
- Review Crack Indexing and its physical significance for SMP application (Section 6.2)
- Review revisions to the Phase 3 walkdown plans and schedule (Section 7.2)

10.0 Meetings, Including Exit

On November 2, 2012, the team conducted an exit meeting to discuss the preliminary findings and observations with Mr. Kevin Walsh, Site Vice President, and other members of Seabrook Station staff. The inspectors verified that no proprietary information was retained by the inspectors or documented in this report.

SUPPLEMENTAL INFORMATION

KEY POINTS OF CONTACT

Licensee Personnel
B. Brown, Design Engineering Manager
A. Chesno, Performance Improvement Manager
K. Chew, License Renewal Engineer
R. Cliché, License Renewal Project Manager
M. Collins, Design Engineering Manager
J. Connolly, Site Engineering Director
R. Noble, Project Manager
M. O'Keefe, Licensing Manager
T. Vassallo, Principal Design Engineer
K. Walsh, Site Vice President
P. Willoughby, Licensing Engineer

LIST OF ITEMS OPENED, CLOSED, DISCUSSED, AND UPDATED

Updated
None

Opened
None

Closed

05000443/2011-010-01	URI	Adequacy of Calculation Methods for ASR
05000443/2011-003-03	URI	Open Operability Determinations for Safety-Related Structures Affected by Alkali-Silica Reaction

LIST OF DOCUMENTS REVIEWED

Procedures
Maintenance Rule Scoping Document, Revision 0
EDS 36180, Structures Monitoring Program, Revision 0, 1, 2

Corrective Action Documents (AR)
1651969, 1629504, 574120, 581434, 1636419, 1673102, 1647722, 1664399, 1677340, 1687932, 1692374, 1698739, 1755727, 1757861, 1819080, 1804477, 1819069

Drawings

Licensing and Design Basis Documents and Calculations
Seabrook Station UFSAR, Revision 14
ACI 318-71
Calculation CD-20
Calculation CD-18
Calculation C-S-1-10168

Miscellaneous Documents
FP 100348, Statistical Analysis-Concrete Compression Test Data (PTL)
FP 100642, Scope for Alkali-Silica Reaction Walkdowns
FP 100641, Procedure for ASR Walkdowns and Assessment Checklist
FP 100661, Compression Testing Concrete Cores (WJE)
FP 100696, Material Properties of ASR-Affected Concrete
FP 100700, Field Investigation
FP 100705, Structure ASR Walkdown Report (MPR 0326-0058-58)
FP 100714, Three Dimensional Dynamic Analysis of Containment Enclosure Building
FP 100715, ASR Impact Study on Containment Enclosure Building
FP 100716, Interim Assessment: Impact of ASR on Structures (MPR-3727)
FP 100717, ACI 318-71 Perspectives
FP 100718, Anchor Test Report (MPR-3722)
FP 100720, Crack Index and Expansion Measurement
FP 100738, Measurements for ASR Crack Indexing on Concrete Structures
FP 100697, MPR 0326-0058-53, White Paper on Structural Implications of ASR: State of the Art, Revision 1
MPR 0326-0058-83, Shear Screening Criteria Used in MPR-3727
FHWA-HIF-09-004, Federal Highway Administration, "Report on the Diagnosis, Prognosis, and Mitigation of Alkali-Silica Reaction in Transportation Structures."

LIST OF ACRONYMS

ACI	American Concrete Institute
ADAMS	Agencywide Documents Access and Management System
AMP	Aging Management Program
AR	Action Request
ASME	American Society of Mechanical Engineers
ASR	Alkali-Silica Reaction
BRE	Building Research Establishment
CCI	Combined Crack Index
CEB	Containment Enclosure Building
CFR	Code of Federal Regulations
CW	Circulating Water
DCR	Demand to Capacity Ratios
DGB	Diesel Generator Building
DRI	Damage Rating Index
DRP	Division of Reactor Projects
DRS	Division of Reactor Safety
EDG	Emergency Diesel Generator
EFW	Emergency Feedwater
EPRI	Electric Power Research Institute
EOC	Extent-of-Condition
ET	Electric Tunnel
EV	Equipment Valve
FEA	Finite Element Analysis
FHWA	Federal Highway Administration
FP	Foreign Print
FPL	Florida Power and Light
FSEL	Franklin Structural Engineering Laboratory
IMC	Inspection Manual Chapter
IP	[NRC] Inspection Procedure
LF	Load Factor
MPR	MPR Associates, Inc.
NRC	Nuclear Regulatory Commission
PARS	Publicly Available Records
P&ID	Piping and Instrument Diagram
PM	Preventative Maintenance
POD	Prompt Operability Determination
PRA	Probabilistic Risk Assessment
psi	pounds per square inch
QA	Quality Assurance
RCA	Radiologically Controlled Areas
RCE	Root Cause Evaluation
RHR	Residual Heat Removal
SDP	Significance Determination Process
SG&H	Simpson, Gumpertz & Heger
SMP	Structures Monitoring Program

SRI	Senior Resident Inspector
UFSAR	Updated Final Safety Analysis Report
UT-A	University of Texas - Austin
UK	United Kingdom
WO	Work Orders

NextEra Crack Rating Chart

Assessment of Severity of ASR in Hardened Concrete by Petrographic Examination

This rating system is based on a modified "best practice" procedure initially developed at tehe Building Research Establishment (BRE) in the United Kingdom, using ASR identification critieria first set out in the British Concrete Association report titled "The Diagnosis of Alkali-Silica Reaction," (1992).

Rating	Description
0	No cracking detected
1	Very slight cracking (no evidence of deleterious ASR)
2	Slight cracking (minor or trace evidence of deleterious ASR)
3	Moderate cracking (moderate evidence of deleterious ASR)
4	Severe cracking (severe evidence of deleterious ASR)
5	Very severe ASR-related cracking
6	Heavily fractured ASR-related damage

UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION I
2100 RENAISSANCE BOULEVARD, SUITE 100
KING OF PRUSSIA, PENNSYLVANIA 19406-2713

Mr. Kevin Walsh
Site Vice President
Seabrook Nuclear Power Plant
NextEra Energy Seabrook, LLC
c/o Mr. Michael O'Keefe
P.O. Box 300
Seabrook, NH 03874

SUBJECT: SEABROOK STATION, UNIT NO. 1 - CONFIRMATORY ACTION LETTER FOLLOW-UP INSPECTION - NRC INSPECTION REPORT 05000443/2012009

Comment [A1]: Comments are of 3 types:

(A)**OPERABILITY** DISCUSSION - Problem with characterizing as "Interim Operability Assessment":
a.Operability is not usually characterized as acceptable for an interim period and the Agency does not have an "interim operability" process and it appears this is a licensee phrase we should consider not using.
b.Justification for why the staff concluded an assessment or evaluation was appropriate or acceptable is not readily identifiable to the reader
(B) - **LR** ALIGNMENT License renewal alignment: In some areas, DLR is concerned that the statement may send a wrong message in terms of an Agency position
(C) - OVERALL **CLARITY**:
a.In some areas, the "story" is not clear (how the NRC arrived at a conclusion…is there background information that would help the reader to understand xyz).
b. The use of the terms "Lower bound" and "upper bound" are unclear. Consider using plainer language

Dear Mr. Walsh:

On November 2, 2012, the U. S. Nuclear Regulatory Commission (NRC) completed a team inspection at Seabrook Station, Unit No. 1. The enclosed inspection report documents the inspection results, which were discussed on November 2, 2012, with you and other members of your staff.

The team inspection examined activities conducted under your license as they relate to safety and compliance with the Commission's rules and regulations and with the conditions of your license. Specifically, the team reviewed selected procedures and records, observed activities, and interviewed station personnel regarding the adequacy of NextEra's actions to address the impact of Alkali-Silica Reaction (ASR) on reinforced concrete structures. The team reviewed selected Confirmatory Action Letter (CAL) 1-2012-002 commitments for adequacy and closure.

Based upon the inspection team on site and in-office reviews, five CAL items were reviewed and closed, as documented in the enclosed report. The remaining six CAL items will be reviewed during our second planned follow-up inspection scheduled for completion in early 2013.

The inspection team determined that NextEra's methods for assessing operability of ASR-affected reinforced concrete structures were technically sound and generally comprehensive. NextEra compared the available design and as-built construction margins to lower bound ASR effects on selected structural design attributes. The team concluded this margins assessment provided a reasonable interim operability basis, until further testing and engineering analysis supports a final operability determination, expected to be completed by mid-2014. The team will review NextEra's proposed testing to address the uncertainties in evaluating the current level and progression of ASR on Seabrook Station reinforced concrete structures in the second follow-up inspection.

Deleted: interim

Comment [A2]: OPERABILITY: Need to explain what this means. Suggested wording might be "The inspetion team determined that NextEra's methods for assessing operability of ASR-affected reinforced concrete structures were was appropriately bounding based on limited available information and conservative assumptions of ASR effect"

In accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) 2.390 of the NRCs "Rules of Practice," a copy of this letter, its enclosure, and your response (if any) will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of the NRC's document system (ADAMS). ADAMS is accessible from the NRC website at http://www.nrc.gov/reading-rm/adams.html (the Public Electronic Reading Room).

Sincerely,

Christopher G. Miller, Director
Division of Reactor Safety

Docket No. 50-443
License No: NPF-86

Enclosures:
1. Inspection Report No. 05000443/2012009
   w/ Attachment: Supplemental Information
2. Confirmatory Action Letter 1-2012-002

cc w/encl: Distribution via ListServ

In accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) 2.390 of the NRCs "Rules of Practice," a copy of this letter, its enclosure, and your response (if any) will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of the NRC's document system (ADAMS). ADAMS is accessible from the NRC website at http://www.nrc.gov/reading-rm/adams.html (the Public Electronic Reading Room).

Sincerely,

Christopher G. Miller, Director
Division of Reactor Safety

Docket No. 50-443
License No: NPF-86

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U.S. NUCLEAR REGULATORY COMMISSION

REGION I

Docket No.:	50-443
License No.:	NPF-86
Report No.:	05000443/2012009
Licensee:	NextEra Energy Seabrook, LLC
Facility:	Seabrook Station, Unit No. 1
Location:	Seabrook, New Hampshire 03874
Dates:	June 18, 2012 to November 2, 2012
Inspectors:	W. Cook, Team Leader, Division of Reactor Safety (DRS) S. Chaudhary, Reactor Inspector, DRS W. Raymond, Senior Resident Inspector A. Buford, Structural Engineer, Division of License Renewal, Office of Nuclear Reactor Regulation (NRR) G. Thomas, Structural Engineer, Division of Engineering, NRR
Accompanied by:	Dr. Kent Harries, Associate Professor of Structural Engineering and Mechanics, University of Pittsburgh
Approved by:	Richard Conte, ASR Project Manager Division of Reactor Safety

SUMMARY OF FINDINGS

IR 05000443/2012009; 06/18/2012 - 11/02/2012; Seabrook Station, Unit No. 1; Confirmatory Action Letter (CAL) Follow-up Inspection Report.

This report covered three weeks of onsite inspection and four months of in-office review by region based inspectors and headquarters reviewers to assess the adequacy of actions taken by NextEra to address the identification of Alkali-Silica Reaction (ASR) in reinforced concrete structures at Seabrook Station. The NRC's program for overseeing the safe operation of commercial nuclear power reactors is described in NUREG-1649, "Reactor Oversight Process," Revision 4, dated December 2006.

Cornerstone: Mitigating Systems

During this inspection the team examined six of the 11 commitments identified in CAL No. 1-2012-002, dated May 16, 2012. These commitments involve actions taken and planned by NextEra to address the degradation of reinforced concrete structures at Seabrook Station due to ASR. Based upon the team's onsite inspection activities and detailed in-office reviews, the team closed CAL Items #1, #3, #5, #6, and #10. The team reviewed CAL Item #2, but did not close this item based upon additional actions needed by NextEra to appropriately address and document this issue. The details of the team's review of each CAL item and the observations pertaining to the adequacy of NextEra's actions to address their commitments to the NRC, to date, are documented in the enclosed report.

The team determined during this inspection that NextEra does not plan to finalize their structural evaluations and operability assessments until: 1) the degree of ASR degradation on station reinforced concrete structures is appropriately reconciled with the station design and licensing basis; and 2) the progression of ASR is appropriately monitored to ensure structural integrity and operability is maintained for the duration of the current operating license. Further, the team determined that NextEra's current position is that no reinforced concrete structure at Seabrook Station will be precluded from monitoring for the affects of ASR until a satisfactory petrographic examination has been completed on that structure to confirm the absence of ASR.

The team acknowledged NextEra's plans to conduct structural performance testing of large scale test specimens (both control and ASR-affected) and then apply the test data to evaluate the current impact of ASR on Seabrook Station concrete structures and to develop appropriate actions for the continued monitoring of the ASR-affected structures. The adequacy of NextEra's proposed test program will be evaluated during the second CAL follow-up inspection, in accordance with CAL Item #8. The adequacy of NextEra's current Structures Monitoring Program will be evaluated coincident with the team's review of CAL Item #9.

As discussed in Section 9.0 of the enclosed report, the team identified additional issues for follow-up during the second inspection. These issues and the remaining CAL items will be examined and assessed for adequacy prior to the closeout of CAL 1-2012-002.

REPORT DETAILS

1.0 Background

Alkali-Silica Reaction (ASR) is a chemical reaction occurring in hardened concrete that can change the physical properties of the concrete and potentially affect structural performance. In June 2009, NextEra identified potential degradation in below grade concrete structures at Seabrook. In August 2010, NextEra completed petrographic evaluation of concrete core samples which confirmed ASR as the degradation mechanism. The degraded condition in Seabrook Category I structures was evaluated in the Corrective Action Program via a prompt operability determination (POD) in September 2010, and revised in April 2011, September 2011 and May 2012. The initial PODs (Revisions 0 and 1) addressed the B electric tunnel (AR 581434) where ASR was first discovered. Five other buildings were identified as part of the extent-of-condition (EOC) review and the evaluation of core samples taken from these structures (AR 1664399). The PODs were updated as new information became available and revised analytical techniques were incorporated.

NextEra initially used the results of mechanical testing of concrete cores to assess the degree of structural degradation due to ASR. This is the traditional method described in American Concrete Institute (ACI) 228.1R for assessing existing concrete structures. NextEra tested the cores for compressive strength and elastic modulus. NextEra used the methods defined in construction and design code ACI 318-1971 to evaluate the structural capacity (operability) of the ASR-affected buildings. However, the mathematical relationships in ACI-318 are based on empirical data from testing of non-degraded concrete and these relationships may not hold true for all stages of ASR-affected concrete.

After further review of industry experience and literature pertaining to ASR, NextEra engineering concluded that the core test data was not indicative of structural performance of ASR-affected reinforced concrete structures. NextEra's engineering evaluation stated that once the cores are removed from the structure, concrete core samples are no longer subject to the strains imposed by the ASR-related expansion or restraints imposed by the steel reinforcing cage. The engineering evaluation also stated that confinement provided by steel reinforcing bars (rebar) and other restraints limit ASR expansion of the concrete within the structure and thereby limit the adverse impact on structural performance. Therefore, NextEra engineering concluded that the reduction of mechanical properties observed in mechanical testing of cores was not representative of in-situ concrete performance. NextEra's current position is that the testing of core is only useful as a diagnostic tool to confirm the presence of ASR. Based on this engineering judgment, NextEra stopped taking cores to evaluate the concrete mechanical properties of structures impacted by ASR and revised the operability assessment approach. NextEra's current approach for assessing structural integrity and operability is to compare available design margins to an assumed reduction in structural capacity due to ASR.

The extent of ASR at Seabrook was documented in a baseline walkdown review of station structures. The review identified the visual signs of ASR through the presence of crack patterns, ASR gel in wet and powder forms, and/or discoloration/dark staining. NextEra's walkdown objectives were to: identify and assess apparent ASR degradation including estimated expansion; identify the condition of concrete in the vicinity of supports that show ASR

distress; and identify the current or past areas of water intrusion. The walkdown results were entered into the corrective action program (AR 1757861) and have established NextEra's current baseline condition assessment of Seabrook structures, in conjunction with six-month crack indexing measurements on selected structures to trend the progression of ASR and possibly establish a rate of expansion.

NextEra's operability evaluations were based upon an examination of available design margins and a presumed ASR reduction in structural design capacity for critical limit states. The details of this methodology and related assumptions were developed in NextEra's Interim Assessment (FP 100716). The assessment assumed lower bound values for potential reductions in structural design properties (limit states) based on research test data from primarily small scale test specimens. The assessment focused on the structural design properties that are the most sensitive to ASR effects (i.e., out-of-plane shear capacity, lap splice development length, and anchorage capacity). The assessment determined the structures were suitable for continued service pending further evaluation of structural performance based on a proposed large scale testing program of beam specimens representative of Seabrook reinforced concrete structures. The test program has been initiated at the Ferguson Structural Engineering Laboratory at the University of Texas at Austin (UT-A), with testing targeted to be completed in 2013 and the results reported in 2014.

2.0 Confirmatory Action Letter 1-2012-002

Confirmatory Action Letter (CAL) 1-2012-002, dated May 16, 2012, was written to confirm commitments by NextEra (established during a meeting with NRC management and staff on April 23, 2012) with regard to planned actions to evaluate ASR-affected reinforced concrete structures at Seabrook Station. In response to the CAL, NextEra committed to provide information to the NRC staff to assess the adequacy of NextEra's corrective actions to address this significant condition adverse to quality. CAL 1-2012-002 is provided as an Enclosure to this report. The NRC staff also formed a working group to provide appropriate oversight of NextEra's activities to address ASR and to coordinate NRC inspection and review activities. The ASR Working Group Charter (ML121250588) outlines the regulatory framework and general acceptance criterion for NRC oversight and review of this issue.

Based on the results of this inspection, CAL Items #1, #3, #5, #6, and #10 are closed; CAL Item #2 is updated; and CAL Items #4, #7, #8, #9, and #11 remain open pending NRC review in the second CAL follow-up inspection (Report No. 05000443/2012010).

3.0 Review of Operability Determinations and the Interim Assessment (CAL Items #1, #3, and #5)

Comment [A3]: CLARITY: consider putting the CAL # in parentheses next to the titles in this subsection. It is not readily apparent to the reader which CAL item is being referenced, especially in the paragraphs such as "shear strength" and "anchorage"

Also – consider adding the actual CAL language at the beginning of each of the sections that refer to CAL item.

3.1 Inspection Scope

The team reviewed the PODs for the B Electric Tunnel of the Control Building (POD 581434) and buildings identified in NextEra's extent-of-condition review (PODs 1664399 and 1757861). As discussed in Section 1.0 above, these PODs were revised to reflect a change in the approach taken by NextEra to evaluate the structural integrity of the station reinforced concrete buildings. Revision 2 of the PODs provides the current quantitative and qualitative analyses of

the ASR-induced changes in structural performance, as further detailed in the licensee's Interim Assessment. The team reviewed the supporting documentation for each significant structural design attribute and conducted multiple interviews and discussions with the responsible NextEra engineering staff and consultants. The team used 10 CFR Part 50, Appendix A (General Design Criteria 1, 2, and 4), and 10 CFR Part 50, Appendix B, Criterion XVI, "Corrective Action," and Criterion XI, "Test Control," as the regulatory basis to assess the adequacy of NextEra's actions to address ASR effects on safety-related Category I and in scope Maintenance Rule reinforced concrete structures. The team used NRC Inspection Manual, "Part 9900 – Operability Determination and Functionality Assessments for Resolution of Degraded or Nonconforming Conditions Adverse to Quality or Safety," to evaluate the licensee's approach to assessing this significant condition adverse to quality.

The extent-of-condition POD (Revisions 0 and 1) initially addressed five structures (AR 1664399). These five structures included the containment enclosure building (CEB), the access tunnel to the radiologically controlled areas (RCAW), the emergency feedwater (EFW) pump house, the residual heat removal (RHR) equipment vault (EV), and the diesel generator building (DGB). During implementation of ASR Structures Walkdown (FP 100705), NextEra identified additional structures with localized areas of patterned cracking, including: the condensate storage tank enclosure, the control building air east intake, the service water cooling tower, the A electrical tunnel, the fuel storage building, the east pipe chase, the west pipe chase, the pre-action valve room, the primary auxiliary building, the service water pump house, the mechanical penetration area (which includes portions of the outer containment wall, AR 1804477), and the waste processing building (AR 1757861).

The team conducted a detailed review of Foreign Print (FP) 100716, "Seabrook Station: Impact of Alkali-Silica Reaction on Concrete Structures and Attachments," Revision 1, which is the initial evaluation of concrete structures at Seabrook Station and provides the basis for continued operability of affected structures for an interim period. As documented in FP 100716, NextEra's interim evaluation will be followed by a second evaluation that "will assess the long-term adequacy of the concrete structures considering the results of the full-scale structural testing program, other in-progress test programs, and results from periodic monitoring of the structures."

3.2 Findings and Observations

The team identified no findings in this area and CAL Items #1, #3 and #5 are closed. Based on a detailed review of the PODs, referenced white papers and associated engineering analyses, including an independent verification by the team of a number of supporting calculations, the team determined NextEra's interim operability bases were appropriate. Given the current known extent of ASR, there is reasonable expectation that the affected reinforced concrete structures at Seabrook Station will remain capable of performing their intended functions for an interim period, while NextEra continues to monitor the condition and complete detailed testing and further engineering analyses (expected to be completed by mid-2014).

The team noted that the areas identified by NextEra to be affected by ASR are generally localized (i.e., part of a wall, not the entire wall or structural member exhibits evidence of ASR). Even though the identified ASR areas are localized, NextEra's engineering evaluations

conservatively assume the entire structure or structural member (wall) is adversely affected. Assuming an entire structural member is affected allows for a direct comparison to the original design calculations of record. Noteworthy observations pertaining to the team's review of the PODs and Interim Assessment follow:

3.2.1 Operable, but Degraded (Below Full Qualification)

Based upon a detailed review of the quantitative and qualitative analyses documented in the PODs and Interim Assessment, the team determined NextEra had appropriately demonstrated that the ASR impacted structures were operable, but degraded and below full qualification. NextEra demonstrated that the structures would maintain structural integrity for design basis loads and load combinations for normal, accident and environmental extreme conditions (including seismic) for an interim period.

The team observed that 26 locations (including containment) had been identified via NextEra's ASR Structures Walkdown as having patterned cracking with a combined crack index (CCI) of greater than 1.0 mm/m. Per the Structures Monitoring Program (EDS 36180, Revision 2), Attachment 3, revised in July 2012, a CCI of >1.0 mm/m requires a structural evaluation. NextEra's Interim Assessment, Section 2.1.2 documents an engineering judgment that biased the performance of detailed structural evaluations to the 11 locations with a CCI > 1.5 mm/m. Although not explicitly stated in Section 2.1.2, the team learned from discussions with NextEra engineers that the locations with a CCI of between 1.0 and 1.5 mm/m (13 locations) were considered bounded by the 11 areas subjected to a detailed evaluation. The lack of a documented structural evaluation for the 13 locations with a CCI of between 1.0 and 1.5 mm/m was considered a minor performance deficiency. NextEra acknowledged this procedural implementation error and entered the issue into their Corrective Action Program (AR 1804477 and AR 1819080). A structural evaluation was completed for containment and reviewed by the team prior to the completion of the inspection period (see Section 3.2.8). However, the evaluations for the remaining locations are yet to be completed by NextEra. The team will examine these evaluations in the next CAL follow-up inspection report.

Near the conclusion of this inspection, NextEra completed a POD for containment (AR 1804477). Preliminary review by the team identified areas for follow-up during the second CAL follow-up inspection. Specifically, the team plans to assess NextEra's evaluation of the potential for ASR-induced pre-stressing of rebar (reference Section 3.2.8) and to review NextEra's future plans for monitoring the localized areas (three) of presumed ASR (not verified by a petrographic exam) on the containment outer wall. NextEra's current monitoring plans for the containment wall areas are documented in FP 100647, "Crack Index Determination." (See Section 6.0 of this report for additional information and team observations concerning Crack Indexing.)

3.2.2 Concrete Material Properties - Compressive Strength and Elasticity Modulus

As discussed in Section 1.0, NextEra stopped taking core samples to evaluate ASR-affected structures. Notwithstanding, Revision 2 of POD 581434 for the B electrical tunnel, concluded that there is no loss of concrete compressive strength due to ASR. This conclusion was based on testing of 15 cores (12 ASR-affected concrete and 3 control locations). NextEra concluded

that ASR had increased the stiffness of the electric tunnel walls because the compressive strength in the ASR impacted concrete was higher than in the control core samples. [The team notes that this conclusion is different than the 22 percent measured compressive strength reduction (compared to the 1979 cylinder test results) that had been previously identified by NextEra from initial core sample results and reported in NRC Inspection Report 05000443/2011007.] Team review of the available supporting concrete core data during this inspection did not validate NextEra's current conclusion.

Comment [A4]: CLARITY: This appears to disagree with the statement in the cover letter that the methods were "technically sound and generally comprehensive". To the reader, the statement seems to "hang" without further discussion following an unfavorable-seeming conclusion. Consider adding a qualifying follow-up statement. How does this lack of agreement from the staff result in a conclusion that the methods were technically sound?

As-built concrete compressive strength can vary due to variations in the mixture (aggregate, sand, cement, and water) and the curing process. Consequently, design and construction specifications were developed to ensure, in spite of this variability, that concrete specified and used in reinforced concrete structures meets acceptable standards of performance. In addition, concrete strength is expected to increase with age and curing. The team also notes that additional inaccuracies are introduced via the core sampling process and associated testing methods. Accordingly, team examination of the 2011 core sample compressive strength values and measured cylinder strength values from 1979 (two percent lower), lead the team to conclude there is neither a significant loss or increase in compressive strength in the ASR-affected B electrical tunnel concrete material properties. Team review of core sample measured modulus of elasticity values identified that although individual cores showed a modulus that was reduced (compared to design), the average modulus value in the RCA walkway, RHR equipment vault, EFW pump house and DGB was within 20 percent of the design modulus value ($\pm$20 percent is acceptable by ACI 318). For the CEB, the average modulus was just beyond (low) the 20 percent allowable. Based upon available core sample results, the team considered the ASR effect on elasticity modulus inconclusive, also.

Comment [A5]: CLARITY: not clear to the reader - two percent lower than what?

Comment [A6]: CLARITY: significant loss or increase in compressive strength - from what starting point?

Overall, the team concluded that the core sampling and associated mechanical testing completed, to date, has not conclusively established the current impact of ASR on concrete material properties. While the team acknowledges that the core sample results may not represent in-situ concrete structural performance, as NextEra has concluded, the core samples and test results (mechanical and petrography) may still provide valuable information and insights relative to the impact (relative degree and progression) of ASR on reinforced concrete structures. Consequently, the team plans to examine core sampling in the second CAL follow-up inspection, with respect to core sample test results being used to understand ASR effects on ACI Code relationships and the overall adequacy of the Structures Monitoring Program. .

3.2.3 Flexural Capacity and Dynamic Response

NextEra completed a comparative study of the Containment Enclosure Building (CEB) (FP 100714 and FP 100715) which evaluated the effects of reduced elastic modulus on seismic response. The CEB was chosen for detailed analysis because it conservatively bounds other site structures due to its relative size and dynamic loading. The CEB parametric study included: an evaluation of the building in a static, three-dimensional finite element analysis (FEA) to determine the response (forces and moments) to operating basis earthquake and safe shutdown earthquake seismic loads before and after ASR damage; a calculation of the wall section capacities; a calculation of demand-to-capacity ratios (DCR); and, a comparison of the DCRs of ASR-affected walls to unaffected walls. Based upon assumed bounding conditions and the assumed state of ASR degradation used in the FEA model, the analyses showed that the seismic acceleration profiles, in-structure response spectrum, and distribution of forces and moments were not significantly impacted. The effect of the lower modulus values on the response of below-grade, ASR-impacted structures was evaluated in Calculation C-S-1-10163. For these below grade structures, NextEra determined that the dynamic structural response remained in the rigid range with no appreciable amplification of the ground response spectra.

Based upon the above, NextEra concluded that the seismic response of the CEB, along with the attached equipment (cable trays and supports) and anchor loads remained practically unchanged due to the assumed ASR effects. The team concluded that NextEra's assessment of this ASR-affected structural design attribute was appropriate for an interim operability determination.

Comment [A7]: OPERABILITY: No discussion of the staff's opinion on what NextEra did. If we found it accebptable, why? Is it only okay on an interim basis? Will the applicability or appropriateness expire?

3.2.4 Shear Capacity

NextEra analyzed the impact of ASR on the B electric tunnel using an FEA in calculation FP 100730 to determine refined structural demand and to compare the shear capacity versus demand for seismic and hydrodynamic loads. NextEra assumed a lower bound 25 percent reduction in out-of-plane concrete shear capacity due to the effects of ASR on walls without shear reinforcement. The team noted that NextEra's design calculation (CD-20, dated 3/28/83) used the average 28-day compressive strength value (5459 psi) to establish that the design shear capacity exceeded the design load/demand. However, the FEA-based calculation used the specified design concrete strength of 3000 psi to compare the available design capacity to design load. The use of the 3000 psi vice 5458 psi value in the FEA identified that adequate margin was available using the as-built specified concrete compressive strength. The team notes that the FEA is a more precise computational design method than the manual methods used in the 1983 design calculation. The team notes that NextEra identified, but did not credit, additional conservatism in their margins analysis based upon the B electrical tunnel average measured core sample compressive strength value of 5140 psi. NextEra's FEA-based evaluation concluded that adequate margin was available to account for the lower bound ASR effect on out-of-plane concrete shear capacity. The team acknowledges that: 1) some additional margin may be credited due to the compressive strength of core samples exceeding the design minimum value of 3000 psi; and 2) the use of a 25 percent reduction in shear capacity, as a lower bound ASR effect, was appropriate for the assessment of this limit state. The team viewed the use of an FEA to assess shear capacity and the lower bound ASR effects as appropriate for the interim operability assessment.

Comment [A8]: CLARITY: Consider plainer language, as "lower bound" and "upper bound" are confusing, to explain the rationale for using a 25% reduction

Comment [A9]: OPERABILITY: Same as comment above.

3.2.5 Review of Finite Element Analysis Modeling

As discussed in Sections 3.2.3 and 3.2.4 above, NextEra used a linear elastic FEA to evaluate the effects of ASR on certain structures and design attributes. The team noted that the input data for the compressive strength and modulus of elasticity for the CEB model were determined based on a visual examination of CEB walls and only a few directly obtained core sample material properties. The observed crack patterns/dimensions on the CEB were correlated by NextEra to a damage rating index (DRI) and associated concrete material properties from test data obtained from core samples taken from several different structures. The input data for poisson ratio was derived exclusively from research data. NextEra acknowledged the limitations of this input data, but in FP 100696 deemed the approach justified because the analysis was a parametric study of the CEB seismic response, comparing design values to ASR-affected values. The team concluded the application of the FEA to a parametric analysis was useful for providing a reasonable expectation of operability for the interim period, but not conclusive with respect to identifying a current or projected state of ASR impact. For example, the team noted that the boundary conditions used at and below elevation zero-foot of the CEB FEA model may need to be re-evaluated and better justified, considering the seismic isolation of the structure wall (separated from the concrete backfill by the waterproofing membrane). The team concluded that the use of a FEA model with more accurate concrete material property data and more representative boundary conditions may be appropriate for a final operability assessment.

Comment [A10]: OPERABILITY: Why was it useful and reasonable but not conclusive?

Comment [A11]: OPERABILITY: Why does this need to be re-evaluated or better justified?

Comment [A12]: OPERABILITY: interim operability vs. final operability vs. Operable. Why is it okay now?

3.2.6 Anchorage

NextEra evaluated the impact of ASR-affected concrete on the performance of anchorage, including both expansion and undercut post-installed anchors. The potential impact of micro-cracking caused by ASR can negatively impact the structural capacity of anchorages and embedments supporting safety-related components. NextEra's interim operability evaluation was supported by anchor performance testing conducted on ASR degraded UT-A test specimens (FP 100718). The tests showed satisfactory performance of the anchors in ASR-affected concrete. NextEra's evaluation illustrated that the assumed lower bound reduction in capacity due to ASR was offset by established anchor manufacturer's design margins (FP 100716). The team concluded that NextEra's interim anchorage operability assessment was satisfactory. However, based upon the limitations of the testing performed, to date, (on ASR-affected test specimens of different composition and compressive strength than Seabrook structures) NextEra plans to conduct further testing. Planned testing involves anchors installed in ASR-affected test specimens that more closely reflect the reinforced concrete structures and anchor configurations at Seabrook.

Comment [A13]: CLARITY: Same comment: Consider plainer language, as "lower bound" and "upper bound" are confusing

Comment [A14]: OPERABILITY: Same Comment as above: No discussion of the staff's opinion on what NextEra did or on the results. If we found it accebptable, why? Is it only okay on an interim basis? Will the applicability or appropriateness expire?

Comment [A15]: OPERABILITY: What is the NRC's position on this testing? Do we agree with the licensee?

3.2.7 Lap Splice Strength

Section 6.3 of NextEra's Interim Assessment addressed reinforcement lap splice degradation as another design attribute impacted by ASR. In accordance with the licensee's lower bound value of a 40 percent reduction in lap splice strength, NextEra's review of design calculations identified several structures with insufficient margin to accommodate this assumed ASR affect. NextEra was able to "recover" margin by adjusting the ACI 318 prescribed design load factors for predicted dead load and/or hydrostatic load. NextEra's term "recover" represents examining the design calculations and determining the accuracy of the predicted loads; if the predicted load can be more accurately quantified, then it is appropriate to remove the load factor (LF) from the associated load/demand calculation. By ACI 318, the LFs account for the uncertainty in accurately predicting the structural loads. The team examined this method and found it satisfactory for the interim operability assessment, but concluded it would not be acceptable for a final operability determination under the current licensing basis. The final operability assessment requires full conformance with the ACI design methodology or revision to the licensing basis.

Comment [A16]: CLARITY: Same comment as above: Consider plainer language, as "lower bound" and "upper bound" are confusing, to explain the rationale for using a 40% reduction

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Comment [A17]: OPERABILITY: Same Comment as above: No discussion of the staff's opinion on what NextEra did or on the results. If we found it accebptable, why? Is it only okay on an interim basis? Will the applicability or appropriateness expire?

Comment [A18]: OPERABILITY: Why is it okay now?

3.2.8 Concrete Confinement and Rebar Pre-Stressing

Team review of FP 100716, Sections 2.1.2 and 4.1.3, identified that the Interim Assessment stated, "Since ASR has a negligible impact on structural demand, the impact of ASR on structures and structural attachments can be assessed solely on the basis of changes in capacities." The team observed that restraint to ASR expansion, from concrete confinement by reinforcement (in two or three dimensions) and/or other external constraints, may cause internal pre-stress in the structural member. The consequence may increase compressive stresses in concrete and increase tensile stresses in the rebar, as long as the restraint is sustained. The team observed that NextEra has only addressed this ASR-induced pre-stress qualitatively in FP 100716 and in the containment structural evaluation (AR 1804477). The team's preliminary engineering judgment is that a quantitative evaluation is more appropriate for a final operability assessment of this condition. Further, it should be recognized that the ASR-induced pre-stress varies with time, depending on the degree of restraint and may not be sustained throughout the service life of an affected structure. Accordingly, any potential beneficial effect should not be relied upon or credited in design.

Comment [A19]: OPERABILITY: Why?

The team acknowledges NextEra's conclusion that ASR-induced pre-stress may result in some beneficial effects in terms of structural stiffness. However, the team's judgment is that this structural demand should be quantified (if practicable) and accounted for in the design calculations as a known load. Quantifying, or otherwise approximating the ASR-induced pre-stress, is similar to accounting for the pre-stress load in pre-stressed concrete design. This issue will be reviewed by the team in the second CAL follow-up inspection.

Comment [A20]: OPERABILITY/CLARITY: How does this relate to operability?

3.2.9 Condition of Rebar

The team examined information gathered and assessed by NextEra with regards to the condition of rebar and any potential erosion or corrosion due to ASR and water in leakage through below grade reinforced concrete structures. The team observed that NextEra had purposefully removed an area of surface concrete in the B electrical tunnel (chronically wet) to examine the condition of the rebar. The engineering staff identified no degradation of the rebar (no oxidation or signs of distress). The team also learned that in the course of removing core samples, in two instances the drill nicked rebar. Examination of the rebar sections removed determined the steel to be in excellent condition (unaffected by ASR or moisture).

Preliminarily, NextEra has concluded that the condition of rebar in ASR degraded concrete should be unaffected unless the cracking becomes deleterious and exposes the rebar to oxidation mechanisms. Otherwise, the alkaline condition within the concrete should prevent any corrosion mechanisms. The NRC continues to evaluate the need for any additional rebar intrusive monitoring or testing, and will evaluate this issue in the second CAL follow-up inspection.

Comment [A21]: OPERABILITY/CLARITY: Same comment as above: How does this relate to operability?

4.0 Review of Alkali-Silicon Reaction Root Cause Evaluation (CAL Item #2)

4.1 Inspection Scope

The team reviewed NextEra's response to this CAL Item, "Submit the root cause for the organizational causes associated with the occurrence of ASR at Seabrook Station and related corrective actions by May 25, 2012." The licensee submitted their root cause evaluation (RCE) via letter dated May 24, 2012. The purpose of the team's review was to assess the adequacy of the licensee's evaluation of the root cause for the ASR issue at Seabrook and the significant contributing causes. The team also examined the methodology and thoroughness of the licensee's evaluation and associated corrective actions as outlined in 10 CFR Part 50, Appendix B, Criterion XVI, "Corrective Action."

4.2 Findings and Observations

This CAL Item will remain open pending NRC review of NextEra's final RCE. NextEra identified two root causes: 1) ASR developed because the concrete mix design unknowingly utilized an aggregate that was susceptible; and 2) the monitoring program for plant systems and structures does not contain a process for periodic reassessment of failure modes. A contributing cause identified by NexEra was the failure to prioritize groundwater elimination or mitigation resulting in more concrete areas exposed to moisture. The team made observations regarding the level of detail and clarity of NextEra's root cause evaluation.

The team acknowledges that the first licensee identified root cause involved the use of susceptible aggregate in the concrete mix design that was undetected by the testing specified by American Society for Testing and Materials (ASTM) construction standards, at the time (late 1970's). Since this time, the role of slow reacting aggregate in ASR has been identified in the construction industry and standard tests are now available to ensure slow reactive aggregates would be properly identified prior to use in construction. The team concluded that this causal factor was beyond the licensee's control.

The team concluded that the second root cause was not adequately characterized in NextEra's May 24, 2012, submittal. Specifically, NextEra did not clearly state the personnel and organizational factors that led to inadequacies in the Structures Monitoring Program (SMP). The team discussed the absence of any human performance aspects in the description of this causal factor and NextEra initiated a revision to the RCE to more appropriately develop and characterize this second root cause and the associated corrective actions. NextEra plans to submit the revised RCE for NRC review. The team will review this revision in the next CAL follow-up inspection report.

The team also noted that NextEra excluded a contributing cause, identified in the RCE, from the evaluation executive summary and May 24, 2012, letter. As stated in the RCE, this contributing cause involved the longstanding "organizational mindset" that groundwater infiltration was more of an "operational nuisance" than a structural integrity concern. This station and engineering staff view prevented a more timely and thorough investigation and examination of the affected concrete reinforced structures on site. NextEra acknowledged this observation.

5.0 Review of Mortar Bar Testing (CAL Item #6)

5.1 Inspection Scope

The team reviewed the results of NextEra recently completed short term expansion testing of mortar bar specimens per test procedures SGH-Z001-12 and SGH-Z002-12. The results of the testing were evaluated per ASTM C1260. The licensee initiated the testing to establish and compare the reaction rates of ASR-affected concrete to non-ASR-affected concrete on site. The tests were performed by a consultant at an offsite facility. The mortar bar specimens were made using the aggregate extracted from core samples taken from ASR-affected structures and non-affected concrete from a slab removed from the waste processing building. NextEra noted that the non-affected concrete slab used for aggregate extraction had shown no visible indications of ASR and was not petrographically examined. The details of the testing are documented in SGH Report 120110-RPY-01 (FP 100734). The team reviewed the SGH report and associated test documents to ascertain the adequacy and technical validity of the testing.

5.2 Findings and Observations

No findings were identified and CAL Item #6 is closed. The test results indicated that both affected and non-affected concrete specimens contained ample reactive aggregate to sustain ASR. The team notes that normal test duration is 14 days and that a specimen expansion of >0.1 percent indicates reactive aggregate, per ASTM C1260. Test results identified that the non-ASR-affected specimens exceeded the 0.1 percent threshold in 5 days and the ASR-affected specimens exceeded the 0.1 percent threshold in 7 days. NextEra allowed the test to extend to 103 days and both specimen types continued to demonstrate active expansion due to ASR. Accordingly, NextEra concluded that there remains the potential for future volumetric expansion due to ASR in concrete structures at Seabrook.

Based upon the Mortar Bar Testing results, NextEra plans to revise their commitment to conduct Prism Testing. Prism Testing is similar to Mortar Bar Testing, but a longer term test of the susceptibility to ASR of aggregate used in concrete. NextEra had hoped to establish, via the Mortar Bar Test, a difference in the remaining versus available concrete constituents for ASR in the specimens. The results demonstrated ample reactive materials in both specimen types and NextEra concluded the Prism Test will not provide any additional ASR insights. The team had no additional observations and will review the revised Prism Testing commitment when it is submitted.

6.0 Review of Crack Indexing (CAL Item #10)

6.1 Inspection Scope

The team conducted a review of FP 100647, "Crack Index Determination," Revision 1, to understand the methodology for NextEra's monitoring of ASR progression in selected reinforced concrete structures. NextEra's commitment to this methodology is documented in CAL Item #10. The team used 10 CFR Part 50, Appendix B, Criterion V, "Instructions, Procedures, and Drawings," to evaluate the implementation and adequacy of the procedural guidance. The team's review was limited in scope, in that, the adequacy of this process, as the sole means of monitoring ASR progression in Seabrook structures, is still under NRC review. The team will evaluate this aspect as part of the review of CAL Item #9, the Maintenance Rule Structures Monitoring Program, during the second CAL follow-up inspection.

The team observed field measurements taken on June 20, 2012, by the responsible contractor and discussed the general methodology and procedural guidance with the individuals performing the crack indexing measurements and supervising NextEra staff. The team noted that NextEra found ASR patterned cracking in many areas within Seismic Category I and Maintenance Rule structures, but only a limited number of these areas have sufficient ASR degradation to merit continued monitoring and detailed evaluations. The ASR walkdowns identified 131 locations with some level of pattern cracking. Of the 131 localized areas, 26 exceeded the initial screening criteria of a combined crack index greater than 1.0 millimeter per meter (mm/m). The 1.0 mm/m threshold was established in the Structures Monitoring Program, Attachment 3, for conducting a structural evaluation. These 26 areas will continue to be monitored at six-month intervals, per FP 100647.

6.2 Findings and Observations

No findings were identified and CAL Item #10 is closed. The team noted that the periodic crack indexing provides the principle method selected by NextEra to monitor the progression of ASR on reinforced concrete structures. The six-month interval measurements are currently planned until a reliable trend of ASR progression can be established, per Structural Engineering Standard Technical Procedure 36180, "Structures Monitoring Program," Attachment 3, Revision 2. As stated above, additional NRC review of the SMP will be conducted in the second CAL follow-up inspection.

Comment [A22]: LR: This section poses some concerns for license renewal. It is not clear to the reader that the NRC may not find crack mapping acceptable, and re-statement of the licensee's approach here appears to imply endorsement

The team also reviewed the current methods and terminology used by NextEra to characterize the degree of ASR pattern cracking, previously addressed in NRC Inspection Report 05000443/2011007. When ASR was initially identified in the B electrical tunnel in mid-to-late 2010, the licensee referred to the Federal Highway Administration (FHWA) guidance document FHWA-HIF-09-004 for crack/damage characterization. Three major categories were identified: mild, moderate, and severe, with ratings such as mild to moderate and moderate to severe, also used. Per FHWA-HIF-09-004, these categories were used to define the recommended remedial actions to be taken once ASR was identified. At that time, NextEra labeled the observed cracking as "severe." Per the FHWA guidance, this category requires "further investigation for selecting remedial actions." This characterization was repeated in the above referenced inspection report. The team determined that NextEra revised their crack

characterization scheme prior to the implementation of the structures extent-of-condition review. The revised crack rating system was based upon "best practices" taken from the Building Research Establishment (BRE) in the United Kingdom (UK). The revised numeric rating system range is from 0 (no cracking detected) to 6 (heavily fractured ASR-related damage). FP 100636, "Petrographic Examination PE Reports," Revision 0, lists the material property results of all core samples taken and petrographically analyzed. FP 100636 also provides the BRE crack rating for each specimen examined. The crack ratings for the specimens examined range from 0 to 4 (a rating of 4 represents severe cracking). A summary table with each numeric rating and its definition is documented in the Supplemental Information attachment to this report.

Comment [A23]: LR: Same comment as above. It appears as though we are closing out the item with the understanding that Crack Mapping will be used by the applicant and accepted by the NRC. Problems could arise for license renewal if DLR does not accept crack mapping, consider leaving this item Open (Also DLR does not understand why it is being closed when there is ongoing review)

7.0 Review of Alkali-Silica Reaction Structures Walkdown/Baseline Assessment

7.1 Inspection Scope

The team examined NextEra's program documents FP 100642, "ASR Walkdown Scope," Revision 1, and FP 100705, "Seabrook Station: Summary of Alkali Silica Reaction Walkdown Results," Revision 0. The team reviewed the walkdown scope and examination criteria and the associated field data, photographic evidence, and analysis of NextEra's observations, as documented in FP 100705. The walkdown scope included Seismic Category I and some in scope Maintenance Rule structures. NextEra's walkdown is being conducted in three phases. Phase 1 involved examination of readily accessible areas of interest; Phase 2 included examination of coated surfaces identified during Phase 1 inspections (coatings had to be removed to expose the concrete surfaces); and Phase 3 examines normally inaccessible structures/areas (e.g. high radiation, manholes, etc.) which have or will be inspected as the opportunity presents itself (e.g. routine maintenance or outage activities).

The walkdowns assess the extent of ASR throughout the plant with the primary objectives of: identifying and assessing any apparent degradation from ASR, including: estimating in-situ expansion (Crack Indexing); assessing whether concrete in the vicinity of supports for safety-related systems or components show any indications of ASR distress; and documenting and characterizing water intrusion or evidence of previous water intrusion, based upon water being a key contributor to concrete deterioration and distress caused by ASR. The visual criteria for documenting potential ASR indications include: typical patterned surface cracks in concrete; crack dimensions (width, length, orientation); evidence of water ingress/out-seepage (past/present); visual evidence of salt deposit and/or ASR gel; and indications of surface deterioration (i.e., pop-outs and/or spalling). Also, any expansion anchors or structural embedments located within 5 feet of the area of interest were examined and documented. The licensee considers their ASR walkdown efforts and observations a baseline condition assessment. This baseline will be used for monitoring the progression of ASR for the duration of the current operating license.

The team performed a number of independent walk-through inspections to verify and assess the thoroughness of the licensee's efforts. The team independently evaluated the extent-of-condition of ASR-affected structures that are readily accessible. The team used the expertise of a consulting structural engineer to assist in the team's review of the current condition of ASR-affected reinforced concrete structures at Seabrook Station.

Comment [A24]: LR: Potential impact on license renewal, and our implied endorsement to let the licensee use this as their extent of condition or baseline walkdown in LR space.

7.2 Findings and Observations

The team identified no findings. On a sampling basis, the team's independent walkdown observations were consistent with the licensee's observations and assessments. At Seabrook, the presence of ASR has been conclusively established by petrography in certain buildings (where core samples were obtained) and in other buildings by inference, using visual examination criteria. The team confirmed that NextEra's position is that all reinforced concrete structures on site are susceptible to ASR, dependent upon the exposure to moisture. Therefore, NextEra does not intend to exclude any structures from ASR monitoring without confirmation via petrography that ASR is nonexistent.

The complete list of structures and localized areas of ASR identified, to date, is documented in FP 100705, Revision 1. The team noted that the results of the walkdown inspection by NextEra were appropriately documented with extensive observation narratives and well supported by clear sketches and photographs. As NextEra completes Phase 3 examinations, the licensee plans to capture the additional observations through revisions to FP 100705. The team noted that the majority of localized areas of ASR are: 1) below grade walls subjected to either ground water intrusion, or particularly high spatial humidity; or 2) exposure to precipitation and high ambient humidity (some exterior above grade structures).

Based upon the team's review of the Phase 1 and 2 ASR walkdown results and via discussions with responsible engineers overseeing the proposed Phase 3 walkdown areas and tentative schedule, the team identified a minor oversight in the Phase 3 walkdown plan. Specifically, the upper elevations of the containment outer wall were not adequately examined for ASR during the Phase I review and not included in the proposed Phase 3 walkdown schedule. The team identified from discussion with the NextEra engineering staff, that the 2010 IWL examination of containment was being credited for part of the Phase 1 ASR walkdown baseline. The team's detailed review of the 2010 IWL inspection results and associated visual examination attributes (reference implementing procedure, ES 1807.031, "Inservice Inspection Procedure Primary Containment Section XI IWL,") identified that the 2010 IWL exam did not include sufficient examination criteria (i.e., active or pattern cracking) for identification of ASR. As evidence of the absence of ASR identification criteria in the IWL examination, during the subsequently performed Phase 1 ASR walkdown by consulting engineers, three locations of ASR related pattern cracking were identified on areas of the containment previously examined by the IWL inspectors. NextEra acknowledged this oversight in crediting the IWL examination and initiated action (AR 1819069) per the Corrective Action Plan. NextEra plans to revise the Phase 3 plan to address this concern. The team plans to examine the adequacy of the proposed Phase 3 changes and implementation schedule during the second CAL follow-up inspection.

8.0 Follow-up of Open Items

Comment [A25]: CLARITY: The information presented in this section provides much detail that would be useful in previous sections, to understand what the initial NRC concerns were, and how they have been addressed in the CAL. To a new reader unfamiliar with the background, this section provides context to other sections. Consider moving or stating some of this information earlier.

8.1 (Closed) Unresolved Item 05000443/2011003-03, Open Operability Determinations for Safety-Related Structures Affected by Alkali-Silica Reaction

This item was open pending NRC review of NextEra actions to revise operability determinations for the electric tunnel and other structures addressed in the extent of condition review for ASR.

The open aspects were as documented in Inspection Reports 2011-03 and 2011-10 related to: 1) effect of the reduced modulus of elasticity on natural frequency of the structures; 2) the effect of the modulus of elasticity on structure flexural response as related to components attached to the structures, such as pipe and cable supports and their anchor bolts; 3) related effects from increased flexure of building on the loading and seismic effects on safety-related pipes and cable tray supports; and, 4) effect of reduced parameters on the whole building (global) response of the CEB structure to seismic loads including further information of the effect on stress and strain in the concrete and rebar system. Following the reviews in Inspection 2011-10, the unresolved item remained open pending NRC review of additional information from NextEra on the effects on cable and pipe support anchors (number 3) and the effects on the CEB response (number 4).

The team reviewed the revised operability determinations for the safety related structures listed below and as described in POD 1664399, Revision 2.

- Control Building – "B" Electrical Tunnel,
- Containment Enclosure Building,
- Diesel Generator Building,
- Residual Heat Removal Equipment Vaults, and
- Emergency Feedwater Pump House

As part of the ASR extent of condition review, NextEra provided structural assessments for the RCA tunnel and other ASR impacted buildings (reference Calculation C-S-1-10168).

The open aspects of numbers 3 and 4 were resolved after NextEra provided additional information. Revision 2 of POD 581434 for the B electric tunnel (ET) provided additional quantitative and qualitative analyses with consideration of ASR-induced changes in concrete properties. The revised POD addressed the changes in modulus on building frequency; flexural response and capacity; shear capacity; and support anchors. The revised POD incorporated the results of the Interim Assessment (FP 100716) relative to the performance of reinforcing steel anchorage to show that postulated reductions in capacities were offset by conservatisms in ACI 318 Code and the assumed loads. The revised POD incorporated the testing at the Ferguson Structural Engineering Laboratory (FP 100718) of cast-in-place and drilled-in anchors to assess the impact of anchor performance in ASR-affected concrete. The test results showed that the anchor capacities remained above the theoretical capacity at crack indices well above the maximum CI observed in Seabrook structures. Finally, the revised POD for the ET also included consideration of a detailed evaluation of the CEB, chosen for detailed analysis because it conservatively bounds other structures in size and exhibits the highest reduction in modulus of elasticity due to ASR.

Further NRC review of this area is described in Sections 3.0 and 4.0 of this report. The team concluded that the initial failure of NextEra to adequately consider the ASR impacts on structural performance, relative to support anchors and dynamic response, were examples of minor performance deficiencies, in that, upon further evaluation these issues were determined to be acceptable as part of the interim operability assessment. This issue was also addressed broadly by the NRC in Finding FIN 05000443/2011-10-02. Unresolved Item 05000443/2011003-03 is closed.

Comment [A26]: LR: Comment (not necessarily suggest report change): "The issues were determined to be acceptable..." By whom? Why is this item closed? Justification for NRC closure of this item is unclear.

8.2 (Closed) URI 2011-010-01 – Adequacy of Calculation Methods for ASR

NextEra initially pursued mechanical testing of concrete cores because that was the traditional method as described in ACI 228.1R for determining properties of existing concrete structures. Upon further review of industry experience and literature for ASR-affected concrete, NextEra determined that the core test data was not indicative of structural performance of the ASR-affected structures. Once removed from the structure, the concrete in the cores is no longer subject to the strains imposed by the ASR-related expansion or restraints imposed by the reinforcing cage. Confinement provided by reinforcing steel and other restraints (e.g., deadweight of the structure) limits ASR expansion of the concrete within the structure, which reduces the extent of deleterious cracking and associated reduction of concrete material properties. NextEra has determined that the structural evaluations based on mechanical properties derived from core samples may under predict structural performance (FP 100697, Structural Assessment of ASR-State of the Art). Since the reduction of mechanical properties derived from testing of cores is not necessarily representative of the structural performance, NextEra changed its approach. For the interim operability assessment, NextEra compared the structural design capacities to design loads/demands and an assumed lower bound ASR effects. This interim operability assessment was based on available industry data from small scale test specimens having ASR degradation worse than that observed at Seabrook. For the final operability assessment, NextEra plans to monitor structures via Crack Indexing and pursue large scale testing of concrete components that are representative of the Seabrook ASR conditions to demonstrate overall structural performance and operability. The large scale testing will be conducted at the Ferguson Structural Engineering Laboratory (FSEL) at the University of Texas, Austin (UT-A).

NextEra responded to CAL Item #8 by letter dated June 21, 2012, and provided a broad overview of the testing planned at FSEL, which will include a shear test program, a lap splice test program, and an anchor test program. The test program will include control specimens that will provide a baseline by which to determine the reductions in capacity due to ASR and to quantify the margins available as calculated using ACI-318. NextEra plans to use the test program to reconcile the ASR condition with the licensing design basis, to inform the structures monitoring program, and to evaluate potential mitigation strategies. NextEra's actions, approach and methods used to resolve the ASR issue, including the proposed test program, will be evaluated by the team in the second CAL follow-up inspection. Unresolved Item 05000443/2011-010-01 is closed.

9.0 Conclusions and Follow-Up Issues

The team determined during this inspection that NextEra does not plan to finalize their structural evaluations and operability assessments until: 1) the degree of ASR degradation on station reinforced concrete structures is appropriately reconciled with the station design and licensing bases; and 2) the progression of ASR is appropriately monitored to ensure structural integrity and operability is maintained for the duration of the current operating license. Further, the team determined that NextEra's current position is that no reinforced concrete structure at Seabrook Station will be precluded from monitoring for the affects of ASR until a satisfactory petrographic examination has been completed on that structure to confirm the absence of ASR. As

discussed in the above sections, NextEra plans to complete performance testing of large scale test specimens and use the test results to finalize the structural operability assessments and modify the Structures Monitoring Program.

The team plans to conduct a second CAL follow-up inspection to review the remaining open CAL items and the open issues documented in this report and listed below:

- Review of pending structural evaluations, including follow-up of the containment POD observations (Section 3.2.1)
- Review of core sample material property testing and SMP (Section 3.2.2)
- Review quantification of pre-stressing effects of ASR expansion (Section 3.2.8)
- Assess the need for any further rebar examinations or testing (Section 3.2.9)
- Review revised RCE submittal (Section 4.2)
- Confirm revised commitment to CAL Item #7 (Section 5.2)
- Review Crack Indexing and its physical significance for SMP application (Section 6.2)
- Review revisions to the Phase 3 walkdown plans and schedule (Section 7.2)

10.0 Meetings, Including Exit

On November 2, 2012, the team conducted an exit meeting to discuss the preliminary findings and observations with Mr. Kevin Walsh, Site Vice President, and other members of Seabrook Station staff. The inspectors verified that no proprietary information was retained by the inspectors or documented in this report.

SUPPLEMENTAL INFORMATION

KEY POINTS OF CONTACT

Licensee Personnel
B. Brown, Design Engineering Manager
A. Chesno, Performance Improvement Manager
K. Chew, License Renewal Engineer
R. Cliché, License Renewal Project Manager
M. Collins, Design Engineering Manager
J. Connolly, Site Engineering Director
R. Noble, Project Manager
M. O'Keefe, Licensing Manager
T. Vassallo, Principal Design Engineer
K. Walsh, Site Vice President
P. Willoughby, Licensing Engineer

LIST OF ITEMS OPENED, CLOSED, DISCUSSED, AND UPDATED

Updated
None

Opened
None

Closed

05000443/2011-010-01	URI	Adequacy of Calculation Methods for ASR
05000443/2011-003-03	URI	Open Operability Determinations for Safety-Related Structures Affected by Alkali-Silica Reaction

LIST OF DOCUMENTS REVIEWED

Procedures
Maintenance Rule Scoping Document, Revision 0
EDS 36180, Structures Monitoring Program, Revision 0, 1, 2

Corrective Action Documents (AR)
1651969, 1629504, 574120, 581434, 1636419, 1673102, 1647722, 1664399, 1677340, 1687932, 1692374, 1698739, 1755727, 1757861, 1819080, 1804477, 1819069

Drawings

Licensing and Design Basis Documents and Calculations
Seabrook Station UFSAR, Revision 14
ACI 318-71
Calculation CD-20
Calculation CD-18
Calculation C-S-1-10168

Miscellaneous Documents
FP 100348, Statistical Analysis-Concrete Compression Test Data (PTL)
FP 100642, Scope for Alkali-Silica Reaction Walkdowns
FP 100641, Procedure for ASR Walkdowns and Assessment Checklist
FP 100661, Compression Testing Concrete Cores (WJE)
FP 100696, Material Properties of ASR-Affected Concrete
FP 100700, Field Investigation
FP 100705, Structure ASR Walkdown Report (MPR 0326-0058-58)
FP 100714, Three Dimensional Dynamic Analysis of Containment Enclosure Building
FP 100715, ASR Impact Study on Containment Enclosure Building
FP 100716, Interim Assessment: Impact of ASR on Structures (MPR-3727)
FP 100717, ACI 318-71 Perspectives
FP 100718, Anchor Test Report (MPR-3722)
FP 100720, Crack Index and Expansion Measurement
FP 100738, Measurements for ASR Crack Indexing on Concrete Structures
FP 100697, MPR 0326-0058-53, White Paper on Structural Implications of ASR: State of the Art, Revision 1
MPR 0326-0058-83, Shear Screening Criteria Used in MPR-3727
FHWA-HIF-09-004, Federal Highway Administration, “Report on the Diagnosis, Prognosis, and Mitigation of Alkali-Silica Reaction in Transportation Structures.”

LIST OF ACRONYMS

ACI	American Concrete Institute
ADAMS	Agencywide Documents Access and Management System
AMP	Aging Management Program
AR	Action Request
ASME	American Society of Mechanical Engineers
ASR	Alkali-Silica Reaction
BRE	Building Research Establishment
CCI	Combined Crack Index
CEB	Containment Enclosure Building
CFR	Code of Federal Regulations
CW	Circulating Water
DCR	Demand to Capacity Ratios
DGB	Diesel Generator Building
DRI	Damage Rating Index
DRP	Division of Reactor Projects
DRS	Division of Reactor Safety
EDG	Emergency Diesel Generator
EFW	Emergency Feedwater
EPRI	Electric Power Research Institute
EOC	Extent-of-Condition
ET	Electric Tunnel
EV	Equipment Valve
FEA	Finite Element Analysis
FHWA	Federal Highway Administration
FP	Foreign Print
FPL	Florida Power and Light
FSEL	Franklin Structural Engineering Laboratory
IMC	Inspection Manual Chapter
IP	[NRC] Inspection Procedure
LF	Load Factor
MPR	MPR Associates, Inc.
NRC	Nuclear Regulatory Commission
PARS	Publicly Available Records
P&ID	Piping and Instrument Diagram
PM	Preventative Maintenance
POD	Prompt Operability Determination
PRA	Probabilistic Risk Assessment
psi	pounds per square inch
QA	Quality Assurance
RCA	Radiologically Controlled Areas
RCE	Root Cause Evaluation
RHR	Residual Heat Removal
SDP	Significance Determination Process
SG&H	Simpson, Gumpertz & Heger
SMP	Structures Monitoring Program

SRI	Senior Resident Inspector
UFSAR	Updated Final Safety Analysis Report
UT-A	University of Texas - Austin
UK	United Kingdom
WO	Work Orders

A-5

NextEra Crack Rating Chart

Assessment of Severity of ASR in Hardened Concrete by Petrographic Examination

This rating system is based on a modified “best practice” procedure initially developed at tehe Building Research Establishment (BRE) in the United Kingdom, using ASR identification critieria first set out in the British Concrete Association report titled “The Diagnosis of Alkali-Silica Reaction,” (1992).

Rating	Description
0	No cracking detected
1	Very slight cracking (no evidence of deleterious ASR)
2	Slight cracking (minor or trace evidence of deleterious ASR)
3	Moderate cracking (moderate evidence of deleterious ASR)
4	Severe cracking (severe evidence of deleterious ASR)
5	Very severe ASR-related cracking
6	Heavily fractured ASR-related damage

Buford, Angela

From: Buford, Angela
Sent: Thursday, November 29, 2012 1:28 PM
To: Cheok, Michael; Murphy, Martin
Subject: FYI: Resolution of NRR Issues on Seabrook CAL Follow-up Report
Attachments: IR 2012-009 11-28-12 DLR Comments.docx

Michael and Marty, FYI.

As you know, NRR/DLR identified two global issues in the ASR inspection report:

(1) The use of the term "Interim Operability" and providing justification for the staff's acceptance of NextEra's assessments
(2) Concerns with the license renewal process being affected by close-out of CAL item #10, Crack Mapping, and the acceptance of the licensee's baseline ASR walkdown

To assist the Region in addressing these comments, I will be providing

(1) suggested verbiage for defining "interim operability" in the cover letter (that applies the licensee's term "interim operability" to the NRC process)
(2) an example of suggested wording to be used in the body of the report to characterize the NRC's acceptance in terms of operability and providing justification
(3) suggestion for wording or a footnote in Sections 6 and 7 of the report (crack indexing and baseline walkdown sections) to make it clear that the closeout/acceptance applies to this process only, and the same may not hold true for other licensing actions or NRC processes (i.e., License Renewal)

Attached is a copy of the latest inspection report that includes specific in-line comments of the nature described above.

Angie

Angela R. Buford | Structural Engineer
Division of License Renewal
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852
t: 301.415.3166
angela.buford@nrc.gov

B/72

Buford, Angela

From: Buford, Angela
Sent: Thursday, November 29, 2012 11:53 AM
To: Galloway, Melanie
Subject: IR 2012-009 11-28-12 DLR Comments.docx
Attachments: IR 2012-009 11-28-12 DLR Comments.docx

Melanie,

Electronic copy of the DLR management comments we discussed.

Buford, Angela

From: Buford, Angela
Sent: Thursday, November 29, 2012 5:00 PM
To: Cook, William
Cc: Raymond, William
Subject: Initial Attempt at answering the comments
Attachments: IR 2012-009 11-28-12 Angie Attempt at DLR Comments.docx

Bill/Bill,

At the risk of my head exploding from reading/thinking about/listening to follow-ups/ on this report, I'm sending a crude attempt (i.e., purely my thoughts or suggestions at understanding what Melanie had in mind) at addressing the comments.

I've left Section 6 and 7 alone because, Bill Cook, you thought you'd take a swing at re-wording Section 6 to make "it in-your-face" obvious that the staff is still considering the adequacy of crack mapping and Section 7, where there is NO WAY we are endorsing NextEra's walkdown as sufficient for any licensing actions. I've got a meeting first thing tomorrow morning where I'll be discussing our conversation and subsequent thoughts, but at that point I won't be giving her any report revisions.

Let's talk tomorrow.

Angie

B7?

UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION I
2100 RENAISSANCE BOULEVARD, SUITE 100
KING OF PRUSSIA, PENNSYLVANIA 19406-2713

Mr. Kevin Walsh
Site Vice President
Seabrook Nuclear Power Plant
NextEra Energy Seabrook, LLC
c/o Mr. Michael O'Keefe
P.O. Box 300
Seabrook, NH 03874

SUBJECT: SEABROOK STATION, UNIT NO. 1 - CONFIRMATORY ACTION LETTER FOLLOW-UP INSPECTION - NRC INSPECTION REPORT 05000443/2012009

Dear Mr. Walsh:

On November 2, 2012, the U. S. Nuclear Regulatory Commission (NRC) completed a team inspection at Seabrook Station, Unit No. 1. The enclosed inspection report documents the inspection results, which were discussed on November 2, 2012, with you and other members of your staff.

The team inspection examined activities conducted under your license as they relate to safety and compliance with the Commission's rules and regulations and with the conditions of your license. Specifically, the team reviewed selected procedures and records, observed activities, and interviewed station personnel regarding the adequacy of NextEra's actions to address the impact of Alkali-Silica Reaction (ASR) on reinforced concrete structures. The team reviewed selected Confirmatory Action Letter (CAL) 1-2012-002 commitments for adequacy and closure.

Based upon the inspection team on site and in-office reviews, five CAL items were reviewed and closed, as documented in the enclosed report. The remaining six CAL items will be reviewed during our second planned follow-up inspection scheduled for completion in early 2013.

The inspection team determined that NextEra's methods for assessing operability of ASR-affected reinforced concrete structures were technically sound and generally comprehensive. NextEra compared the available design and as-built construction margins to lower bound ASR effects on selected structural design attributes. The team concluded this margins assessment provided a reasonable basis for operability until additional information can be obtained through further testing and engineering analysis, expected to be completed by mid-2014. The team will review NextEra's proposed testing to address the uncertainties in evaluating the current level and progression of ASR on Seabrook Station reinforced concrete structures in the second follow-up inspection.

Comment [A1]: Comments are of 3 types:

(A)**OPERABILITY** DISCUSSION - Problem with characterizing as "Interim Operability Assessment":
a.Operability is not usually characterized as acceptable for an interim period and the Agency does not have an "interim operability" process and it appears this is a licensee phrase we should consider not using.
b.Justification for why the staff concluded an assessment or evaluation was appropriate or acceptable is not readily identifiable to the reader
(B) - **LR** ALIGNMENT License renewal alignment: In some areas, DLR is concerned that the statement may send a wrong message in terms of an Agency position
(C) - OVERALL **CLARITY**:
a.In some areas, the "story" is not clear (how the NRC arrived at a conclusion…is there background information that would help the reader to understand xyz).
b. The use of the terms "Lower bound" and "upper bound" are unclear. Consider using plainer language

Deleted: interim

Comment [A2]: OPERABILITY: Need to explain what this means. Suggested wording might be "The inspetion team determined that NextEra's methods for assessing operability of ASR-affected reinforced concrete structures were was appropriately bounding based on limited available information and conservative assumptions of ASR effect"

Deleted: interim operability basis

Deleted: ,

Deleted: supports a final operability determination

In accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) 2.390 of the NRCs "Rules of Practice," a copy of this letter, its enclosure, and your response (if any) will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of the NRC's document system (ADAMS). ADAMS is accessible from the NRC website at http://www.nrc.gov/reading-rm/adams.html (the Public Electronic Reading Room).

Sincerely,

Christopher G. Miller, Director
Division of Reactor Safety

Docket No. 50-443
License No: NPF-86

Enclosures:
1. Inspection Report No. 05000443/2012009
   w/ Attachment: Supplemental Information
2. Confirmatory Action Letter 1-2012-002

cc w/encl: Distribution via ListServ

In accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) 2.390 of the NRCs "Rules of Practice," a copy of this letter, its enclosure, and your response (if any) will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of the NRC's document system (ADAMS). ADAMS is accessible from the NRC website at http://www.nrc.gov/reading-rm/adams.html (the Public Electronic Reading Room).

Sincerely,

Christopher G. Miller, Director
Division of Reactor Safety

Docket No. 50-443
License No: NPF-86

Enclosures:
1. Inspection Report No. 05000443/2012009
   w/ Attachment: Supplemental Information
2. Confirmatory Action Letter 1-2012-002

cc w/encl: Distribution via ListServ

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NAME	WCook/	ABurritt/	RConte/	JTrapp/	CMiller/
DATE					

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U.S. NUCLEAR REGULATORY COMMISSION

REGION I

Docket No.:	50-443
License No.:	NPF-86
Report No.:	05000443/2012009
Licensee:	NextEra Energy Seabrook, LLC
Facility:	Seabrook Station, Unit No. 1
Location:	Seabrook, New Hampshire 03874
Dates:	June 18, 2012 to November 2, 2012
Inspectors:	W. Cook, Team Leader, Division of Reactor Safety (DRS) S. Chaudhary, Reactor Inspector, DRS W. Raymond, Senior Resident Inspector A. Buford, Structural Engineer, Division of License Renewal, Office of Nuclear Reactor Regulation (NRR) G. Thomas, Structural Engineer, Division of Engineering, NRR
Accompanied by:	Dr. Kent Harries, Associate Professor of Structural Engineering and Mechanics, University of Pittsburgh
Approved by:	Richard Conte, ASR Project Manager Division of Reactor Safety

SUMMARY OF FINDINGS

IR 05000443/2012009; 06/18/2012 - 11/02/2012; Seabrook Station, Unit No. 1; Confirmatory Action Letter (CAL) Follow-up Inspection Report.

This report covered three weeks of onsite inspection and four months of in-office review by region based inspectors and headquarters reviewers to assess the adequacy of actions taken by NextEra to address the identification of Alkali-Silica Reaction (ASR) in reinforced concrete structures at Seabrook Station. The NRC's program for overseeing the safe operation of commercial nuclear power reactors is described in NUREG-1649, "Reactor Oversight Process," Revision 4, dated December 2006.

Cornerstone: Mitigating Systems

During this inspection the team examined six of the 11 commitments identified in CAL No. 1-2012-002, dated May 16, 2012. These commitments involve actions taken and planned by NextEra to address the degradation of reinforced concrete structures at Seabrook Station due to ASR. Based upon the team's onsite inspection activities and detailed in-office reviews, the team closed CAL Items #1, #3, #5, #6, and #10. The team reviewed CAL Item #2, but did not close this item based upon additional actions needed by NextEra to appropriately address and document this issue. The details of the team's review of each CAL item and the observations pertaining to the adequacy of NextEra's actions to address their commitments to the NRC, to date, are documented in the enclosed report.

The team determined during this inspection that NextEra does not plan to finalize their structural evaluations and operability assessments until: 1) the degree of ASR degradation on station reinforced concrete structures is appropriately reconciled with the station design and licensing basis; and 2) the progression of ASR is appropriately monitored to ensure structural integrity and operability is maintained for the duration of the current operating license. Further, the team determined that NextEra's current position is that no reinforced concrete structure at Seabrook Station will be precluded from monitoring for the affects of ASR until a satisfactory petrographic examination has been completed on that structure to confirm the absence of ASR.

The team acknowledged NextEra's plans to conduct structural performance testing of large scale test specimens (both control and ASR-affected) and then apply the test data to evaluate the current impact of ASR on Seabrook Station concrete structures and to develop appropriate actions for the continued monitoring of the ASR-affected structures. The adequacy of NextEra's proposed test program will be evaluated during the second CAL follow-up inspection, in accordance with CAL Item #8. The adequacy of NextEra's current Structures Monitoring Program will be evaluated coincident with the team's review of CAL Item #9.

As discussed in Section 9.0 of the enclosed report, the team identified additional issues for follow-up during the second inspection. These issues and the remaining CAL items will be examined and assessed for adequacy prior to the closeout of CAL 1-2012-002.

REPORT DETAILS

1.0 Background

Alkali-Silica Reaction (ASR) is a chemical reaction occurring in hardened concrete that can change the physical properties of the concrete and potentially affect structural performance. In June 2009, NextEra identified potential degradation in below grade concrete structures at Seabrook. In August 2010, NextEra completed petrographic evaluation of concrete core samples which confirmed ASR as the degradation mechanism. The degraded condition in Seabrook Category I structures was evaluated in the Corrective Action Program via a prompt operability determination (POD) in September 2010, and revised in April 2011, September 2011 and May 2012. The initial PODs (Revisions 0 and 1) addressed the B electric tunnel (AR 581434) where ASR was first discovered. Five other buildings were identified as part of the extent-of-condition (EOC) review and the evaluation of core samples taken from these structures (AR 1664399). The PODs were updated as new information became available and revised analytical techniques were incorporated.

NextEra initially used the results of mechanical testing of concrete cores to assess the degree of structural degradation due to ASR. This is the traditional method described in American Concrete Institute (ACI) 228.1R for assessing existing concrete structures. NextEra tested the cores for compressive strength and elastic modulus. NextEra used the methods defined in construction and design code ACI 318-1971 to evaluate the structural capacity (operability) of the ASR-affected buildings. However, the mathematical relationships in ACI-318 are based on empirical data from testing of non-degraded concrete and these relationships may not hold true for all stages of ASR-affected concrete.

After further review of industry experience and literature pertaining to ASR, NextEra engineering concluded that the core test data was not indicative of structural performance of ASR-affected reinforced concrete structures. NextEra's engineering evaluation stated that once the cores are removed from the structure, concrete core samples are no longer subject to the strains imposed by the ASR-related expansion or restraints imposed by the steel reinforcing cage. The engineering evaluation also stated that confinement provided by steel reinforcing bars (rebar) and other restraints limit ASR expansion of the concrete within the structure and thereby limit the adverse impact on structural performance. Therefore, NextEra engineering concluded that the reduction of mechanical properties observed in mechanical testing of cores was not representative of in-situ concrete performance. NextEra's current position is that the testing of core is only useful as a diagnostic tool to confirm the presence of ASR. Based on this engineering judgment, NextEra stopped taking cores to evaluate the concrete mechanical properties of structures impacted by ASR and revised the operability assessment approach. NextEra's current approach for assessing structural integrity and operability is to compare available design margins to an assumed reduction in structural capacity due to ASR.

The extent of ASR at Seabrook was documented in a baseline walkdown review of station structures. The review identified the visual signs of ASR through the presence of crack patterns, ASR gel in wet and powder forms, and/or discoloration/dark staining. NextEra's walkdown objectives were to: identify and assess apparent ASR degradation including estimated expansion; identify the condition of concrete in the vicinity of supports that show ASR

distress; and identify the current or past areas of water intrusion. The walkdown results were entered into the corrective action program (AR 1757861) and have established NextEra's current baseline condition assessment of Seabrook structures, in conjunction with six-month crack indexing measurements on selected structures to trend the progression of ASR and possibly establish a rate of expansion.

NextEra's operability evaluations were based upon an examination of available design margins and a presumed ASR reduction in structural design capacity for critical limit states. The details of this methodology and related assumptions were developed in NextEra's Interim Assessment (FP 100716). The assessment assumed lower bound values of structural capacity for ASR-affected concrete ~~for potential reductions in structural design properties (~~ for various limit states~~)~~ based on research test data from primarily small scale test specimens. The assessment focused on the structural ~~design properties~~ limit states that are the most sensitive to ASR effects (i.e., out-of-plane shear capacity, lap splice development length, and anchorage capacity). The assessment determined the structures were suitable for continued service pending further evaluation of structural performance based on a proposed large scale testing program of beam specimens representative of Seabrook reinforced concrete structures. The test program has been initiated at the Ferguson Structural Engineering Laboratory at the University of Texas at Austin (UT-A), with testing targeted to be completed in 2013 and the results reported in 2014.

Comment [G3]: General Comment: In using the term "lower bound value(s)" through out the report, using the example of the shear limit state, please understand that the assumed 25% potential reduction in shear capacity due to ASR effect is an "upper-bound" value of potential reduction in shear capacity. This in turn would result in a reduced shear capacity of 0.75 times the shear capacity of unaffected concrete, which is a "lower-bound" value of shear capacity for ASR-affected concrete. The term "limit state" refers to structural modes of failure such as axial compression/tension, flexure, shear, bond etc.

Deleted: NextEra's operability evaluations were based upon an examination of available design margins and a presumed ASR reduction in structural design capacity for critical limit states. The details of this methodology and related assumptions were developed in NextEra's Interim Assessment (FP 100716). The assessment assumed lower bound values for potential reductions in structural design properties (limit states) based on research test data from primarily small scale test specimens. The assessment focused on the structural design properties that are the most sensitive to ASR effects (i.e., out-of-plane shear capacity, lap splice development length, and anchorage capacity). The assessment determined the structures were suitable for continued service pending further evaluation of structural performance based on a proposed large scale testing program of beam specimens representative of Seabrook reinforced concrete structures. The test program has been initiated at the Ferguson Structural Engineering Laboratory at the University of Texas at Austin (UT-A), with testing targeted to be completed in 2013 and the results reported in 2014. ¶

2.0 Confirmatory Action Letter 1-2012-002

Confirmatory Action Letter (CAL) 1-2012-002, dated May 16, 2012, was written to confirm commitments by NextEra (established during a meeting with NRC management and staff on April 23, 2012) with regard to planned actions to evaluate ASR-affected reinforced concrete structures at Seabrook Station. In response to the CAL, NextEra committed to provide information to the NRC staff to assess the adequacy of NextEra's corrective actions to address this significant condition adverse to quality. CAL 1-2012-002 is provided as an Enclosure to this report. The NRC staff also formed a working group to provide appropriate oversight of NextEra's activities to address ASR and to coordinate NRC inspection and review activities. The ASR Working Group Charter (ML121250588) outlines the regulatory framework and general acceptance criterion for NRC oversight and review of this issue.

Based on the results of this inspection, CAL Items #1, #3, #5, #6, and #10 are closed; CAL Item #2 is updated; and CAL Items #4, #7, #8, #9, and #11 remain open pending NRC review in the second CAL follow-up inspection (Report No. 05000443/2012010).

3.0 Review of Operability Determinations and the Interim Assessment (CAL Items #1, #3, and #5)

Comment [A4]: CLARITY: consider putting the CAL # in parentheses next to the titles in this subsection. It is not readily apparent to the reader which CAL item is being referenced, especially in the paragraphs such as "shear strength" and "anchorage"

Also – consider adding the actual CAL language at the beginning of each of the sections that refer to CAL item.

3.1 Inspection Scope

The team reviewed the PODs for the B Electric Tunnel of the Control Building (POD 581434) and buildings identified in NextEra's extent-of-condition review (PODs 1664399 and 1757861). As discussed in Section 1.0 above, these PODs were revised to reflect a change in the approach taken by NextEra to evaluate the structural integrity of the station reinforced concrete buildings. Revision 2 of the PODs provides the current quantitative and qualitative analyses of

the ASR-induced changes in structural performance, as further detailed in the licensee's Interim Assessment. The team reviewed the supporting documentation for each significant structural design attribute and conducted multiple interviews and discussions with the responsible NextEra engineering staff and consultants. The team used 10 CFR Part 50, Appendix A (General Design Criteria 1, 2, and 4), and 10 CFR Part 50, Appendix B, Criterion XVI, "Corrective Action," and Criterion XI, "Test Control," as the regulatory basis to assess the adequacy of NextEra's actions to address ASR effects on safety-related Category I and in scope Maintenance Rule reinforced concrete structures. The team used NRC Inspection Manual, "Part 9900 – Operability Determination and Functionality Assessments for Resolution of Degraded or Nonconforming Conditions Adverse to Quality or Safety," to evaluate the licensee's approach to assessing this significant condition adverse to quality.

The extent-of-condition POD (Revisions 0 and 1) initially addressed five structures (AR 1664399). These five structures included the containment enclosure building (CEB), the access tunnel to the radiologically controlled areas (RCAW), the emergency feedwater (EFW) pump house, the residual heat removal (RHR) equipment vault (EV), and the diesel generator building (DGB). During implementation of ASR Structures Walkdown (FP 100705), NextEra identified additional structures with localized areas of patterned cracking, including: the condensate storage tank enclosure, the control building air east intake, the service water cooling tower, the A electrical tunnel, the fuel storage building, the east pipe chase, the west pipe chase, the pre-action valve room, the primary auxiliary building, the service water pump house, the mechanical penetration area (which includes portions of the outer containment wall, AR 1804477), and the waste processing building (AR 1757861).

The team conducted a detailed review of Foreign Print (FP) 100716, "Seabrook Station: Impact of Alkali-Silica Reaction on Concrete Structures and Attachments," Revision 1, which is the initial evaluation of concrete structures at Seabrook Station and provides the basis for continued operability of affected structures for an interim period. As documented in FP 100716, NextEra's interim evaluation will be followed by a second evaluation that "will assess the long-term adequacy of the concrete structures considering the results of the full-scale structural testing program, other in-progress test programs, and results from periodic monitoring of the structures."

3.2 Findings and Observations

The team identified no findings in this area and CAL Items #1, #3 and #5 are closed. Based on a detailed review of the PODs, referenced white papers and associated engineering analyses, including an independent verification by the team of a number of supporting calculations, the team determined NextEra's interim operability bases were appropriate. Given the current known extent of ASR, there is reasonable expectation that the affected reinforced concrete structures at Seabrook Station will remain capable of performing their intended functions for an interim period, while NextEra continues to monitor the condition and complete detailed testing and further engineering analyses (expected to be completed by mid-2014).

The team noted that the areas identified by NextEra to be affected by ASR are generally localized (i.e., part of a wall, not the entire wall or structural member exhibits evidence of ASR). Even though the identified ASR areas are localized, NextEra's engineering evaluations

conservatively assume the entire structure or structural member (wall) is adversely affected. Assuming an entire structural member is affected allows for a direct comparison to the original design calculations of record. Noteworthy observations pertaining to the team's review of the PODs and Interim Assessment follow:

3.2.1 Operable, but Degraded (Below Full Qualification)

Based upon a detailed review of the quantitative and qualitative analyses documented in the PODs and Interim Assessment, the team determined NextEra had appropriately demonstrated that the ASR impacted structures were operable, but degraded and below full qualification. NextEra demonstrated that the structures would maintain structural integrity for design basis loads and load combinations for normal, accident and environmental extreme conditions (including seismic) for an interim period.

The team observed that 26 locations (including containment) had been identified via NextEra's ASR Structures Walkdown as having patterned cracking with a combined crack index (CCI) of greater than 1.0 mm/m. Per the Structures Monitoring Program (EDS 36180, Revision 2), Attachment 3, revised in July 2012, a CCI of >1.0 mm/m requires a structural evaluation. NextEra's Interim Assessment, Section 2.1.2 documents an engineering judgment that biased the performance of detailed structural evaluations to the 11 locations with a CCI > 1.5 mm/m. Although not explicitly stated in Section 2.1.2, the team learned from discussions with NextEra engineers that the locations with a CCI of between 1.0 and 1.5 mm/m (13 locations) were considered bounded by the 11 areas subjected to a detailed evaluation. The lack of a documented structural evaluation for the 13 locations with a CCI of between 1.0 and 1.5 mm/m was considered a minor performance deficiency. NextEra acknowledged this procedural implementation error and entered the issue into their Corrective Action Program (AR 1804477 and AR 1819080). A structural evaluation was completed for containment and reviewed by the team prior to the completion of the inspection period (see Section 3.2.8). However, the evaluations for the remaining locations are yet to be completed by NextEra. The team will examine these evaluations in the next CAL follow-up inspection report.

Near the conclusion of this inspection, NextEra completed a POD for containment (AR 1804477). Preliminary review by the team identified areas for follow-up during the second CAL follow-up inspection. Specifically, the team plans to assess NextEra's evaluation of the potential for ASR-induced pre-stressing of rebar (reference Section 3.2.8) and to review NextEra's future plans for monitoring the localized areas (three) of presumed ASR (not verified by a petrographic exam) on the containment outer wall. NextEra's current monitoring plans for the containment wall areas are documented in FP 100647, "Crack Index Determination." (See Section 6.0 of this report for additional information and team observations concerning Crack Indexing.)

3.2.2 Concrete Material Properties - Compressive Strength and Elasticity Modulus

As discussed in Section 1.0, NextEra stopped taking core samples to evaluate ASR-affected structures. Notwithstanding, Revision 2 of POD 581434 for the B electrical tunnel, concluded that there is no loss of concrete compressive strength due to ASR. This conclusion was based on testing of 15 cores (12 ASR-affected concrete and 3 control locations). NextEra concluded

that ASR had increased the stiffness of the electric tunnel walls because the compressive strength in the ASR impacted concrete was higher than in the control core samples. [The team notes that this conclusion is different than the 22 percent measured compressive strength reduction (compared to the 1979 cylinder test results) that had been previously identified by NextEra from initial core sample results and reported in NRC Inspection Report 05000443/2011007.]

Team review of the available supporting concrete core data during this inspection did not validate NextEra's current conclusion. The team noted that as-built concrete compressive strength can vary due to variations in the mixture (aggregate, sand, cement, and water) and the curing process. Consequently, design and construction specifications were developed to ensure, in spite of this variability, that concrete specified and used in reinforced concrete structures meets acceptable standards of performance. In addition, concrete strength is expected to increase with age and curing. The team also notes that additional inaccuracies are introduced via the core sampling process and associated testing methods. Accordingly, team examination of the 2011 core sample compressive strength data showed a two percent reduction in compressive strength than the original measured cylinder strength values from 1979. This lead the team to conclude that there is neither a significant loss or increase in compressive strength in the ASR-affected B electrical tunnel concrete material properties. Team review of core sample measured modulus of elasticity values identified that although individual cores showed a modulus that was reduced (compared to design), the average modulus value in the RCA walkway, RHR equipment vault, EFW pump house and DGB was within 20 percent of the design modulus value ($\pm$20 percent is acceptable by ACI 318). For the CEB, the average modulus was just beyond (low) the 20 percent allowable. Based upon available core sample results, the team considered the ASR effect on elasticity modulus inconclusive, also.

Comment [A5]: CLARITY: This appears to disagree with the statement in the cover letter that the methods were "technically sound and generally comprehensive". To the reader, the statement seems to "hang" without further discussion following an unfavorable-seeming conclusion. Consider adding a qualifying follow-up statement. How does this lack of agreement from the staff result in a conclusion that the methods were technically sound?

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Comment [A6]: CLARITY: not clear to the reader - two percent lower than what?

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Comment [A7]: CLARITY: significant loss or increase in compressive strength - from what starting point?

Overall, the team concluded that the core sampling and associated mechanical testing completed, to date, has not conclusively established the current impact of ASR on concrete material properties. While the team acknowledges that the core sample results may not represent in-situ concrete structural performance, as NextEra has concluded, the core samples and test results (mechanical and petrography) may still provide valuable information and insights relative to the impact (relative degree and progression) of ASR on reinforced concrete structures. Consequently, the team plans to examine core sampling in the second CAL follow-up inspection, with respect to core sample test results being used to understand ASR effects on ACI Code relationships and the overall adequacy of the Structures Monitoring Program. .

3.2.3 Flexural Capacity and Dynamic Response

NextEra completed a comparative study of the Containment Enclosure Building (CEB) (FP 100714 and FP 100715) which evaluated the effects of reduced elastic modulus on seismic response. The CEB was chosen for detailed analysis because it conservatively bounds other site structures due to its relative size and dynamic loading. The CEB parametric study included: an evaluation of the building in a static, three-dimensional finite element analysis (FEA) to determine the response (forces and moments) to operating basis earthquake and safe shutdown earthquake seismic loads before and after ASR damage; a calculation of the wall section capacities; a calculation of demand-to-capacity ratios (DCR); and, a comparison of the

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DCRs of ASR-affected walls to unaffected walls. Based upon assumed bounding conditions and the current state of ASR degradation used in the FEA model, the analyses showed that the seismic acceleration profiles, in-structure response spectrum, and distribution of forces and moments were not significantly impacted. The effect of the lower modulus values on the response of below-grade, ASR-impacted structures was evaluated in Calculation C-S-1-10163. For these below grade structures, NextEra determined that the dynamic structural response remained in the rigid range with no appreciable amplification of the ground response spectra.

Based upon the above, NextEra concluded that the seismic response of the CEB, along with the attached equipment (cable trays and supports) and anchor loads remained practically unchanged due to the assumed ASR effects. The team concluded that NextEra's assessment of this ASR-affected structural design attribute was appropriate for an operability determination because it showed that the effects of the current state of ASR would not compromise structural integrity.

3.2.4 Shear Capacity

NextEra analyzed the impact of ASR on the B electric tunnel using an FEA in calculation FP 100730 to determine refined structural demand and to compare the shear capacity versus demand for seismic and hydrodynamic loads. NextEra assumed a lower bound 25 percent reduction in out-of-plane concrete shear capacity due to the effects of ASR on walls without shear reinforcement. The team noted that NextEra's design calculation (CD-20, dated 3/28/83) used the average 28-day compressive strength value (5459 psi) to establish that the design shear capacity exceeded the design load/demand. However, the FEA-based calculation used the specified design concrete strength of 3000 psi to compare the available design capacity to design load. The use of the 3000 psi vice 5458 psi value in the FEA identified that adequate margin was available using the as-built specified concrete compressive strength. The team notes that the FEA is a more precise computational design method than the manual methods used in the 1983 design calculation. The team notes that NextEra identified, but did not credit, additional conservatism in their margins analysis based upon the B electrical tunnel average measured core sample compressive strength value of 5140 psi. NextEra's FEA-based evaluation concluded that adequate margin was available to account for the lower bound ASR effect on out-of-plane concrete shear capacity. The team viewed the use of an FEA to assess shear capacity and the lower bound ASR effects as appropriate for the operability assessment because 1) some additional margin may be credited due to the compressive strength of core samples exceeding the design minimum value of 3000 psi; and 2) the use of a 25 percent reduction in shear capacity, as a lower bound ASR effect, was appropriate for the assessment of this limit state.

3.2.5 Review of Finite Element Analysis Modeling

As discussed in Sections 3.2.3 and 3.2.4 above, NextEra used a linear elastic FEA to evaluate the effects of ASR on certain structures and design attributes. The team noted that the input data for the compressive strength and modulus of elasticity for the CEB model were determined based on a visual examination of CEB walls and only a few directly obtained core sample material properties. The observed crack patterns/dimensions on the CEB were correlated by NextEra to a damage rating index (DRI) and associated concrete material properties from test

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Comment [A8]: OPERABILITY: No discussion of the staff's opinion on what NextEra did. If we found it accebptable, why? Is it only okay on an interim basis? Will the applicability or appropriateness expire?

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Comment [A9]: CLARITY: Consider plainer language, as "lower bound" and "upper bound" are confusing, to explain the rationale for using a 25% reduction

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Comment [A10]: OPERABILITY: Same as comment above.

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Comment [A11]: OPERABILITY: Same as comment above.

Moved up [1]: The team viewed the use of an FEA to assess shear capacity and the lower bound ASR effects as appropriate for the interim operability assessment.

data obtained from core samples taken from several different structures. The input data for poisson ratio was derived exclusively from research data. NextEra acknowledged the limitations of this input data, but in FP 100696 deemed the approach justified because the analysis was a parametric study of the CEB seismic response, comparing design values to ASR-affected values. The team concluded the application of the FEA to a parametric analysis was useful for providing a reasonable expectation of operability for the interim period, but not conclusive with respect to identifying a current or projected state of ASR impact, since some assumptions were not representative of the actual structure. For example, the team noted that the boundary conditions used at and below elevation zero-foot of the CEB FEA model may need to be re-evaluated and better justified, considering the seismic isolation of the structure wall (separated from the concrete backfill by the waterproofing membrane). Nonetheless, given the information available regarding the current state of ASR, this does not affect operability. The team concluded that the use of a FEA model with more accurate concrete material property data and more representative boundary conditions may be appropriate for future operability assessment, as ASR progresses over time.

3.2.6 Anchorage

NextEra evaluated the impact of ASR-affected concrete on the performance of anchorage, including both expansion and undercut post-installed anchors. The potential impact of micro-cracking caused by ASR can negatively impact the structural capacity of anchorages and embedments supporting safety-related components. NextEra's interim operability evaluation was supported by anchor performance testing conducted on ASR degraded UT-A test specimens (FP 100718). The tests showed satisfactory performance of the anchors in ASR-affected concrete. NextEra's evaluation illustrated that the assumed lower bound reduction in capacity due to ASR was offset by established anchor manufacturer's design margins (FP 100716). The team concluded that NextEra's interim anchorage operability assessment was satisfactory and that it showed sufficient margin in the anchor design to exceed demand, considering a reduction in strength due to ASR. However, based upon the limitations of the testing performed to date (on ASR-affected test specimens of different composition and compressive strength than Seabrook structures) NextEra plans to conduct further testing. Planned testing involves anchors installed in ASR-affected test specimens that more closely reflect the reinforced concrete structures and anchor configurations at Seabrook.

3.2.7 Lap Splice Strength

Section 6.3 of NextEra's Interim Assessment addressed reinforcement lap splice degradation as another design attribute impacted by ASR. In accordance with the licensee's lower bound value of a 40 percent reduction in lap splice strength, NextEra's review of design calculations identified several structures with insufficient margin to accommodate this assumed ASR affect. NextEra was able to "recover" margin by adjusting the ACI 318 prescribed design load factors for predicted dead load and/or hydrostatic load. NextEra's term "recover" represents examining the design calculations and determining the accuracy of the predicted loads; if the predicted load can be more accurately quantified, then it is appropriate to remove the load factor (LF) from the associated load/demand calculation. By ACI 318, the LFs account for the uncertainty in accurately predicting the structural loads. The team examined this method and found it satisfactory for the operability assessment, but concluded it may not be acceptable for future

Comment [A12]: OPERABILITY: Why was it useful and reasonable but not conclusive?

Comment [A13]: OPERABILITY: Why does this need to be re-evaluated or better justified?

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Comment [A14]: OPERABILITY: interim operability vs. final operability vs. Operable. Why is it okay now?

Comment [A15]: CLARITY: Same comment: Consider plainer language, as "lower bound" and "upper bound" are confusing

Comment [A16]: OPERABILITY: Same Comment as above: No discussion of the staff's opinion on what NextEra did or on the results. If we found it accebptable, why? Is it only okay on an interim basis? Will the applicability or appropriateness expire?

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Comment [A17]: OPERABILITY: What is the NRC's position on this testing? Do we agree with the licensee?

Comment [A18]: CLARITY: Same comment as above: Consider plainer language, as "lower bound" and "upper bound" are confusing, to explain the rationale for using a 40% reduction

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Comment [A19]: OPERABILITY: Same Comment as above: No discussion of the staff's opinion on what NextEra did or on the results. If we found it accebptable, why? Is it only okay on an interim basis? Will the applicability or appropriateness expire?

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operability determinations under the current licensing basis. The final operability assessment requires full conformance with the ACI design methodology or revision to the licensing basis.

Comment [A20]: OPERABILITY: Why is it okay now?

3.2.8 Concrete Confinement and Rebar Pre-Stressing

Team review of FP 100716, Sections 2.1.2 and 4.1.3, identified that the Interim Assessment stated, "Since ASR has a negligible impact on structural demand, the impact of ASR on structures and structural attachments can be assessed solely on the basis of changes in capacities." The team observed that restraint to ASR expansion, from concrete confinement by reinforcement (in two or three dimensions) and/or other external constraints, may cause internal pre-stress in the structural member. The consequence may increase compressive stresses in concrete and increase tensile stresses in the rebar, as long as the restraint is sustained. The team observed that NextEra has only addressed this ASR-induced pre-stress qualitatively in FP 100716 and in the containment structural evaluation (AR 1804477). The team's preliminary engineering judgment is that a quantitative evaluation is more appropriate for a final operability assessment of this condition so that the additional demand due to ASR can be accounted for in engineering evaluations. Further, it should be recognized that the ASR-induced pre-stress varies with time, depending on the degree of restraint and may not be sustained throughout the service life of an affected structure. Accordingly, any potential beneficial effect should not be relied upon or credited in design.

Comment [A21]: OPERABILITY: Why?

The team acknowledges NextEra's conclusion that ASR-induced pre-stress may result in some beneficial effects in terms of structural stiffness. However, the team's judgment is that this structural demand should be quantified (if practicable) and accounted for in the design calculations as a known load. Quantifying, or otherwise approximating the ASR-induced pre-stress, is similar to accounting for the pre-stress load in pre-stressed concrete design. This issue will be reviewed by the team in the second CAL follow-up inspection.

Comment [A22]: OPERABILITY/CLARITY: How does this relate to operability?

3.2.9 Condition of Rebar

The team examined information gathered and assessed by NextEra with regards to the condition of rebar and any potential erosion or corrosion due to ASR and water in leakage through below grade reinforced concrete structures. The team observed that NextEra had purposefully removed an area of surface concrete in the B electrical tunnel (chronically wet) to examine the condition of the rebar. The engineering staff identified no degradation of the rebar (no oxidation or signs of distress). The team also learned that in the course of removing core samples, in two instances the drill nicked rebar. Examination of the rebar sections removed determined the steel to be in excellent condition (unaffected by ASR or moisture).

Preliminarily, NextEra has concluded that the condition of rebar in ASR degraded concrete should be unaffected unless the cracking becomes deleterious and exposes the rebar to oxidation mechanisms. Otherwise, the alkaline condition within the concrete should prevent any corrosion mechanisms. The NRC continues to evaluate the need for any additional rebar intrusive monitoring or testing, and will evaluate this issue in the second CAL follow-up inspection.

Comment [A23]: OPERABILITY/CLARITY: Same comment as above: How does this relate to operability?

4.0 Review of Alkali-Silicon Reaction Root Cause Evaluation (CAL Item #2)

4.1 Inspection Scope

The team reviewed NextEra's response to this CAL Item, "Submit the root cause for the organizational causes associated with the occurrence of ASR at Seabrook Station and related corrective actions by May 25, 2012." The licensee submitted their root cause evaluation (RCE) via letter dated May 24, 2012. The purpose of the team's review was to assess the adequacy of the licensee's evaluation of the root cause for the ASR issue at Seabrook and the significant contributing causes. The team also examined the methodology and thoroughness of the licensee's evaluation and associated corrective actions as outlined in 10 CFR Part 50, Appendix B, Criterion XVI, "Corrective Action."

4.2 Findings and Observations

This CAL Item will remain open pending NRC review of NextEra's final RCE. NextEra identified two root causes: 1) ASR developed because the concrete mix design unknowingly utilized an aggregate that was susceptible; and 2) the monitoring program for plant systems and structures does not contain a process for periodic reassessment of failure modes. A contributing cause identified by NexEra was the failure to prioritize groundwater elimination or mitigation resulting in more concrete areas exposed to moisture. The team made observations regarding the level of detail and clarity of NextEra's root cause evaluation.

The team acknowledges that the first licensee identified root cause involved the use of susceptible aggregate in the concrete mix design that was undetected by the testing specified by American Society for Testing and Materials (ASTM) construction standards, at the time (late 1970's). Since this time, the role of slow reacting aggregate in ASR has been identified in the construction industry and standard tests are now available to ensure slow reactive aggregates would be properly identified prior to use in construction. The team concluded that this causal factor was beyond the licensee's control.

The team concluded that the second root cause was not adequately characterized in NextEra's May 24, 2012, submittal. Specifically, NextEra did not clearly state the personnel and organizational factors that led to inadequacies in the Structures Monitoring Program (SMP). The team discussed the absence of any human performance aspects in the description of this causal factor and NextEra initiated a revision to the RCE to more appropriately develop and characterize this second root cause and the associated corrective actions. NextEra plans to submit the revised RCE for NRC review. The team will review this revision in the next CAL follow-up inspection report.

The team also noted that NextEra excluded a contributing cause, identified in the RCE, from the evaluation executive summary and May 24, 2012, letter. As stated in the RCE, this contributing cause involved the longstanding "organizational mindset" that groundwater infiltration was more of an "operational nuisance" than a structural integrity concern. This station and engineering staff view prevented a more timely and thorough investigation and examination of the affected concrete reinforced structures on site. NextEra acknowledged this observation.

5.0 Review of Mortar Bar Testing (CAL Item #6)

5.1 Inspection Scope

The team reviewed the results of NextEra recently completed short term expansion testing of mortar bar specimens per test procedures SGH-Z001-12 and SGH-Z002-12. The results of the testing were evaluated per ASTM C1260. The licensee initiated the testing to establish and compare the reaction rates of ASR-affected concrete to non-ASR-affected concrete on site. The tests were performed by a consultant at an offsite facility. The mortar bar specimens were made using the aggregate extracted from core samples taken from ASR-affected structures and non-affected concrete from a slab removed from the waste processing building. NextEra noted that the non-affected concrete slab used for aggregate extraction had shown no visible indications of ASR and was not petrographically examined. The details of the testing are documented in SGH Report 120110-RPY-01 (FP 100734). The team reviewed the SGH report and associated test documents to ascertain the adequacy and technical validity of the testing.

5.2 Findings and Observations

No findings were identified and CAL Item #6 is closed. The test results indicated that both affected and non-affected concrete specimens contained ample reactive aggregate to sustain ASR. The team notes that normal test duration is 14 days and that a specimen expansion of >0.1 percent indicates reactive aggregate, per ASTM C1260. Test results identified that the non-ASR-affected specimens exceeded the 0.1 percent threshold in 5 days and the ASR-affected specimens exceeded the 0.1 percent threshold in 7 days. NextEra allowed the test to extend to 103 days and both specimen types continued to demonstrate active expansion due to ASR. Accordingly, NextEra concluded that there remains the potential for future volumetric expansion due to ASR in concrete structures at Seabrook.

Based upon the Mortar Bar Testing results, NextEra plans to revise their commitment to conduct Prism Testing. Prism Testing is similar to Mortar Bar Testing, but a longer term test of the susceptibility to ASR of aggregate used in concrete. NextEra had hoped to establish, via the Mortar Bar Test, a difference in the remaining versus available concrete constituents for ASR in the specimens. The results demonstrated ample reactive materials in both specimen types and NextEra concluded the Prism Test will not provide any additional ASR insights. The team had no additional observations and will review the revised Prism Testing commitment when it is submitted.

6.0 Review of Crack Indexing (CAL Item #10)

6.1 Inspection Scope

The team conducted a review of FP 100647, "Crack Index Determination," Revision 1, to understand the methodology for NextEra's monitoring of ASR progression in selected reinforced concrete structures. NextEra's commitment to this methodology is documented in CAL Item #10. The team used 10 CFR Part 50, Appendix B, Criterion V, "Instructions, Procedures, and Drawings," to evaluate the implementation and adequacy of the procedural guidance. The team's review was limited in scope, in that, the adequacy of this process, as the sole means of monitoring ASR progression in Seabrook structures, is still under NRC review. The team will evaluate this aspect as part of the review of CAL Item #9, the Maintenance Rule Structures Monitoring Program, during the second CAL follow-up inspection.

The team observed field measurements taken on June 20, 2012, by the responsible contractor and discussed the general methodology and procedural guidance with the individuals performing the crack indexing measurements and supervising NextEra staff. The team noted that NextEra found ASR patterned cracking in many areas within Seismic Category I and Maintenance Rule structures, but only a limited number of these areas have sufficient ASR degradation to merit continued monitoring and detailed evaluations. The ASR walkdowns identified 131 locations with some level of pattern cracking. Of the 131 localized areas, 26 exceeded the initial screening criteria of a combined crack index greater than 1.0 millimeter per meter (mm/m). The 1.0 mm/m threshold was established in the Structures Monitoring Program, Attachment 3, for conducting a structural evaluation. These 26 areas will continue to be monitored at six-month intervals, per FP 100647.

6.2 Findings and Observations

No findings were identified and CAL Item #10 is closed. The team noted that the periodic crack indexing provides the principle method selected by NextEra to monitor the progression of ASR on reinforced concrete structures. The six-month interval measurements are currently planned until a reliable trend of ASR progression can be established, per Structural Engineering Standard Technical Procedure 36180, "Structures Monitoring Program," Attachment 3, Revision 2. As stated above, additional NRC review of the SMP will be conducted in the second CAL follow-up inspection.

Comment [A24]: LR: This section poses some concerns for license renewal. It is not clear to the reader that the NRC may not find crack mapping acceptable, and re-statement of the licensee's approach here appears to imply endorsement

The team also reviewed the current methods and terminology used by NextEra to characterize the degree of ASR pattern cracking, previously addressed in NRC Inspection Report 05000443/2011007. When ASR was initially identified in the B electrical tunnel in mid-to-late 2010, the licensee referred to the Federal Highway Administration (FHWA) guidance document FHWA-HIF-09-004 for crack/damage characterization. Three major categories were identified: mild, moderate, and severe, with ratings such as mild to moderate and moderate to severe, also used. Per FHWA-HIF-09-004, these categories were used to define the recommended remedial actions to be taken once ASR was identified. At that time, NextEra labeled the observed cracking as "severe." Per the FHWA guidance, this category requires "further investigation for selecting remedial actions." This characterization was repeated in the above referenced inspection report. The team determined that NextEra revised their crack

characterization scheme prior to the implementation of the structures extent-of-condition review. The revised crack rating system was based upon "best practices" taken from the Building Research Establishment (BRE) in the United Kingdom (UK). The revised numeric rating system range is from 0 (no cracking detected) to 6 (heavily fractured ASR-related damage). FP 100636, "Petrographic Examination PE Reports," Revision 0, lists the material property results of all core samples taken and petrographically analyzed. FP 100636 also provides the BRE crack rating for each specimen examined. The crack ratings for the specimens examined range from 0 to 4 (a rating of 4 represents severe cracking). A summary table with each numeric rating and its definition is documented in the Supplemental Information attachment to this report.

Comment [A25]: LR: Same comment as above. It appears as though we are closing out the item with the understanding that Crack Mapping will be used by the applicant and accepted by the NRC. Problems could arise for license renewal if DLR does not accept crack mapping, consider leaving this item Open (Also DLR does not understand why it is being closed when there is ongoing review)

7.0 Review of Alkali-Silica Reaction Structures Walkdown/Baseline Assessment

7.1 Inspection Scope

The team examined NextEra's program documents FP 100642, "ASR Walkdown Scope," Revision 1, and FP 100705, "Seabrook Station: Summary of Alkali Silica Reaction Walkdown Results," Revision 0. The team reviewed the walkdown scope and examination criteria and the associated field data, photographic evidence, and analysis of NextEra's observations, as documented in FP 100705. The walkdown scope included Seismic Category I and some in scope Maintenance Rule structures. NextEra's walkdown is being conducted in three phases. Phase 1 involved examination of readily accessible areas of interest; Phase 2 included examination of coated surfaces identified during Phase 1 inspections (coatings had to be removed to expose the concrete surfaces); and Phase 3 examines normally inaccessible structures/areas (e.g. high radiation, manholes, etc.) which have or will be inspected as the opportunity presents itself (e.g. routine maintenance or outage activities).

The walkdowns assess the extent of ASR throughout the plant with the primary objectives of: identifying and assessing any apparent degradation from ASR, including: estimating in-situ expansion (Crack Indexing); assessing whether concrete in the vicinity of supports for safety-related systems or components show any indications of ASR distress; and documenting and characterizing water intrusion or evidence of previous water intrusion, based upon water being a key contributor to concrete deterioration and distress caused by ASR. The visual criteria for documenting potential ASR indications include: typical patterned surface cracks in concrete; crack dimensions (width, length, orientation); evidence of water ingress/out-seepage (past/present); visual evidence of salt deposit and/or ASR gel; and indications of surface deterioration (i.e., pop-outs and/or spalling). Also, any expansion anchors or structural embedments located within 5 feet of the area of interest were examined and documented. The licensee considers their ASR walkdown efforts and observations a baseline condition assessment. This baseline will be used for monitoring the progression of ASR for the duration of the current operating license.

The team performed a number of independent walk-through inspections to verify and assess the thoroughness of the licensee's efforts. The team independently evaluated the extent-of-condition of ASR-affected structures that are readily accessible. The team used the expertise of a consulting structural engineer to assist in the team's review of the current condition of ASR-affected reinforced concrete structures at Seabrook Station.

Comment [A26]: LR: Potential impact on license renewal, and our implied endorsement to let the licensee use this as their extent of condition or baseline walkdown in LR space.

7.2 Findings and Observations

The team identified no findings. On a sampling basis, the team's independent walkdown observations were consistent with the licensee's observations and assessments. At Seabrook, the presence of ASR has been conclusively established by petrography in certain buildings (where core samples were obtained) and in other buildings by inference, using visual examination criteria. The team confirmed that NextEra's position is that all reinforced concrete structures on site are susceptible to ASR, dependent upon the exposure to moisture. Therefore, NextEra does not intend to exclude any structures from ASR monitoring without confirmation via petrography that ASR is nonexistent.

The complete list of structures and localized areas of ASR identified, to date, is documented in FP 100705, Revision 1. The team noted that the results of the walkdown inspection by NextEra were appropriately documented with extensive observation narratives and well supported by clear sketches and photographs. As NextEra completes Phase 3 examinations, the licensee plans to capture the additional observations through revisions to FP 100705. The team noted that the majority of localized areas of ASR are: 1) below grade walls subjected to either ground water intrusion, or particularly high spatial humidity; or 2) exposure to precipitation and high ambient humidity (some exterior above grade structures).

Based upon the team's review of the Phase 1 and 2 ASR walkdown results and via discussions with responsible engineers overseeing the proposed Phase 3 walkdown areas and tentative schedule, the team identified a minor oversight in the Phase 3 walkdown plan. Specifically, the upper elevations of the containment outer wall were not adequately examined for ASR during the Phase I review and not included in the proposed Phase 3 walkdown schedule. The team identified from discussion with the NextEra engineering staff, that the 2010 IWL examination of containment was being credited for part of the Phase 1 ASR walkdown baseline. The team's detailed review of the 2010 IWL inspection results and associated visual examination attributes (reference implementing procedure, ES 1807.031, "Inservice Inspection Procedure Primary Containment Section XI IWL,") identified that the 2010 IWL exam did not include sufficient examination criteria (i.e., active or pattern cracking) for identification of ASR. As evidence of the absence of ASR identification criteria in the IWL examination, during the subsequently performed Phase 1 ASR walkdown by consulting engineers, three locations of ASR related pattern cracking were identified on areas of the containment previously examined by the IWL inspectors. NextEra acknowledged this oversight in crediting the IWL examination and initiated action (AR 1819069) per the Corrective Action Plan. NextEra plans to revise the Phase 3 plan to address this concern. The team plans to examine the adequacy of the proposed Phase 3 changes and implementation schedule during the second CAL follow-up inspection.

8.0 Follow-up of Open Items

Comment [A27]: CLARITY: The information presented in this section provides much detail that would be useful in previous sections, to understand what the initial NRC concerns were, and how they have been addressed in the CAL. To a new reader unfamiliar with the background, this section provides context to other sections. Consider moving or stating some of this information earlier.

8.1 (Closed) Unresolved Item 05000443/2011003-03, Open Operability Determinations for Safety-Related Structures Affected by Alkali-Silica Reaction

This item was open pending NRC review of NextEra actions to revise operability determinations for the electric tunnel and other structures addressed in the extent of condition review for ASR.

The open aspects were as documented in Inspection Reports 2011-03 and 2011-10 related to: 1) effect of the reduced modulus of elasticity on natural frequency of the structures; 2) the effect of the modulus of elasticity on structure flexural response as related to components attached to the structures, such as pipe and cable supports and their anchor bolts; 3) related effects from increased flexure of building on the loading and seismic effects on safety-related pipes and cable tray supports; and, 4) effect of reduced parameters on the whole building (global) response of the CEB structure to seismic loads including further information of the effect on stress and strain in the concrete and rebar system. Following the reviews in Inspection 2011-10, the unresolved item remained open pending NRC review of additional information from NextEra on the effects on cable and pipe support anchors (number 3) and the effects on the CEB response (number 4).

The team reviewed the revised operability determinations for the safety related structures listed below and as described in POD 1664399, Revision 2.

- Control Building – "B" Electrical Tunnel,
- Containment Enclosure Building,
- Diesel Generator Building,
- Residual Heat Removal Equipment Vaults, and
- Emergency Feedwater Pump House

As part of the ASR extent of condition review, NextEra provided structural assessments for the RCA tunnel and other ASR impacted buildings (reference Calculation C-S-1-10168).

The open aspects of numbers 3 and 4 were resolved after NextEra provided additional information. Revision 2 of POD 581434 for the B electric tunnel (ET) provided additional quantitative and qualitative analyses with consideration of ASR-induced changes in concrete properties. The revised POD addressed the changes in modulus on building frequency; flexural response and capacity; shear capacity; and support anchors. The revised POD incorporated the results of the Interim Assessment (FP 100716) relative to the performance of reinforcing steel anchorage to show that postulated reductions in capacities were offset by conservatisms in ACI 318 Code and the assumed loads. The revised POD incorporated the testing at the Ferguson Structural Engineering Laboratory (FP 100718) of cast-in-place and drilled-in anchors to assess the impact of anchor performance in ASR-affected concrete. The test results showed that the anchor capacities remained above the theoretical capacity at crack indices well above the maximum CI observed in Seabrook structures. Finally, the revised POD for the ET also included consideration of a detailed evaluation of the CEB, chosen for detailed analysis because it conservatively bounds other structures in size and exhibits the highest reduction in modulus of elasticity due to ASR.

Further NRC review of this area is described in Sections 3.0 and 4.0 of this report. The team concluded that the initial failure of NextEra to adequately consider the ASR impacts on structural performance, relative to support anchors and dynamic response, were examples of minor performance deficiencies, in that, upon further evaluation these issues were determined to be acceptable as part of the interim operability assessment. This issue was also addressed broadly by the NRC in Finding FIN 05000443/2011-10-02. Unresolved Item 05000443/2011003-03 is closed.

Comment [A28]: LR: Comment (not necessarily suggest report change): "The issues were determined to be acceptable..." By whom? Why is this item closed? Justification for NRC closure of this item is unclear.

8.2 (Closed) URI 2011-010-01 – Adequacy of Calculation Methods for ASR

NextEra initially pursued mechanical testing of concrete cores because that was the traditional method as described in ACI 228.1R for determining properties of existing concrete structures. Upon further review of industry experience and literature for ASR-affected concrete, NextEra determined that the core test data was not indicative of structural performance of the ASR-affected structures. Once removed from the structure, the concrete in the cores is no longer subject to the strains imposed by the ASR-related expansion or restraints imposed by the reinforcing cage. Confinement provided by reinforcing steel and other restraints (e.g., deadweight of the structure) limits ASR expansion of the concrete within the structure, which reduces the extent of deleterious cracking and associated reduction of concrete material properties. NextEra has determined that the structural evaluations based on mechanical properties derived from core samples may under predict structural performance (FP 100697, Structural Assessment of ASR-State of the Art). Since the reduction of mechanical properties derived from testing of cores is not necessarily representative of the structural performance, NextEra changed its approach. For the interim operability assessment, NextEra compared the structural design capacities to design loads/demands and an assumed lower bound ASR effects. This interim operability assessment was based on available industry data from small scale test specimens having ASR degradation worse than that observed at Seabrook. For the final operability assessment, NextEra plans to monitor structures via Crack Indexing and pursue large scale testing of concrete components that are representative of the Seabrook ASR conditions to demonstrate overall structural performance and operability. The large scale testing will be conducted at the Ferguson Structural Engineering Laboratory (FSEL) at the University of Texas, Austin (UT-A).

NextEra responded to CAL Item #8 by letter dated June 21, 2012, and provided a broad overview of the testing planned at FSEL, which will include a shear test program, a lap splice test program, and an anchor test program. The test program will include control specimens that will provide a baseline by which to determine the reductions in capacity due to ASR and to quantify the margins available as calculated using ACI-318. NextEra plans to use the test program to reconcile the ASR condition with the licensing design basis, to inform the structures monitoring program, and to evaluate potential mitigation strategies. NextEra's actions, approach and methods used to resolve the ASR issue, including the proposed test program, will be evaluated by the team in the second CAL follow-up inspection. Unresolved Item 05000443/2011-010-01 is closed.

9.0 Conclusions and Follow-Up Issues

The team determined during this inspection that NextEra does not plan to finalize their structural evaluations and operability assessments until: 1) the degree of ASR degradation on station reinforced concrete structures is appropriately reconciled with the station design and licensing bases; and 2) the progression of ASR is appropriately monitored to ensure structural integrity and operability is maintained for the duration of the current operating license. Further, the team determined that NextEra's current position is that no reinforced concrete structure at Seabrook Station will be precluded from monitoring for the affects of ASR until a satisfactory petrographic examination has been completed on that structure to confirm the absence of ASR. As

discussed in the above sections, NextEra plans to complete performance testing of large scale test specimens and use the test results to finalize the structural operability assessments and modify the Structures Monitoring Program.

The team plans to conduct a second CAL follow-up inspection to review the remaining open CAL items and the open issues documented in this report and listed below:

- Review of pending structural evaluations, including follow-up of the containment POD observations (Section 3.2.1)
- Review of core sample material property testing and SMP (Section 3.2.2)
- Review quantification of pre-stressing effects of ASR expansion (Section 3.2.8)
- Assess the need for any further rebar examinations or testing (Section 3.2.9)
- Review revised RCE submittal (Section 4.2)
- Confirm revised commitment to CAL Item #7 (Section 5.2)
- Review Crack Indexing and its physical significance for SMP application (Section 6.2)
- Review revisions to the Phase 3 walkdown plans and schedule (Section 7.2)

10.0 Meetings, Including Exit

On November 2, 2012, the team conducted an exit meeting to discuss the preliminary findings and observations with Mr. Kevin Walsh, Site Vice President, and other members of Seabrook Station staff. The inspectors verified that no proprietary information was retained by the inspectors or documented in this report.

SUPPLEMENTAL INFORMATION

KEY POINTS OF CONTACT

Licensee Personnel
B. Brown, Design Engineering Manager
A. Chesno, Performance Improvement Manager
K. Chew, License Renewal Engineer
R. Cliché, License Renewal Project Manager
M. Collins, Design Engineering Manager
J. Connolly, Site Engineering Director
R. Noble, Project Manager
M. O'Keefe, Licensing Manager
T. Vassallo, Principal Design Engineer
K. Walsh, Site Vice President
P. Willoughby, Licensing Engineer

LIST OF ITEMS OPENED, CLOSED, DISCUSSED, AND UPDATED

Updated
None

Opened
None

Closed

05000443/2011-010-01	URI	Adequacy of Calculation Methods for ASR
05000443/2011-003-03	URI	Open Operability Determinations for Safety-Related Structures Affected by Alkali-Silica Reaction

LIST OF DOCUMENTS REVIEWED

Procedures
Maintenance Rule Scoping Document, Revision 0
EDS 36180, Structures Monitoring Program, Revision 0, 1, 2

Corrective Action Documents (AR)
1651969, 1629504, 574120, 581434, 1636419, 1673102, 1647722, 1664399, 1677340, 1687932, 1692374, 1698739, 1755727, 1757861, 1819080, 1804477, 1819069

Drawings

Licensing and Design Basis Documents and Calculations
Seabrook Station UFSAR, Revision 14
ACI 318-71
Calculation CD-20
Calculation CD-18
Calculation C-S-1-10168

Miscellaneous Documents
FP 100348, Statistical Analysis-Concrete Compression Test Data (PTL)
FP 100642, Scope for Alkali-Silica Reaction Walkdowns
FP 100641, Procedure for ASR Walkdowns and Assessment Checklist
FP 100661, Compression Testing Concrete Cores (WJE)
FP 100696, Material Properties of ASR-Affected Concrete
FP 100700, Field Investigation
FP 100705, Structure ASR Walkdown Report (MPR 0326-0058-58)
FP 100714, Three Dimensional Dynamic Analysis of Containment Enclosure Building
FP 100715, ASR Impact Study on Containment Enclosure Building
FP 100716, Interim Assessment: Impact of ASR on Structures (MPR-3727)
FP 100717, ACI 318-71 Perspectives
FP 100718, Anchor Test Report (MPR-3722)
FP 100720, Crack Index and Expansion Measurement
FP 100738, Measurements for ASR Crack Indexing on Concrete Structures
FP 100697, MPR 0326-0058-53, White Paper on Structural Implications of ASR: State of the Art, Revision 1
MPR 0326-0058-83, Shear Screening Criteria Used in MPR-3727
FHWA-HIF-09-004, Federal Highway Administration, "Report on the Diagnosis, Prognosis, and Mitigation of Alkali-Silica Reaction in Transportation Structures."

LIST OF ACRONYMS

ACI	American Concrete Institute
ADAMS	Agencywide Documents Access and Management System
AMP	Aging Management Program
AR	Action Request
ASME	American Society of Mechanical Engineers
ASR	Alkali-Silica Reaction
BRE	Building Research Establishment
CCI	Combined Crack Index
CEB	Containment Enclosure Building
CFR	Code of Federal Regulations
CW	Circulating Water
DCR	Demand to Capacity Ratios
DGB	Diesel Generator Building
DRI	Damage Rating Index
DRP	Division of Reactor Projects
DRS	Division of Reactor Safety
EDG	Emergency Diesel Generator
EFW	Emergency Feedwater
EPRI	Electric Power Research Institute
EOC	Extent-of-Condition
ET	Electric Tunnel
EV	Equipment Valve
FEA	Finite Element Analysis
FHWA	Federal Highway Administration
FP	Foreign Print
FPL	Florida Power and Light
FSEL	Franklin Structural Engineering Laboratory
IMC	Inspection Manual Chapter
IP	[NRC] Inspection Procedure
LF	Load Factor
MPR	MPR Associates, Inc.
NRC	Nuclear Regulatory Commission
PARS	Publicly Available Records
P&ID	Piping and Instrument Diagram
PM	Preventative Maintenance
POD	Prompt Operability Determination
PRA	Probabilistic Risk Assessment
psi	pounds per square inch
QA	Quality Assurance
RCA	Radiologically Controlled Areas
RCE	Root Cause Evaluation
RHR	Residual Heat Removal
SDP	Significance Determination Process
SG&H	Simpson, Gumpertz & Heger
SMP	Structures Monitoring Program

SRI	Senior Resident Inspector
UFSAR	Updated Final Safety Analysis Report
UT-A	University of Texas - Austin
UK	United Kingdom
WO	Work Orders

NextEra Crack Rating Chart

Assessment of Severity of ASR in Hardened Concrete by Petrographic Examination

This rating system is based on a modified "best practice" procedure initially developed at tehe Building Research Establishment (BRE) in the United Kingdom, using ASR identification critieria first set out in the British Concrete Association report titled "The Diagnosis of Alkali-Silica Reaction," (1992).

Rating	Description
0	No cracking detected
1	Very slight cracking (no evidence of deleterious ASR)
2	Slight cracking (minor or trace evidence of deleterious ASR)
3	Moderate cracking (moderate evidence of deleterious ASR)
4	Severe cracking (severe evidence of deleterious ASR)
5	Very severe ASR-related cracking
6	Heavily fractured ASR-related damage

Buford, Angela

From: Raymond, William NRO
Sent: Friday, November 30, 2012 8:42 AM
To: Conte, Richard; Cook, William; Buford, Angela
Cc: Trapp, James; Galloway, Melanie; Miller, Chris; Chaudhary, Suresh
Subject: RE: DLR Comment Resolutions of Seabrook Rpt

Here is another part of the same article wit my emphasis added...

At the plant's annual press briefing, communications manager Alan Griffith, said engineers are studying the deterioration, caused by Alkali Silicon Reaction, contamination of concrete in structures under water. He pointed out that **no** such **deterioration** has been found in critical areas, including the **dome** housing the plant's radioactive fuel rods.

"You're talking about almost 6 feet of steel reinforced concrete. The containment structure itself is fully intact and unaffected by ASR."

Griffith says that preliminary studies indicate that that several structures affected by ASR are fully functional, but that the owner, *NextEra Energy will take steps to seal concrete in those areas* **if** the **Nuclear Regulatory Commission requires it.** NextEra is seeking an extension of its operating license until 2050, and the ASR study will be part of its decision-making process. The media briefing held Wednesday is an annual NRC requirement.

Two points:
1) TO SAY THE CONTAINMENT IS UNAFFECTED BY ASR IS DISINGENUOUS, AT BEST
2) WILL FIX THE PROBLEM ONLY IF REQUIRD BY TH NRC – WELL, SO MUCH FOR A ROBUST CA PROCESS

From: Conte, Richard RJ
Sent: Thursday, November 29, 2012 8:16 PM
To: Cook, William; Buford, Angela
Cc: Trapp, James; Galloway, Melanie; Raymond, William; Miller, Chris; Raymond, William; Chaudhary, Suresh
Subject: RE: DLR Comment Resolutions of Seabrook Rpt

We hope to be signing the report on Monday before noon, to release to NextEra in the afternoon - release to ADAMS and ListServ will be Tuesday 12/3

Also, Interesting statements in the news of the day – could be quotes out of context. Not sure what the dome housing fuel rods is – Rx Vessel Head and it is subject to ASR ???. Are they saying primary containment is not a critical area and what does deterioration mean.

Seabrook Station Concrete Deterioration Not In Critical Areas, Spokesman Says. The AP (11/29) reports, "Officials at the Seabrook Nuclear Plant say the plant is operating safely although concrete deterioration has been found in some structures." Seabrook Station spokesman Alan Griffith "said Wednesday at the plant's annual press briefing that engineers were studying the deterioration in concrete in structures under water caused by Alkali Silicon Reaction." Griffith noted that the "deterioration has not been found in critical areas, including the dome housing the plant's radioactive fuel rods."

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To explain away the apparent increase in CI data, SGH concluded (page 6) that the CI data collected on December 2012 appears larger than the CI data measured in June 2012 because ..."the concrete was significantly colder...this may cause the concrete to contract between the cracks, increasing the apparent crack widths". The opposite is true. The colder concrete would contract but result in tighter rather than wider cracks- crack widths should decrease, not increase in colder weather. The fact that wider cracks were measured in colder weather indicates the actual CIs are likely larger than suggested by the December data since some of the increase would be offset (masked) by the seasonal fluctuations.

5. Null Result for Expansion Measurement FP 100812 (Section 6, page 5)
   I am still reviewing this report to see how it correlates with the CI measurements. More to come later. I have two initial comments:
   a. If CI data shows apparent increase when expansion data in 2D shows no change, then either (i) the CI measurement does not accurately reflect expansion (strain) in the structure; or, (ii) the CI data does reflect expansion (strain) in the structure but the expansion measurement in 2D only is not an accurate indicator of changes in the structure. Which is true?
   b. How did the gage points at locations 1, 9, and 14 get out of measurement range? Where they always out of measurement range and thus were not initially installed correctly? Or, were they within measurement range when installed but then moved out of measurement range? If the latter is the case, what is the significance relative to expansions in the structure? Accuracy of the expansion measurement technique?

Overall, the CI and expansion data show any structural changes are very small, such that there are no challenges to the conclusions on the current ODs. The above observations highlight the need for NextEra to continue the 6-month measurements and trending until (i) a stable pattern in the CI measurement data is evident and the results are reliable and predictable 9on a per building basis); and, (ii) tests at FSEL are completed and the results incorporated into a final OD.

Bill Raymond

Buford, Angela

From: Buford, Angela
Sent: Friday, November 30, 2012 12:04 PM
To: Erickson, Alice
Subject: RE: Can you review this statement quickly?!

You too!! ☺

From: Erickson, Alice
Sent: Friday, November 30, 2012 12:00 PM
To: Buford, Angela
Subject: RE: Can you review this statement quickly?!

Thanks, I appreciate your help. That's what I was calling to bug you about. Have a good weekend!

From: Buford, Angela
Sent: Friday, November 30, 2012 11:56 AM
To: Erickson, Alice
Cc: Raymond, William
Subject: RE: Can you review this statement quickly?!

That's right! I added (in blue) just a couple minor edits.

If you still need to, you can give me a call.

From: Erickson, Alice
Sent: Friday, November 30, 2012 10:35 AM
To: Buford, Angela
Subject: Can you review this statement quickly?!

Good morning Angie,

I was working with Bill Raymond this morning on comments related to the allegation checklist and he suggested adding a detail from the timeline you prepared, that I had missed. Michael requested we leave all names out so I made some minor edits, but can you please review the statement below that I plan to include to ensure I haven't mischaracterized it?

1. In an interview on 11/1/12, the cognizant engineer stated that in April 2012, NextEra knew they had data on containment that exceeded CCI tier 3. The cognizant engineer said they evaluated the situation with the rationale that even if it was ASR, there is no impact on containment because of heavy reinforcement. The cognizant engineer said they recognized the need to document ~~that~~ the tier 3 cracking and do a structural evaluation per the Corrective Action Program, but it never got done until NRC raised the issue in July 2012.

Any comments are greatly appreciated! I need to get back to Ron ASAP.

Thanks,

Alice

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6.0 Review of Crack Indexing (CAL Item #10)

6.1 Inspection Scope

CAL Item #10 committed NextEra to perform the initial six-month interval crack measurements and crack indexing at 20 locations in areas that exhibit the highest crack indices by July 15, 2012, and provide the results for NRC review. The team conducted a review of FP 100647, "Crack Index Determination," Revision 1, to understand the methodology for NextEra's monitoring of ASR progression in selected reinforced concrete structures. The team used 10 CFR Part 50, Appendix B, Criterion V, "Instructions, Procedures, and Drawings," to evaluate the implementation and adequacy of the procedural guidance. The team's review was limited in scope, in that, the adequacy of crack mapping, as the sole means of monitoring ASR progression in Seabrook structures, is still under NRC review. The team will evaluate the adequacy of the Structures Monitoring Program, which includes crack indexing as a component of the overall program, during the review of CAL Item #9, "Update the Maintenance Rule Structures Monitoring Program to include monitoring requirements for selected locations in areas that exhibit ASR," during the second CAL follow-up inspection. The team noted that the SMP, as submitted to the NRC as an aging management program as part of NextEra's license renewal application will also continue to be reviewed as part of the staff's license renewal review.

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The team observed field measurements taken on June 20, 2012, by the responsible contractor and discussed the general methodology and procedural guidance with the individuals performing the crack indexing measurements and the supervising NextEra staff. The team noted that NextEra found ASR patterned cracking in many areas within Seismic Category I and Maintenance Rule structures, but only a limited number of these areas have sufficient ASR degradation to merit continued monitoring and detailed evaluations. The ASR walkdowns identified 131 locations with some level of pattern cracking. Of the 131 localized areas, 26 exceeded the initial screening criteria of a combined crack index greater than 1.0 millimeter per meter (mm/m). The 1.0 mm/m threshold was contained in the Structures Monitoring Program, Attachment 3, for conducting a structural evaluation. These 26 areas will continue to be monitored at six-month intervals, per FP 100647.

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6.2 Findings and Observations

No findings were identified and the CAL Item #10 commitment is closed. The team noted that the periodic crack indexing currently provides the principle method selected by NextEra to monitor the progression of ASR on reinforced concrete structures. The six-month interval measurements are currently planned until a reliable trend of ASR progression can be established, per Structural Engineering Standard Technical Procedure 36180, "Structures Monitoring Program," Attachment 3, Revision 2. As stated above, additional NRC review of the Structures Monitoring Program will be conducted in the second CAL follow-up inspection and the license renewal review.

The team also reviewed the current methods and terminology used by NextEra to characterize the degree of ASR pattern cracking, previously addressed in NRC Inspection Report 05000443/2011007. When ASR was initially identified in the B electrical tunnel in

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mid-to-late 2010, the licensee referred to the Federal Highway Administration (FHWA) guidance document FHWA-HIF-09-004 for crack/damage characterization. Three major categories were identified: mild, moderate, and severe, with ratings such as mild to moderate and moderate to severe, also used. Per FHWA-HIF-09-004, these categories were used to define the recommended remedial actions to be taken once ASR was identified. At that time, NextEra labeled the observed cracking as "severe." Per the FHWA guidance, this category requires "further investigation for selecting remedial actions." This characterization was repeated in the above referenced inspection report. The team determined that NextEra revised their crack characterization scheme prior to the implementation of the structures extent-of-condition review. The revised crack rating system was based upon "best practices" taken from the Building Research Establishment (BRE) in the United Kingdom (UK). The revised numeric rating system range is from 0 (no cracking detected) to 6 (heavily fractured ASR-related damage).
FP 100636, "Petrographic Examination PE Reports," Revision 0, lists the material property results of all core samples taken and petrographically analyzed. FP 100636 also provides the BRE crack rating for each specimen examined. The crack ratings for the specimens examined range from 0 to 4 (a rating of 4 represents severe cracking).

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6.2 Findings and Observations

No findings were identified and the CAL Item #10 commitment is closed. The team noted that the periodic crack indexing currently provides the principle method selected by NextEra to monitor the progression of ASR on reinforced concrete structures. The six-month interval measurements are currently planned until a reliable trend of ASR progression can be established, per Structural Engineering Standard Technical Procedure 36180, "Structures Monitoring Program," Attachment 3, Revision 2. As stated above, additional NRC review of the Structures Monitoring Program will be conducted in the second CAL follow-up inspection and the license renewal review.

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Marshall, Michael

From: Galloway, Melanie
Sent: Monday, December 03, 2012 7:56 AM
To: Marshall, Michael
Subject: FW: Seabrook ASR Report another take

Michael,

On the items I identified re DLR, we ended up on a place I am comfortable with. I will fill you in later on other aspects when I see you or can call.

Melanie

PS Angie did a great job and was a huge help all week. Couldn't have done it without her. More on that too.

From: Miller, Chris
Sent: Friday, November 30, 2012 4:51 PM
To: Trapp, James; Galloway, Melanie
Cc: Conte, Richard
Subject: RE: Seabrook ASR Report another take

Thanks all.

From: Trapp, James
Sent: Friday, November 30, 2012 4:49 PM
To: Galloway, Melanie; Miller, Chris
Cc: Conte, Richard
Subject: RE: Seabrook ASR Report another take

It's in the report – have a good weekend – Thanks!

From: Galloway, Melanie
Sent: Friday, November 30, 2012 4:48 PM
To: Miller, Chris; Trapp, James
Cc: Conte, Richard
Subject: RE: Seabrook ASR Report another take

I'm OK with that.

From: Miller, Chris
Sent: Friday, November 30, 2012 4:47 PM
To: Galloway, Melanie; Trapp, James
Cc: Conte, Richard
Subject: RE: Seabrook ASR Report another take

It should be noted that the inspection team results are based solely on 10 CFR Part 50 requirements. The ~~Agency~~ NRC is currently in the process of conducting a separate review of the ASR issue as part of the license renewal process in accordance with 10 CFR Part 54. As such, certain aspects of the ASR issue

B7(6)

discussed here may also have applicability to the license renewal review and entail additional consideration and require additional information beyond that discussed in this report. Remove: herein (e.g., crack mapping).

From: Galloway, Melanie
Sent: Friday, November 30, 2012 4:42 PM
To: Trapp, James; Miller, Chris
Cc: Conte, Richard
Subject: RE: Seabrook ASR Report

What do you think?

From: Trapp, James
Sent: Friday, November 30, 2012 4:35 PM
To: Miller, Chris; Galloway, Melanie
Cc: Conte, Richard
Subject: Seabrook ASR Report

It should be noted that the inspection team results are based solely on 10 CFR Part 50 requirements. The ~~Agency~~ NRC is currently in the process of conducting a separate review of the ASR issue as part of the license renewal process in accordance with 10 CFR Part 54. As such, certain aspects of the ASR issue discussed here may also have applicability to the license renewal review and entail additional consideration and information beyond that discussed herein (e.g., crack mapping).

For your consideration – we are VERY open to suggestions. Thanks

Buford, Angela

From: Buford, Angela
Sent: Monday, December 03, 2012 1:03 PM
To: Graves, Herman
Subject: RE: In-situ Monitoring of ASR 11-27-12.docx

Thank you! I'll give you a call tomorrow. From your comments, I'm not sure how you would recommend shortening the write-up, so let me know if you have further thoughts on this.

Angie

From: Graves, Herman
Sent: Friday, November 30, 2012 3:28 PM
To: Buford, Angela
Subject: RE: In-situ Monitoring of ASR 11-27-12.docx

Angie,

Good job, I can see that you have done quite a bit of reading. I believe that the write-up can be shortened a bit. I have attached some comments for your consideration.

Give me a call if you would like to discuss.

Thanks,

<<Herman>>
<<301.251.7625>>
mail to: Herman.Graves@nrc.gov

From: Buford, Angela
Sent: Thursday, November 29, 2012 6:44 AM
To: Cook, William; Raymond, William; Conte, Richard; Chaudhary, Suresh
Cc: Graves, Herman
Subject: In-situ Monitoring of ASR 11-27-12.docx

Please find attached the crack mapping paper. Consider this a draft, because I'd like to get your comments and incorporate them before the paper is final.

I realize it's an extremely quick turnaround, but if there are any pressing or substantive comments/concerns, please provide them to me by COB today (Thursday). If not possible today, then tomorrow at the latest.

Thanks a lot!

Angie

B77

Buford, Angela

From: Buford, Angela
Sent: Monday, December 03, 2012 12:19 PM
To: Marshall, Michael
Subject: For Your Review: In-situ Monitoring of ASR 11-28-12 sent to region.docx
Attachments: In-situ Monitoring of ASR 11-28-12 sent to region.docx

Michael,

Please see the attached file. I have made some minimal changes throughout the document from Abdul and Bill Cook's comments, but please focus on the last two parts, the incorporation of the Damage Rating Index portion and the Conclusion/Recommendations section.

Please also consider whether you think a more "direct", or possibly bulletized version of the conclusion section is better or warranted.

Thanks,

Angie

In situ Monitoring of ASR-affected Concrete

A study on crack indexing and damage rating index to assess the severity of ASR and to monitor ASR progression

Written By:
Angela Buford

Key Messages:

1. Surface cracking may not be indicative of the conditions of the concrete through the section, and crack indexing measurements may not consistently indicate the level of ASR severity from one structure to another. For each group of similar (i.e., reinforcement detail, size, environmental conditions) structures, additional examinations are necessary to correlate crack measurements to severity of ASR degradation.

2. Crack mapping results should be correlated to actual strains (and therefore stresses) in the concrete and rebar in order to accurately represent the effect of ASR-induced stresses in engineering evaluations for structural behavior.

3. Damage Rating Index (DRI) is a more accurate measure of ASR severity than crack indexing, and alleviates many of the pitfalls of the crack indexing method. DRI should be considered as a method to assess damage related to ASR.

Alkali-Silica Reaction (ASR)

ASR is a chemical reaction that occurs in concrete between alkali hydroxides dissolved in the cement pore solution and reactive silica phases in the aggregates. The product of the reaction is an expansive gel around the aggregate particles, which imbibes water from the pore fluid, and, having much larger volume than the reacting components, triggers a progressive damage of the material (Winnicki and Pietruszczak 2008). The pressures imparted by the gel onto the concrete can exceed the tensile strength of the aggregates and the cement paste and cause microcracking and macrocracking in the aggregate and surrounding paste. With the presence of moisture, the gel expands and can cause destructive cracking and deleterious expansion of the concrete. The extent of the concrete deterioration depends on aggregate reactivity, high levels of alkalinity, availability of moisture, temperature, and structural restraint (Williams, Choudhuri, and Perez 2009). Concrete expansion and cracking can lead to serious operational and serviceability problems in concrete structures (Rivard et al. 2002).

Surface Cracking and Expansion

The Federal Highway Administration (FHWA) Report on the Diagnosis, Prognosis, and Mitigation of Alkali-Silica Reaction in Transportation Structures states that "in concrete members undergoing internal expansion due to ASR and subject to wetting and drying cycles (cyclic exposure to sun, rain, wind, etc.), the concrete often shows surface cracking because of induced tension cracking in the 'less expansive' surface layer (because of variable humidity conditions and leaching of alkalis) under the expansive thrust of the inner concrete core (with more constant humidity and pH conditions)." Cracks first form as three or four-pronged star patterns resulting from expansion of the gel reacting with the aggregate. If the concrete is not subject to directional stress, the crack pattern developed forms irregular polygons, commonly referred to as map cracking (Swamy 1992). This cracking is usually enough to relieve the pressure and accommodate the resulting volume increase (Figg 1987; reported by Farny et. Al. 2007).

Map cracking is one of the most commonly reported visual signs associated with ASR. The pattern and severity of cracking vary depending on the type and quantity of reactive aggregate used, the alkali content of the concrete, exposure conditions, distribution of stresses, and degree of confinement in the concrete (Smaoui et al. 2004). ASR can also be characterized by longitudinal cracking, surface discoloration, aggregate pop-out, and surface deposits (gel or efflorescence) (Williams, Choudhuri, and Perez 2009). Although pattern cracking is a characteristic visual indication that ASR may be present in the concrete, ASR can exist in concrete without indications of pattern cracking. Newman (2003) noted that "while superficial cracking patterns can often be reminiscent of ASR, it is important to be aware that reliable diagnosis can never be adequately based on the appearance of surface cracking alone." This consideration is also emphasized by Barnes (2001), whose research cites examples where cracking was thought to be and diagnosed as ASR, and also examples in which ASR gel and associated cracked aggregate particles were found in concrete that was uncracked. In addition, in ASR-affected structures with reinforcement close to the surface or in heavily reinforced structures, surface cracking may be suppressed while internal damage exists throughout the section. The presence and extent of surface cracking is not a conclusive indication that ASR is present or measure of concrete degradation due to ASR; and conversely, the absence of surface cracking does not conclusively indicate the absence of ASR.

Crack Mapping/Indexing

In order to determine the effect of ASR on the performance of a concrete structure, it is important that there be an understanding of current concrete condition (ASR damage reached to-date) and the rate of expansion. Crack indexing is a method that is proposed to measure crack widths and expansion of cracks over time. For this visual examination individual crack widths are measured over a defined grid and the total amount of cracking is quantified. The examination is repeated over regular intervals and the results are compared over time, with a goal of establishing a rate of ASR progression. The Institute of Structural Engineers (ISE 1992) proposed a method for crack mapping that consists of measuring the ASR crack widths along five parallel lines that are each 1 m long. Lines are traced directly onto the concrete structure. The total width of intersecting cracks along each line is summed and divided by the length over which they were measured, to determine the severity of ASR cracking, and then over time to determine the rate of expansion. Another method, suggested by Laboratoire Central des Ponts et Chaussees (LCPC 1997), consists of measuring the widths of all cracks intersecting two perpendicular 1m lines originating from the same point and their two diagonals 1.4 m long. The total crack index is determined as a value in millimeters per meter and compared to criteria that correspond to action levels.

Summary of General Discussion on Crack Mapping

It is stated throughout ASR research that crack mapping is somewhat limited in its applicability to understanding ASR degradation in concrete. Saint-Pierre et al. (2007) note that compared to other non-destructive methods developed for assessing the damage induced by ASR, the semi-quantitative surface methods like crack mapping appear to be less effective. It is generally agreed that while results of crack indexing can potentially give some indication of how ASR is progressing over time, establishing an absolute trend that directly correlates expansion levels to ASR progression may not be a reliable practice. Most ASR research also indicates that using crack measurement alone to characterize the current state of ASR degradation would not be advised, since the practice relies on the assumption that the surface cracking on the face of a structure is wholly congruent to ASR severity. In the 2010 Addendum to its report titled "Structural Effects of Alkali-Silica Reaction - Technical guidance on the Appraisal of Existing Structures," ISE stated that the crack summation procedures for estimating expansion to date work well in directions where there is little restraint from structural stress, reinforcement, or prestress. This suggests that in structures with higher restraint, this would not be the case. In addition, crack mapping is limited in that it can only give data on two-way crack measurements and does not capture cracking in the out-of-plane direction. It is suggested that further activities be carried out for assessing current condition of the concrete and current expansion rate, as well as correlating the expansion to structural integrity.

In addition, crack indexing evaluation criteria should not be universally applied to all structures because surface cracking may not give a reliable indication of the ASR degradation to the structure. Due to variability in size, location, environment, reinforcement detailing, and relative severity of ASR damage, it may be necessary to obtain an understanding of the ASR effects for each individual structure or group of structures with similar physical properties and environments. Indeed, Newman (2003) stated "it is important to relate cracking patterns variously to structural geometry and/or design, apparent concreting sequence, localized detailing (especially where cracking may be coincident with water leakage) and both environmental and in-service conditions." Deschenes et al. (2009) also state that research into the method highlighted that a number of factors (size and shape of member, restraint present, depth of cover, etc.) leading to poor correlation between crack indexing and measured expansions.

Surface Cracking vs. Internal ASR Damage

The correlation between surface cracking and ASR deterioration may be closer to unity for specimens used in the laboratory that are only allowed to deteriorate due to ASR conditions. However, for concrete in the field, the surface indications sometimes poorly correlate to the extent of ASR degradation within the concrete. Since conditions are so variable from one region to another, and even from one place to another in the same structure, poor correlations are often observed between the severity of surface cracking and the presence of the internal signs of ASR (i.e., reaction products, micro-cracking, and expansion) (Nishibayashi et al. 1989 and Stark 1990 reported by Smaoui et al. 2002). Development of cracking on the surface depends strongly on the amount of reinforcement close to the surface (Smaoui et al. 2002) and also depends on external environmental conditions such as wetting-drying, freezing-thawing, and exposure to saline solutions (Smaoui et al. 2002). Two examples of situations in which external conditions can affect the surface cover concrete such that the surface features are not indicative of the actual ASR degradation of the structure are presented here for consideration. In one case, presence and extent of surface cracking can depend on the pH of the surface which can be affected by leaching and carbonation. As such, wetting-drying cycles can affect the features of ASR, as conditions at the surface layer could be less favorable to the development of ASR, due to the [lower] humidity during the drying periods and the leaching of alkalis during the wetting periods (Poitevin 1983 and Swamy 1995, reported by Smaoui et al. 2004). In other words, if the outer surface layer of concrete is exposed to conditions that would cause the ASR severity or development to be lower, but conditions inside the concrete remain conducive to ASR development (i.e., high relative humidity); surface conditions would not be representative of the ASR within the concrete section. Crack indexing efforts would incorrectly characterize the level of ASR degradation as minor, when within the section the ASR degradation might be more severe.

Another example in which environmental conditions have caused surface conditions to be different than conditions within the concrete is the subject of a study done by Berube et al (2002). In this study, an attempt was made to correlate ASR expansion with type of exposure to moisture. Results showed that in specimens exposed to wetting-drying cycles saw more surface cracking but less actual expansion than specimens that were always exposed to humidity. In this case, the larger amount of surface cracking evident in the specimens exposed to wetting-drying cycles did not show to correlate well to the actual expansion due to ASR, with the ASR expansion being less severe than the cracking would indicate. Conversely, the specimens that showed less surface cracking saw a greater expansion due to ASR, which shows that visual examination of surface cracking alone may not be adequate.

Smaoui et al. (2004) state that although the intensity of surface cracking on ASR-affected concrete in service can help to assess the severity of ASR, quantitative measurement of this intensity [i.e., crack mapping] [could] lead to values that generally underestimate the true expansion attained, except maybe when the surface concrete layer does not suffer any ASR expansion at all. If the concrete surface layer undergoes ASR expansion that is less than that of the inner concrete, according to Smaoui et al. (2004), "the measurement of surface cracking will tend to give expansion values lower than the overall expansion of the concrete element under study." This research indicates that the degree of correlation between surface cracking and actual ASR expansion or degradation tends to vary with the level of exposure, which means that crack indexing over a number of structures with varying environmental conditions may not conclusively measure the extent or severity of ASR degradation. It should also be noted here that periodic crack indexing measurements also have the potential to be misleading since crack sizes can vary seasonally.

ASR-induced Stresses

The ISE (2010) noted that for some structures exposed to ASR, internal damage occurs through the depth [of the section] but visible cracking is suppressed by heavy reinforcement. In reinforced concrete structures, expansion of ASR cracks generates tensile stresses in the reinforcing steel while also causing compressive stresses in the concrete surrounding the rebar (this phenomenon is often likened to prestress in the concrete and noted to temporarily improve structural behavior). According to Smaoui et al., 2004, the most useful information in the structural evaluation of an ASR-affected concrete member is the state of the stresses in the concrete, but more importantly in the steel reinforcement. The ASR-induced stresses increase the structural demand on the steel and concrete, but this new design load has likely not been accounted for in the original design or in further structural evaluations. According to Multon et al. (2005), "assessment models have to take into consideration the property of stresses to modify ASR-induced expansions and their effect on the mechanical response of ASR-damaged structures..." The expansion reached to date, the current rate of expansion, and the potential for future expansion of the concrete are particularly critical pieces of information to determine whether or not the reinforcing steel has reached or will at some point reach its plastic limit, thus creating risk of structural failure (FHWA 2010).

Crack mapping alone to determine ASR effects on the structure does not allow for the consideration of rebar stresses. Visual examination and measurement of crack growth should be correlated to strain measurements taken of ASR-affected concrete and the reinforcing steel. In similar structures, then, the visual indications of expansion due to ASR can relate to stresses in the concrete and reinforcing steel in order to apply ASR-induced stress as an additional load in structural evaluations. Smaoui et al., 2004 propose that if it is not possible to do a destructive examination (i.e., exposing the rebar or taking deep cores) of the structure in question, "an indirect method is based on the expansion accumulated to date...Assuming that this expansion corresponds to that of the reinforcement steel, the stresses within the reinforcement and the concrete could thus be determined from the modulus of elasticity of the steel and the corresponding sections of the concrete elements under investigation." For determining added stresses in in situ structures, once correlation has been made with respect to size and rebar configuration between the in situ structure and a test specimen, it would be appropriate to use crack mapping as a measure of ASR degradation when introducing the additional ASR-induced stresses on concrete and reinforcing steel in structural evaluations.

Discussion on Applicability of Crack Indexing

This report is not intended to present the position that crack indexing and resulting data should not be part of a structural monitoring program to assess the ongoing effects of ASR in concrete. In fact, crack indexing is recommended by the Federal Highway Administration (FHWA 2010) "to obtain a quantitative rating of the 'surface' deterioration of the structure as a whole" (it should be noted that in the FHWA document, the word "surface" is emphasized with quotation marks, which implies recognition that crack indexing measurements alone provide information limited only to what is occurring at the concrete surface). This report's position is that crack mapping can only be useful once there is an understanding of how the conditions inside the concrete, (i.e., relative humidity, presence and severity of cracking, and added stresses in the concrete, reinforcing detail) correlate to the cracking observed at the surface. The FHWA (2010) document agrees, indicating that to obtain an understanding of the current state of ASR degradation and in order to correlate the surface cracking to the actual effects of ASR-induced expansion on the structure, other investigations of the in-situ structure are necessary. In addition to crack indexing, FHWA recommendations that apply to nuclear structures include taking stress [strain] measurements in reinforcing steel, obtaining temperature and humidity readings, and performing non-destructive testing such as pulse velocity measurements (the recommendation to use pulse velocity measurements is in agreement with the experimental findings of Saint-Pierre et al. 2007). The Institution of Structural Engineers (ISE 2010) suggests that expansion to date and severity of ASR should be evaluated using examination and testing of cores for changes in modulus of elasticity and development of hysteresis (stiffness deterioration). It is also proposed that strain sensors be used as a method of monitoring ASR progression (Harries 2012) in order to monitor and quantify out-of-plane expansion.

In addition to provisions for monitoring (or predicting) progression of ASR, it is recommended that each structure or group of similar structures undergo petrographic analysis to determine the current state of ASR damage, in order to provide an accurate baseline from which to understand the current severity level and monitor ASR progression.

Discussion on Applicability of Damage Rating Index

The damage rating index (DRI) was developed by Grattan-Bellew and Danay in 1992 (Reported by Smaoui et al. 2004) as a method to determine the extent of internal damage in concrete affected by ASR (Rivard et al. 2002). The DRI is a method for quantifying both qualitative and quantitative observations and determining severity of ASR using petrographic analysis of polished sections of concrete. It is based on the recognition of a series of petrographic features that are commonly associated with ASR (Rivard et al. 2002). The DRI accounts for defects observed in the concrete, such as the presence and distribution of reaction products, existence of internal microcracking, and location of microcracking (within the aggregate vs. through the cement paste) by assigning a weighting factor to each and quantifying overall damage. When the factors are normalized to an area of 100 cm^2, the resulting number is the DRI. Rivard et. Al. (2000) noted that the abundance of individual defects and the overall DRI values increased with regularity with increased ASR expansion. It should be noted that the specimens used by Rivard et. Al. were comprised of reactive aggregates with different reaction mechanisms, but ASR expansion indeed correlated with DRI measures of ASR severity.

Smaoui et al. (2004) performed damage rating indexing on specimens from five concrete mixes using different reactive aggregates to determine if there was a reliable and accurate correlation between ASR damage determined by DRI and ASR expansion measurements. They noted that there exists a potential error in estimating expansion of ASR concrete in the field and establishing a DRI-expansion relationship with laboratory testing. In some of the lab specimens, relatively similar DRI values were obtained for very different expansion levels for cylinders which had been cast with the same concrete mix (and progressed ASR over time). The tests indicated that expansion levels (of in situ structures compared to laboratory specimens) may not be the best indication of ASR degradation. For example, the presence of air bubbles in the proximity of reactive aggregates [in field concrete] usually has the effect of reducing the expansion due to

ASR (Landry 1994, Reported by Smaoui et al. 2004). In other words, air bubbles that exist in the in situ concrete structure could result in a smaller expansion of the structure as concluded under crack mapping activities while more severe ASR damage could be present in the structure because ASR features have "room" to grow inside the existing structure before extensive cracking is notable on the concrete surface. Smaoui et al. (2004) concluded that "for evaluating the expansion attained to date by ASR-affected concrete, it may be necessary to reconsider the relevant defects and their respective weighting factors and take into account a certain number of factors such as the presence or absence of entrained air and preexisting cracks and alteration rims" to assess the severity of ASR in structures. It is notable that the research done by Rivard et al. (2000) showed that DRI correlated well with actual ASR expansion, while subsequent work done by Smaoui et al. (2004) proposed that in some cases lack of gross expansion did not correlate to low ASR degradation, and that air bubbles prevented macro-level expansion even though ASR effects were severe. Crack indexing would not have identified this severe ASR progression since that method only measures expansion of surface cracks,

Rivard et al. noted a possible limitation of the DRI method: that weighting factors assigned to each defect may not universally apply to all types of reactive aggregates (reported by Smaoui et al. 2004) and that weighting factor adjustments may be needed depending on the type of reactive aggregate being examined. In other words, DRI results (and their correlation to concrete expansion) should not be applied universally between concretes with different aggregates (with different types of siliceous materials), However, the FHWA (2010) notes that the DRI method can be useful for quantitative assessment of ASR damage for concretes with the same constituents (i.e., same type of reactive aggregate and cement mix design), and can provide useful relative information when cores are taken and a damage rating developed for each structure by the same experienced technician.

Conclusion/Recommendations

In order for the effects of ASR on concrete to be understood, the parameters that need to be understood are (1) the amount of cracking inside the concrete, (2) ASR-induced expansion-to-date and rate of expansion, and (3) effects of ASR on concrete and rebar stresses. Visual examination of the concrete surface, without any other information about the concrete beneath the surface, is not recommended for either determining the current level of ASR degradation or projecting the future effects of ASR in concrete. Crack indexing would be an adequate and reasonable method of monitoring ASR progression once surface cracking can be correlated to actual ASR degradation, including cracking, expansion, and corresponding stresses (strains) in the concrete and rebar. Laboratory and in-situ testing must be performed to correlate surface cracking with loss of mechanical properties because cracking patterns may vary for different structural geometry and/or design, apparent concreting sequence, localized detailing (especially where cracking may be coincident with water leakage) and both environmental and in-service conditions (Newman et al. 2003).

At a minimum, for each set of structures with the same environmental conditions (e.g. chronically wetted, exposed to freeze-thaw action, constant wetting/drying) and section properties (e.g. wall thickness, rebar layout), an initial petrographic analysis should be done to establish the current state of ASR degradation. The severity of ASR damage on the inside of the structure should be correlated to the surface cracking found on the face of the concrete. The expansion measured by subsequent periodic crack indexing can then be assessed on a structure by structure basis depending on that correlation. Also, depending on the correlation between the surface and interior indications for each set of structures, it may be appropriate to adjust the individual crack width and CCI acceptance criteria for different groups of structures. An added benefit to doing an initial petrographic analysis is that the cores removed from the structure could be studied for subparallel microcracking that would not be detected from crack mapping efforts, which only show cracks on the surface face. This is the minimum effort that should be undertaken to gain at least a more informed understanding, for each set of similar structures (physical attributes and environmental conditions), of the ASR expansion reached to date and rate of expansion. The ability to correlate in situ conditions with laboratory testing would strengthen the reliability of the crack indexing method.

A recommended "more than minimum" approach to monitoring ASR progression, in agreement with Dr. Harries' recommendation (2012), would be the use of embedded strain sensors in the concrete to provide a measure of expansion in the concrete. This would provide the most accurate measure of expansion due to ASR and would provide the benefit of understanding expansion due to cracking in the third direction. The application of strain instrumentation would also be able to quantify strains (stresses) on the rebar and concrete in order to apply the additional demand due to ASR to a structural engineering evaluation. Finally, this method would help to establish a rate of expansion in the concrete, and could provide insights into understanding the ASR degradation mechanism, including relating environmental conditions specific to a structure to the rate of change of ASR progression, in order to characterize the potential and extent of continued degradation over time.

The DRI method has been shown to be an effective method for assessing the damage level of ASR-affected structures. However, due to the limitation of this method in being able to apply weighting factors consistently between various types of aggregates, practical implementation of this method would mean that site-specific criteria for severity ratings and weighting factors for ASR indications may need to be established in accordance with the reactivity of the aggregate used on site. Also, since there is no standard test procedure available and thus the DRI method results could be variable from one petrographer to another, it would be important to ensure quality and consistency in the implementation of the method. If consistency could be ensured through quality of the technician performing the initial examination and subsequent examinations, the DRI would provide a beneficial and useful understanding of current ASR degradation and degradation over time.

References

(coming soon)

Buford, Angela

From: Buford, Angela
Sent: Tuesday, December 04, 2012 3:28 PM
To: Cook, William
Subject: RE: LR comments on Seabrook IR

Ah – I like it! Things don't always go that far over my head, Haha.

From: Cook, William
Sent: Tuesday, December 04, 2012 3:23 PM
To: Buford, Angela
Subject: RE: LR comments on Seabrook IR

Just an expression..... Recognition of performance (good or bad) may be exercised in any number of ways, but my birthday can't be taken away.

From: Buford, Angela
Sent: Tuesday, December 04, 2012 11:01 AM
To: Cook, William
Subject: RE: LR comments on Seabrook IR

Was your birthday yesterday? Happy Birthday!!! December 3 is my *half* birthday, so obviously it's an exciting day for all. ☺

From: Cook, William
Sent: Monday, December 03, 2012 5:17 PM
To: Buford, Angela
Subject: RE: LR comments on Seabrook IR

The report is issued and I still have my Birthday intact.

From: Buford, Angela
Sent: Monday, December 03, 2012 3:28 PM
To: Cook, William
Subject: RE: LR comments on Seabrook IR

How did it turn out? Or, what feedback did you give Chris?

From: Cook, William
Sent: Friday, November 30, 2012 4:28 PM
To: Buford, Angela
Subject: FW: LR comments on Seabrook IR
Importance: High

FYI

From: Miller, Chris
Sent: Friday, November 30, 2012 4:03 PM
To: Cook, William; Trapp, James; Conte, Richard
Cc: Powell, Gerry

B7-8

Subject: FW: LR comments on Seabrook IR
Importance: High

Let me know your thoughts on the proposed changes, and if they add value-let's make them. On section 6 unless we have better wording and assuming we can live with their changes, we should make the changes in order to facilitate moving on.

From: Galloway, Melanie
Sent: Friday, November 30, 2012 3:55 PM
To: Miller, Chris
Cc: Cheok, Michael
Subject: LR comments on Seabrook IR
Importance: High

Chris,

I just wanted to let you know where we are. Again, our staffs have been coordinating very well on this IR.

In terms of the license renewal-related items, I am fine with the changes to Section 7 and have no further comments. I have some additions and wording changes for clarity as it relates to LR in Section 6 (crack mapping) that Angie has provided to Bill Cook—we need to agree on changes to this section before the report is issued. Bill was not inclined to include them believing they were unnecessary. I am not wedded to the exact words and there may be different ways of saying but because of the potential impact and misunderstanding regarding LR, I would like the essence of these points included. I would be happy to discuss with you. I have attached our suggested wording to Section 6 here.

I have also offered suggestions in a few sections regarding operability—to provide clarity in particular for folks reading it with less familiarity with the issues. But I am just providing these for your consideration. Unlike the Section 6 comments, they don't directly affect LR and are clearly only in your area.

So here goes:

In the first paragraph of Section 3.2.1, last sentence, we use the phrase "pending completion" which means that the structural integrity is maintained once the corrective action to address the non-conforming action is complete, in other words, at some point in the future. Is that really what we mean? If so, that seems like a problem. If not, I would suggest rewriting "pending completion."

As a general comment, we have eliminated reference to "interim" OD but still refer to "final" OD which now seems out of place. I would offer that "updated" might be a better word choice than final. Also, take a look at Section 3.2.5—from the sentence starting "The team concluded ..." till the end of that section, we seem to be saying that there is a current problem ("not conclusive with respect to identifying ...", "need to be re-evaluated and better justified", "more accurate concrete data and more representative boundary conditions"). If we can say that the current use of the FEA is bounding due to conservative ASR assumptions and that these further analyses will be done to avoid use of the conservative assumptions, we might have a clearer explanation. A similar issue exists in Section 3.2.6.

Lastly, on operability, in Section 3.2.7, we really seem to be saying that there is a problem now. If we are saying that for some reason it is OK but that they will need to comply with ACI or update the CLB, then shouldn't it really be an open item or URI in the inspection report until one of those actions is done?

Again, on the operability items, I only offer them for your consideration in the hope of making the report clearer to all readers—incorporate as you see fit.

Melanie

Buford, Angela

From: Buford, Angela
Sent: Monday, December 10, 2012 11:15 AM
To: Marshall, Michael
Subject: In-situ Monitoring of ASR 12-10-12 Final.docx
Attachments: In-situ Monitoring of ASR 12-10-12 Final.docx

Michael,

I wanted to have this to you sooner but there was a problem with my Microsoft word and I had to re-write all of the changes.

This version contains track changes. If you agree with the changes, you can select to accept all changes in document, or to modify the document as you see appropriate. If you want me to send you a clean copy, let me know. I need to be in the office to finish the reference section, so for now that part continues to be blank.

Angie

B-7-9

In situ Monitoring of ASR-affected Concrete

A study on crack indexing and damage rating index to assess the severity of ASR and to monitor ASR progression

Written By:
Angela Buford

Key Messages:

1. Surface cracking may not be indicative of the conditions of the concrete through the section, and crack indexing measurements may not consistently indicate the level of ASR severity from one structure to another. For each group of similar (i.e., reinforcement detail, size, environmental conditions) structures, additional examinations are necessary to correlate crack measurements to severity of ASR degradation.

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Alkali-Silica Reaction (ASR)

ASR is a chemical reaction that occurs in concrete between alkali hydroxides dissolved in the cement pore solution and reactive silica phases in the aggregates. The product of the reaction is an expansive gel around the aggregate particles, which imbibes water from the pore fluid, and, having much larger volume than the reacting components, triggers a progressive damage of the material (Winnicki and Pietruszczak 2008). The pressures imparted by the gel onto the concrete can exceed the tensile strength of the aggregates and the cement paste and cause microcracking and macrocracking in the aggregate and surrounding paste. With the presence of moisture, the gel expands and can cause destructive cracking and deleterious expansion of the concrete. The extent of the concrete deterioration depends on aggregate reactivity, high levels of alkalinity, availability of moisture, temperature, and structural restraint (Williams, Choudhuri, and Perez 2009). Concrete expansion and cracking can lead to serious operational and serviceability problems in concrete structures (Rivard et al. 2002).

Surface Cracking and Expansion

The Federal Highway Administration (FHWA) Report on the Diagnosis, Prognosis, and Mitigation of Alkali-Silica Reaction in Transportation Structures states that "in concrete members undergoing internal expansion due to ASR and subject to wetting and drying cycles (cyclic exposure to sun, rain, wind, etc.), the concrete often shows surface cracking because of induced tension cracking in the 'less expansive' surface layer (because of variable humidity conditions and leaching of alkalis) under the expansive thrust of the inner concrete core (with more constant humidity and pH conditions)." Cracks first form as three or four-pronged star patterns resulting from expansion of the gel reacting with the aggregate. If the concrete is not subject to directional stress, the crack pattern developed forms irregular polygons, commonly referred to as map cracking (Swamy 1992). This cracking is usually enough to relieve the pressure and accommodate the resulting volume increase (Figg 1987; reported by Farny et. Al. 2007).

Map cracking is one of the most commonly reported visual signs associated with ASR. The pattern and severity of cracking vary depending on the type and quantity of reactive aggregate used, the alkali content of the concrete, exposure conditions, distribution of stresses, and degree of confinement in the concrete (Smaoui et al. 2004). ASR can also be characterized by longitudinal cracking, surface discoloration, aggregate pop-out, and surface deposits (gel or efflorescence) (Williams, Choudhuri, and Perez 2009). Although pattern cracking is a characteristic visual indication that ASR may be present in the concrete, ASR can exist in concrete without indications of pattern cracking. Newman (2003) noted that "while superficial cracking patterns can often be reminiscent of ASR, it is important to be aware that reliable diagnosis can never be adequately based on the appearance of surface cracking alone." This consideration is also emphasized by Barnes (2001), whose research cites examples where cracking was thought to be and diagnosed as ASR, and also examples in which ASR gel and associated cracked aggregate particles were found in concrete that was uncracked. In addition, in ASR-affected structures with reinforcement close to the surface or in heavily reinforced structures, surface cracking may be suppressed while internal damage exists throughout the section. The presence and extent of surface cracking is not a conclusive indication that ASR is present or measure of concrete degradation due to ASR; and conversely, the absence of surface cracking does not conclusively indicate the absence of ASR.

<u>Crack Mapping/Indexing</u>

In order to determine the effect of ASR on the performance of a concrete structure, it is important that there be an understanding of current concrete condition (ASR damage reached to-date) and the rate of expansion. Crack indexing is a method that is proposed to measure crack widths and expansion of cracks over time. For this visual examination individual crack widths are measured over a defined grid and the total amount of cracking is quantified. The examination is repeated over regular intervals and the results are compared over time, with a goal of establishing a rate of ASR progression. The Institute of Structural Engineers (ISE 1992) proposed a method for crack mapping that consists of measuring the ASR crack widths along five parallel lines that are each 1 m long. Lines are traced directly onto the concrete structure. The total width of intersecting cracks along each line is summed and divided by the length over which they were measured, to determine the severity of ASR cracking, and then over time to determine the rate of expansion. Another method, suggested by Laboratoire Central des Ponts et Chaussees (LCPC 1997), consists of measuring the widths of all cracks intersecting two perpendicular 1m lines originating from the same point and their two diagonals 1.4 m long. The total crack index is determined as a value in millimeters per meter and compared to criteria that correspond to action levels.

<u>Summary of General Discussion on Crack Mapping</u>

It is stated throughout ASR research that crack mapping is somewhat limited in its applicability to understanding ASR degradation in concrete. Saint-Pierre et al. (2007) note that compared to other non-destructive methods developed for assessing the damage induced by ASR, the semi-quantitative surface methods like crack mapping appear to be less effective. It is generally agreed that while results of crack indexing can potentially give some indication of how ASR is progressing over time, establishing an absolute trend that directly correlates expansion levels to ASR progression may not be a reliable practice. Most ASR research also indicates that using crack measurement alone to characterize the current state of ASR degradation would not be advised, since the practice relies on the assumption that the surface cracking on the face of a structure is wholly congruent to ASR severity. In the 2010 Addendum to its report titled "Structural Effects of Alkali-Silica Reaction - Technical guidance on the Appraisal of Existing Structures," ISE stated that the crack summation procedures for estimating expansion to date work well in directions where there is little restraint from structural stress, reinforcement, or prestress. This suggests that in structures with higher restraint, this would not be the case. In addition, crack mapping is limited in that it can only give data on two-way crack measurements and does not capture cracking in the out-of-plane direction. It is suggested that further activities be carried out for assessing current condition of the concrete and current expansion rate, as well as correlating the expansion to structural integrity.

In addition, crack indexing evaluation criteria should not be universally applied to all structures because surface cracking may not give a reliable indication of the ASR degradation to the structure. Due to variability in size, location, environment, reinforcement detailing, and relative severity of ASR damage, it may be necessary to obtain an understanding of the ASR effects for each individual structure or group of structures with similar physical properties and environments. Indeed, Newman (2003) stated "it is important to relate cracking patterns variously to structural geometry and/or design, apparent concreting sequence, localized detailing (especially where cracking may be coincident with water leakage) and both environmental and in-service conditions." Deschenes et al. (2009) also state that research into the method highlighted that a number of factors (size and shape of member, restraint present, depth of cover, etc.) leading to poor correlation between crack indexing and measured expansions.

Surface Cracking vs. Internal ASR Damage

The correlation between surface cracking and ASR deterioration may be closer to unity for specimens used in the laboratory that are only allowed to deteriorate due to ASR conditions. However, for concrete in the field, the surface indications sometimes poorly correlate to the extent of ASR degradation within the concrete. Since conditions are so variable from one region to another, and even from one place to another in the same structure, poor correlations are often observed between the severity of surface cracking and the presence of the internal signs of ASR (i.e., reaction products, micro-cracking, and expansion) (Nishibayashi et al. 1989 and Stark 1990 reported by Smaoui et al. 2002). Development of cracking on the surface depends strongly on the amount of reinforcement close to the surface (Smaoui et al. 2002) and also depends on external environmental conditions such as wetting-drying, freezing-thawing, and exposure to saline solutions (Smaoui et al. 2002). Two examples of situations in which external conditions can affect the surface cover concrete such that the surface features are not indicative of the actual ASR degradation of the structure are presented here for consideration. In one case, presence and extent of surface cracking can depend on the pH of the surface which can be affected by leaching and carbonation. As such, wetting-drying cycles can affect the features of ASR, as conditions at the surface layer could be less favorable to the development of ASR, due to the [lower] humidity during the drying periods and the leaching of alkalis during the wetting periods (Poitevin 1983 and Swamy 1995, reported by Smaoui et al. 2004). In other words, if the outer surface layer of concrete is exposed to conditions that would cause the ASR severity or development to be lower, but conditions inside the concrete remain conducive to ASR development (i.e., high relative humidity); surface conditions would not be representative of the ASR within the concrete section. Crack indexing efforts would incorrectly characterize the level of ASR degradation as minor, when within the section the ASR degradation might be more severe.

Another example in which environmental conditions have caused surface conditions to be different than conditions within the concrete is the subject of a study done by Berube et al (2002). In this study, an attempt was made to correlate ASR expansion with type of exposure to moisture. Results showed that in specimens exposed to wetting-drying cycles saw more surface cracking but less actual expansion than specimens that were always exposed to humidity. In this case, the larger amount of surface cracking evident in the specimens exposed to wetting-drying cycles did not show to correlate well to the actual expansion due to ASR, with the ASR expansion being less severe than the cracking would indicate. Conversely, the specimens that showed less surface cracking saw a greater expansion due to ASR, which shows that visual examination of surface cracking alone may not be adequate.

Smaoui et al. (2004) state that although the intensity of surface cracking on ASR-affected concrete in service can help to assess the severity of ASR, quantitative measurement of this intensity [i.e., crack mapping] [could] lead to values that generally underestimate the true expansion attained, except maybe when the surface concrete layer does not suffer any ASR expansion at all. If the concrete surface layer undergoes ASR expansion that is less than that of the inner concrete, according to Smaoui et al. (2004), "the measurement of surface cracking will tend to give expansion values lower than the overall expansion of the concrete element under study." This research indicates that the degree of correlation between surface cracking and actual ASR expansion or degradation tends to vary with the level of exposure, which means that crack indexing over a number of structures with varying environmental conditions may not conclusively measure the extent or severity of ASR degradation.

Comment [mxm21]: EXPAND: This statement merits explanation, support, and context. This appears to be a statement that would be true whether ASR is or is not the source of the cracking? So it may merit a paragraph of its own.

Deleted: It should also be noted here that periodic crack indexing measurements also have the potential to be misleading since crack sizes can vary seasonally.

ASR-induced Stresses

The ISE (2010) noted that for some structures exposed to ASR, internal damage occurs through the depth [of the section] but visible cracking is suppressed by heavy reinforcement. In reinforced concrete structures, expansion of ASR cracks generates tensile stresses in the reinforcing steel while also causing compressive stresses in the concrete surrounding the rebar (this phenomenon is often likened to prestress in the concrete and noted to temporarily improve structural behavior). According to Smaoui et al., 2004, the most useful information in the structural evaluation of an ASR-affected concrete member is the state of the stresses in the concrete, but more importantly in the steel reinforcement. The ASR-induced stresses increase the structural demand on the steel and concrete, but this new design load has likely not been accounted for in the original design or in further structural evaluations. According to Multon et al. (2005), "assessment models have to take into consideration the property of stresses to modify ASR-induced expansions and their effect on the mechanical response of ASR-damaged structures..." The expansion reached to date, the current rate of expansion, and the potential for future expansion of the concrete are particularly critical pieces of information to determine whether or not the reinforcing steel has reached or will at some point reach its plastic limit, thus creating risk of structural failure (FHWA 2010).

Crack mapping alone to determine ASR effects on the structure does not allow for the consideration of rebar stresses. Visual examination and measurement of crack growth should be correlated to strain measurements taken of ASR-affected concrete and the reinforcing steel. In similar structures, then, the visual indications of expansion due to ASR can relate to stresses in the concrete and reinforcing steel in order to apply ASR-induced stress as an additional load in structural evaluations. Smaoui et al., 2004 propose that if it is not possible to do a destructive examination (i.e., exposing the rebar or taking deep cores) of the structure in question, "an indirect method is based on the expansion accumulated to date...Assuming that this expansion corresponds to that of the reinforcement steel, the stresses within the reinforcement and the concrete could thus be determined from the modulus of elasticity of the steel and the corresponding sections of the concrete elements under investigation." For determining added stresses in in situ structures, once correlation has been made with respect to size and rebar configuration between the in situ structure and a test specimen, it would be appropriate to use crack mapping as a measure of ASR degradation when introducing the additional ASR-induced stresses on concrete and reinforcing steel in structural evaluations.

Discussion on Applicability of Crack Indexing

This report is not intended to present the position that crack indexing and resulting data should not be part of a structural monitoring program to assess the ongoing effects of ASR in concrete. In fact, crack indexing is recommended by the Federal Highway Administration (FHWA 2010) "to obtain a quantitative rating of the 'surface' deterioration of the structure as a whole" (it should be noted that in the FHWA document, the word "surface" is emphasized with quotation marks, which implies recognition that crack indexing measurements alone provide information limited only to what is occurring at the concrete surface). This report's position is that crack mapping can only be useful once there is an understanding of how the conditions inside the concrete, (i.e., relative humidity, presence and severity of cracking, and added stresses in the concrete, reinforcing detail) correlate to the cracking observed at the surface. The FHWA (2010) document agrees, indicating that to obtain an understanding of the current state of ASR degradation and in order to correlate the surface cracking to the actual effects of ASR-induced expansion on the structure, other investigations of the in-situ structure are necessary. In addition to crack indexing, some FHWA recommendations for transportation structures that can be appropriately applied to nuclear structures include taking stress [strain] measurements in reinforcing steel, obtaining temperature and humidity readings, and performing non-destructive testing such as pulse velocity measurements (the recommendation to use pulse velocity measurements is in agreement with the experimental findings of Saint-Pierre et al. 2007). The Institution of Structural Engineers (ISE 2010) suggests that expansion to date and severity of ASR should be evaluated using examination and testing of cores for changes in modulus of elasticity and development of hysteresis (stiffness deterioration). It is also proposed that strain sensors be used as a method of monitoring ASR progression (Harries 2012) in order to monitor and quantify out-of-plane expansion.

Comment [mxm22]: DELETE: To avoid any possible confusion that FHWA has made recommendations for nuclear power plant, please delete "FHWA" and rework the this part of the sentence if necessary for readability.

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In addition to provisions for monitoring (or predicting) progression of ASR, it is recommended that each structure or group of similar structures undergo petrographic analysis to determine the current state of ASR damage, in order to provide an accurate baseline from which to understand the current severity level and monitor ASR progression.

Discussion on Applicability of Damage Rating Index

The damage rating index (DRI) was developed by Grattan-Bellew and Danay in 1992 (Reported by Smaoui et al. 2004) as a method to determine the extent of internal damage in concrete affected by ASR (Rivard et al. 2002). The DRI is a method for quantifying both qualitative and quantitative observations and determining severity of ASR using petrographic analysis of polished sections of concrete. It is based on the recognition of a series of petrographic features that are commonly associated with ASR (Rivard et al. 2002). The DRI accounts for defects observed in the concrete, such as the presence and distribution of reaction products, existence of internal microcracking, and location of microcracking (within the aggregate vs. through the cement paste) by assigning a weighting factor to each and quantifying overall damage. When the factors are normalized to an area of 100 cm^2, the resulting number is the DRI. Rivard et. Al. (2000) noted that the abundance of individual defects and the overall DRI values increased with regularity with increased ASR expansion. It should be noted that the specimens used by Rivard et. Al. were comprised of reactive aggregates with different reaction mechanisms, but ASR expansion indeed correlated with DRI measures of ASR severity.

Smaoui et al. (2004) performed damage rating indexing on specimens from five concrete mixes using different reactive aggregates to determine if there was a reliable and accurate correlation between ASR damage determined by DRI and ASR expansion measurements. They noted that there exists a potential error in estimating expansion of ASR concrete in the field and establishing a DRI-expansion relationship with laboratory testing. In some of the lab specimens, relatively similar DRI values were obtained for very different expansion levels for cylinders which had been cast with the same concrete mix (and progressed ASR over time). The tests indicated that expansion levels (of in situ structures compared to laboratory specimens) may not be the best indication of ASR degradation. For example, the presence of air bubbles in the proximity of reactive aggregates [in field concrete] usually has the effect of reducing the expansion due to ASR (Landry 1994, Reported by Smaoui et al. 2004). In other words, air bubbles that exist in the in situ concrete structure could result in a smaller expansion of the structure as concluded under crack mapping activities while more severe ASR damage could be present in the structure because ASR features have "room" to grow inside the existing structure before extensive cracking is notable on the concrete surface. Smaoui et al. (2004) concluded that "for evaluating the expansion attained to date by ASR-affected concrete, it may be necessary to reconsider the relevant defects and their respective weighting factors and take into account a certain number of factors such as the presence or absence of entrained air and preexisting cracks and alteration rims" to assess the severity of ASR in structures. It is notable that the research done by Rivard et al. (2000) showed that DRI correlated well with actual ASR expansion, while subsequent work done by Smaoui et al. (2004) proposed that in some cases lack of gross expansion did not correlate to low ASR degradation, and that air bubbles prevented macro-level expansion even though ASR effects were severe. Crack indexing would not have identified this severe ASR progression since that method only measures expansion of surface cracks,

Rivard et al. noted a possible limitation of the DRI method: that weighting factors assigned to each defect may not universally apply to all types of reactive aggregates (reported by Smaoui et al. 2004) and that weighting factor adjustments may be needed depending on the type of reactive aggregate being examined. In other words, DRI results (and their correlation to concrete expansion) should not be applied universally between concretes with different aggregates (with different types of siliceous materials), However, the FHWA (2010) notes that the DRI method can be useful for quantitative assessment of ASR damage for concretes with the same constituents (i.e., same type of reactive aggregate and cement mix design), and can provide useful relative information when cores are taken and a damage rating developed for each structure by the same experienced technician.

Conclusion/Recommendations

In order for the effects of ASR on concrete to be understood, the parameters that need to be understood are (1) the amount of cracking inside the concrete, (2) ASR-induced expansion-to-date and rate of expansion, and (3) effects of ASR on concrete and rebar stresses. To understand the affects of ASR on structural behavior, the effects of ASR damage inside the rebar cage should be applied to engineering analyses or laboratory testing of an equivalent structure for each group of similar structures.

Visual examination of the concrete surface, without any other information about the concrete beneath the surface, is not recommended for either determining the current level of ASR degradation or projecting the future effects of ASR in concrete. Crack indexing would be an adequate and reasonable method of monitoring ASR progression once surface cracking can be correlated to actual ASR degradation, including cracking, expansion, and corresponding stresses (strains) in the concrete and rebar. Laboratory and in-situ testing must be performed to correlate surface cracking with loss of mechanical properties because cracking patterns may vary for different structural geometry and/or design, apparent concreting sequence, localized

Comment [mxm23]: CONSIDER: In addition to a statement about what is needed for the concrete, consider a comparable statement for what is needed for the structure. Then in a similar fashion like the role CCI or DRI could play in that assessment.

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detailing (especially where cracking may be coincident with water leakage) and both environmental and in-service conditions (Newman et al. 2003).

At a minimum, for each set of structures with the same environmental conditions (e.g. chronically wetted, exposed to freeze-thaw action, constant wetting/drying) and section properties (e.g. wall thickness, rebar layout), an initial petrographic analysis should be done to establish the current state of ASR degradation. The severity of ASR damage on the inside of the structure should be correlated to the surface cracking found on the face of the concrete. The expansion measured by subsequent periodic crack indexing can then be assessed on a structure by structure basis depending on that correlation. Also, depending on the correlation between the surface and interior indications for each set of structures, it may be appropriate to adjust the individual crack width and CCI acceptance criteria for different groups of structures. An added benefit to doing an initial petrographic analysis is that the cores removed from the structure could be studied for subparallel microcracking that would not be detected from crack mapping efforts, which only show cracks on the surface face. This is the minimum effort that should be undertaken to gain at least a more informed understanding, for each set of similar structures (physical attributes and environmental conditions), of the ASR expansion reached to date and rate of expansion. The ability to correlate in situ conditions with laboratory testing would strengthen the reliability of the crack indexing method.

A recommended "more than minimum" approach to monitoring ASR progression would be the use of embedded strain sensors in the concrete to provide a measure of expansion in the concrete. This would provide the most accurate measure of expansion due to ASR and would provide the benefit of understanding expansion due to cracking in the third direction. The application of strain instrumentation would also be able to quantify strains (stresses) on the rebar and concrete in order to apply the additional demand due to ASR to a structural engineering evaluation. Finally, this method would help to establish a rate of expansion in the concrete, and could provide insights into understanding the ASR degradation mechanism, including relating environmental conditions specific to a structure to the rate of change of ASR progression, in order to characterize the potential and extent of continued degradation over time. The data could also be used in engineering analyses to predict the effects of ASR on structural behavior.

The DRI method has been shown to be an effective method for assessing the damage level of ASR-affected structures. However, due to the limitation of this method in being able to apply weighting factors consistently between various types of aggregates, practical implementation of this method would mean that site-specific criteria for severity ratings and weighting factors for ASR indications may need to be established in accordance with the reactivity of the aggregate used on site. Also, since there is no standard test procedure available and thus the DRI method results could be variable from one petrographer to another, it would be important to ensure quality and consistency in the implementation of the method. If consistency could be ensured through quality of the technician performing the initial examination and subsequent examinations, the DRI would provide a beneficial and useful understanding of current ASR degradation and degradation over time.

Comment [mxm24]: REVISE: If we do not intend to make Dr. Harries documents public, then we should avoid reference to them.

Deleted: , in agreement with Dr. Harries' recommendation (2012),

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---Page Break---

References

(coming soon)

[redacted]

Marshall, Michael

From: Marshall, Michael
Sent: Thursday, January 03, 2013 3:19 PM
To: Conte, Richard
Cc: Erickson, Alice; Sheikh, Abdul; Buford, Angela
Subject: RE: Requesting a No Technical Objections (NTO) Review from Key Members of the Working Group

Hello Rich,

RASB does not have any technical objections to the proposed response to NextEra concerning the requested changes to Seabrook ASR CAL items 7 and 11. We do have one editorial comment for your consideration. You should consider describing the benefits/advantages of having the test plan details available to the NRC prior to starting/completing testing as opposed to merely the results from a the planned tests.

Michael L. Marshall, Jr.
Chief
Aging Management of Structures, Electrical, and Systems Branch
Division of License Renewal
Office of Nuclear Reactor Regulation

301-415-2871
Email: michael.marshall@nrc.gov

From: Conte, Richard
Sent: Friday, December 28, 2012 4:01 PM
To: Khanna, Meena; Kobetz, Timothy; Marshall, Michael; Murphy, Martin
Cc: Lamb, John; Milano, Patrick; Morey, Dennis; Trapp, James
Subject: Requesting a No Technical Objections (NTO) Review from Key Members of the Working Group

For Addressees Only: The response letter is for NextEra revision to two of the CAL commitments. They are self explanatory.

I am requesting a NTO review.

Since new CAL no. 11 is being modeled off of CAL No. 8 it should be ok. What they need to submit on the docket for technical details should come as we interact with them in the ensuing months. They will most likely need to revise what was already submitted for CAL No. 8

The second file is the incoming from Dec. 13. We can't wait for next working group on Jan 9 since we are trying to issue this before Friday Jan. 11.

It is making its way around for concurrence up to enforcement specialists in the region for now.

Please prioritize on this when you get back and respond by COB Jan 3 NLT noon Jan 4.

Cc's: FYI

Rich Conte, Seabrook ASR Team Lead, Region I
(610) 337-5183 (Office)

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INSPECTION PLAN FOR
NEXTERA CONTROL OF TESTING AND CONTRACTOR SUPPORT
FOR ASR ISSUES
Jan to April , 2013

Revision 0 – 1/4/13

Resource Estimate:

1. Two inspection weeks (60 hrs direct inspection), one for last week in Jan. 2013 and perhaps one additional week if anchor/embedment testing is delayed.
2. Time charge to 92702 CAL Follow-up , OA; prep and doc OAP and OAD
3. Report No. 05000443/2012010, 2nd CAL followup report
4. Outside R1 support: A. Buford, NRR
5. All issues of concern should be brought the attention of Region I, Suresh Chaudhary (610-337-5335) or Richard Conte (610-337-5183)

Inspection Criteria:

1. Procurement control documents (some available in Licensee CERTEX system and other yet to be identified)
2. Submitted topical NextEra QA Plan, Revison 12, June 2012 (submitted on docket July 3, 2012), IAW 50.54(a)(2) which requires that measures be implemented along with and ANSI N 45.2.11, Procurement Control (exceptions should be noted)

Scope of review:

Priority of review: observe implementation as it occurs or review activity completion/test results, the adequacy of plans/procedures should be sampled as it undercuts both of the above areas – do not rely on plans and procedure alone and no draft material will be used.

1. Review any updated NEXTERA/MPR/Uof T procurement documents that exhibit control of contractor and work products – with financial information redacted.

2. Review any updated NEXTERA/MPR specifications for either the R&D Effort on Anchors/Embedments (priority) and/or R&D effort for Shear Testing and Lap-splice testing at the Ferguson Engineering Lab at the University of Texas.

3. Continue review and status of Crazed Cracking on one section of Primary Containment and if details for longer term monitoring are available.

4. If available review "White Paper" on overarching view of how testing in testing is correlated to in-situ building conditions at Seabrook.

5. Review results and NextEraMPR review of Testing completed in 2012 at U of T in support of the Prompt Operability Determinations or for the selection of material for construction of test specimens to date or planned.

6. Tour facility and review test equipment along with selected calibration records (load cells, strain gages, etc.

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7. If laboratory testing is conducted place emphasis on:
    a. Calibration of test equipments,
    b. Proper implementation of Procurement Documents and Test Procedures,
    c. Observe set-up and test conditions are consistent with test procedures and standards,
    d. Observe and assure that the failure modes or critical test data is properly documented.
    e. Review and assure that test personnel are properly qualified and certified.

<u>End of Week Brief:</u>

Summarize the status of the review as an "out brief" not "exit," to be coordinated with any team members on site at Seabrook.

Marshall, Michael

From: Buford, Angela
Sent: Wednesday, January 09, 2013 3:26 PM
To: Erickson, Alice; Marshall, Michael
Subject: HEADS UP: Structures Monitoring Paper FW: ASR Working Group Meeting

Follow Up Flag: Follow up
Flag Status: Completed

Categories: Review

Michael and Alice, I think you were on this distribution. It just probably wasn't clear because the email subject didn't specify the paper was enclosed. See attachment below

---

From: Cook, William
Sent: Tuesday, January 08, 2013 3:50 PM
To: Conte, Richard; Ali, Syed; Buford, Angela; Cartwright, William; Chaudhary, Suresh; Cline, Leonard; Cruz, Holly; Erickson, Alice; Floyd, Niklas; Fuhrmann, Mark; Graves, Herman; Hogan, Rosemary; Hughey, John; Khanna, Meena; Kobetz, Timothy; Lamb, John; Manoly, Kamal; Marshall, Michael; Merzke, Daniel; Milano, Patrick; Morey, Dennis; Murphy, Martin; Ott, William; Philip, Jacob; Raymond, William; Schroeder, Daniel; Sheikh, Abdul; Sircar, Madhumita; Stuchell, Sheldon; Thomas, George; Trapp, James
Subject: RE: ASR Working Group Meeting

SMP Position Paper Rev2.docx

One of the brief discussion topics tomorrow is the proposed Structures Monitoring Program position paper. I have attached the January 7, 2013 Draft, if you are interested. I do not plan to go into detail about its content, just introduce the proposed recommendation.

Thanks,
Bill

-----Original Appointment-----
From: Conte, Richard
Sent: Saturday, January 05, 2013 2:22 PM
To: Conte, Richard; Ali, Syed; Buford, Angela; Cartwright, William; Chaudhary, Suresh; Cline, Leonard; Cook, William; Cruz, Holly; Erickson, Alice; Floyd, Niklas; Fuhrmann, Mark; Graves, Herman; Hogan, Rosemary; Hughey, John; Khanna, Meena; Kobetz, Timothy; Lamb, John; Manoly, Kamal; Marshall, Michael; Merzke, Daniel; Milano, Patrick; Morey, Dennis; Murphy, Martin; Ott, William; Philip, Jacob; Raymond, William; Schroeder, Daniel; Sheikh, Abdul; Sircar, Madhumita; Stuchell, Sheldon; Thomas, George; Trapp, James
Subject: ASR Working Group Meeting
When: Wednesday, January 09, 2013 2:00 PM-3:00 PM (GMT-05:00) Eastern Time (US & Canada).
Where: Phone or Office

When: Wednesday, January 09, 2013 2:00 PM-3:00 PM (GMT-05:00) Eastern Time (US & Canada).

B87-

Where: Phone or Office

Note: The GMT offset above does not reflect daylight saving time adjustments.

~~*~*~*~*~*~*~*~*

Agenda and Talking Points are below:

<< File: ASR WGM of 01-09-2013.docx >>

Hope to discuss 3 position papers, Bill Cook with send the third next week – latest Conte has is below

<< File: Assessment of ACI 318-71 as Design Basis - AErickson ASheikh HGraves GThomas MMarshall (11-9-2012).doc >>

<< File: In-situ Monitoring of ASR Paper, 2012-12-19 (Final).doc >>

Marshall, Michael

From: Erickson, Alice
Sent: Thursday, January 10, 2013 10:13 AM
To: Marshall, Michael
Subject: Sending White Paper to OGC for Comment

Michael,

I spoke with Max Smith yesterday about a few items in the white paper I have written, and he said he would be more than happy to provide me comments from OGCs perspective. After our meeting yesterday with Region I staff, I plant to revise the paper to address any comments I receive and to put it in the format that Bill Cook requested.

It would be beneficial if we could request that OGC weigh in on whether on not they agree with our position that the NRC's role would be that of the "Building Official" as described in ACI 318-71. In addition, any other comments or views that they could share would also be of value.

Thanks,

Alice Erickson
General Engineer
Office of Nuclear Reactor Regulation
Division of License Renewal
Aging Management of Structures, Electrical, and Systems Branch

Mail Stop: O-11F1
Phone: (301) 415-1933
Email: Alice.Erickson@nrc.gov

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Buford, Angela

From: Fuhrmann, Mark
Sent: Tuesday, January 15, 2013 10:44 AM
To: Buford, Angela
Subject: RE: are you looking for comments on the paper "In-situ Monitoring of ASR-affected Concrete"?

Ok, I'll take a look at it...do you have the references put together yet?

Mark Fuhrmann, Ph.D.
Geochemist
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Mail Stop CSB 2C-07m
11555 Rockville Pike
Rockville, MD 20852-2738

mark.fuhrmann@nrc.gov
Phone: 301-251-7472
Fax: 301-251-7410

From: Buford, Angela
Sent: Tuesday, January 15, 2013 8:49 AM
To: Fuhrmann, Mark
Subject: RE: are you looking for comments on the paper "In-situ Monitoring of ASR-affected Concrete"?

Yes, I am seeking comments on this paper. Right now, I'm not aware that it has been combined with any other papers.

From: Fuhrmann, Mark
Sent: Monday, January 14, 2013 4:56 PM
To: Buford, Angela
Subject: are you looking for comments on the paper "In-situ Monitoring of ASR-affected Concrete"?

Hi Angela:
Are you looking for comments on the paper "In-situ Monitoring of ASR-affected Concrete"? or was this one of the papers that were combined.
The phone conversation last week was a bit confusing in this regard.
Mark

Mark Fuhrmann, Ph.D.
Geochemist
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Mail Stop CSB 2C-07m
11555 Rockville Pike
Rockville, MD 20852-2738

mark.fuhrmann@nrc.gov

B/8

From: Buford, Angela
Sent: Tuesday, January 15, 2013 8:49 AM
To: Fuhrmann, Mark
Subject: RE: are you looking for comments on the paper "In-situ Monitoring of ASR-affected Concrete"?

Yes, I am seeking comments on this paper. Right now, I'm not aware that it has been combined with any other papers.

From: Fuhrmann, Mark
Sent: Monday, January 14, 2013 4:56 PM
To: Buford, Angela
Subject: are you looking for comments on the paper "In-situ Monitoring of ASR-affected Concrete"?

Hi Angela:
Are you looking for comments on the paper "In-situ Monitoring of ASR-affected Concrete"? or was this one of the papers that were combined.
The phone conversation last week was a bit confusing in this regard.
Mark

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Phone: 301-251-7472
Fax: 301-251-7410

Marshall, Michael

From: Marshall, Michael
Sent: Tuesday, January 15, 2013 3:16 PM
To: Galloway, Melanie
Cc: Erickson, Alice; Buford, Angela
Subject: RESPONSE: Papers that RASB has Prepared for the Seabrook ASR Issue Working Group
Attachments: Assessment of ACI 318-71 as Design Basis - AErickson ASheikh HGraves GThomas MMarshall (11-9-2012).doc; In-situ Monitoring of ASR Paper, 2012-12-19 (Final).doc

Hello Melanie,

Yesterday, during my monthly meeting with you and John, you expressed an interest in reading the papers that RASB has prepared for the Seabrook ASR Issue Working Group at the request of Region 1. Attached are the papers that Alice and Angie have drafted that the working group is reviewing. Currently, we are receiving and reviewing comments from the working group member, which are due by Friday, January 18, 2013. By early or mid February 2013, we plan to finalize the papers. In addition, we plan to send Alice's finalized paper to OGC for an opinion on whether the NRC is or is not the building official.

If you have any comments that you would like to share with us, I would appreciate receiving them by Friday, January 25, 2013, so we have an opportunity to address them and still finalize the papers in February 2013.

Best Regards,

Michael L. Marshall, Jr.
Chief
Aging Management of Structures, Electrical, and Systems Branch
Division of License Renewal
Office of Nuclear Reactor Regulation

301-415-2871
Email: michael.marshall@nrc.gov

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Thomas, George

From: Thomas, George
Sent: Wednesday, January 16, 2013 9:07 AM
To: Murphy, Martin
Subject: FW: Plans for Next two Week
Attachments: Seabrook ASR Team Inspection #2 - Week One Plan.docx

Marty,

I got this email from Bill Cook regarding plan for Inspection #2 of Seabrook CAL inspections for the second Report. I am not sure if I continue to be part of the inspection team, and if so whether Region has your permission and what my specific role is. Please advise.

Thanks.
George

From: Cook, William
Sent: Wednesday, January 16, 2013 8:16 AM
To: Buford, Angela; Floyd, Niklas; Trapp, James; Chaudhary, Suresh; Raymond, William; Thomas, George; Conte, Richard
Subject: Plans for Next two Week

All,
Sorry for not getting this revision of the inspection plan out sooner. Call if any questions.
Thanks,
Bill

Inspection Plan (01/11/2013)

Seabrook Station ASR Team Inspection Report (05000443/2012010) Plan – Week 1 (January 22-25, 2013 at Seabrook Station and January 28 – February 1, 21013 at UT-Austin)

<u>Resource Estimate</u>:

1. ~80 hours at Seabrook (Trapp, Raymond, Cook, Floyd) and ~60 hours at UT-A (Conte, Chaudary, Buford)
2. Time charge to 92702 CAL Follow-up , OA; Prep and Doc, OAP and OAD, respectively

<u>Inspection Activities at Seabrook Station:</u>

1) Team members continue to enhance familiarity with the physical layout and visual evidence of ASR on site. Team members continue to tour and inspect affected areas, spaces and buildings, as needed, to improve understanding and historical perspective of the ASR problem and NextEra's progress in addressing this issue and ensuring structural integrity and operability impact. Continue to conduct open and candid dialog with the responsible licensee representatives to ensure a good flow of information between NextEra and the NRC staff regarding ASR.

2) Complete the review and assessment of the revision to CAL Item No. 2, the ASR root cause evaluation and associated corrective actions.

   The team expects that the revision (not docketed as of January 2, 2013) will be a clarification of the root cause associated with the adequacy of the SMP and the associated human performance and organization aspects that contributed to the failure of the SMP to promptly identify ASR on site.

3) Review and discuss NextEra's Integrated CAP for addressing ASR (CAL Item #4)

   The team will review NextEra's plans for maintaining the integrated plan as a living document under the CAP and how it will be updated and eventually closed by NextEra.

4) Review and discuss NextEra's proposed Phase 3 Walkdown scope and schedule, if available.

   This topic was raised with NextEra during the last inspection. The team plans to gain further insights with respect to the licensee's perspective on the adequacy of the implementing schedule (from an extent of condition view) and with respect to the proposed testing to ensure the site conditions are appropriately bounded.

5) Review and discuss the adequacy of the revised SMP (CAL Item #9)

The revision to the SMP was a result of corrective actions (Appendix B, Criterion XVI) to more appropriately address and monitor ASR on Seabrook Station reinforced concrete structures. Based upon the current revision of the SMP position paper, the team will engage the NextEra staff for an initial reaction and response. NextEra's response will dictate how the NRC will proceed (NRC options include: management meeting, CAL revision, Order).

6) Outline the NRC's current view of NextEra's ACI 318-71 compliance. Specifically, address the applicability of Chapter 20 and how the proposed testing does not comply with either in-itu load testing or analysis to demonstrate strength of the structures. Accordingly, a license amendment will be necessary to seek final review and approval for an evaluation method not prescribed by ACI 318-71 [50.59 and 50.55(a)]. Gather and record NextEra's response to this position for further regulatory consideration, as appropriate.

Inspection Activities at University of Texas – Austin

Reference Material:

1. Procurement control documents, some available in NextEra's CERTEX system (others yet to be identified)
2. Submitted topical NextEra QA Plan, Revision 12, June 2012 (submitted on docket July 3, 2012), IAW 50.54(a)(2) which requires that measures be implemented along with and ANSI N 45.2.11, Procurement Control (exceptions should be noted)

Scope of UT-A Review:

Priority of review: observe implementation as it occurs or review activity completion/test results, the adequacy of plans/procedures should be sampled as it undercuts both of the above areas – do not rely on plans and procedure alone and no draft material will be used.

1. Review any updated NextEra/MPR/University of Texas - Austin procurement documents that exhibit control of contractor and work products – with financial information redacted.

2. Review any updated NextEra/MPR specifications for either the R&D Effort on Anchors/Embedments (priority) and/or R&D effort for Shear Testing and Lap-splice testing at the Ferguson Engineering Lab at the University of Texas - Austin.

3. Continue review and status of "crazed cracking" on one section of Primary Containment and if details for longer term monitoring are available.

4. If available, review "White Paper" on overarching view of how testing is correlated to in-situ building conditions at Seabrook.

5. Review results and NextEra/MPR review of Testing completed in 2012 at U of T in support of the Prompt Operability Determinations or for the selection of material for construction of test specimens to date or planned.

6. Tour facility and review test equipment along with selected calibration records (load cells, strain gages, etc.

7. If laboratory testing is conducted place emphasis on:
   a. Calibration of test equipments,
   b. Proper implementation of Procurement Documents and Test Procedures,
   c. Observe set-up and test conditions are consistent with test procedures and standards,
   d. Observe and assure that the failure modes or critical test data is properly documented.
   e. Review and assure that test personnel are properly qualified and certified.

<u>End of Week Out-Brief (Date and Time TBD):</u>

Summarize the results of the team's review and any significant observations or concerns. Coordinate out-brief with Region I participants, if practical.

Marshall, Michael

From:	Erickson, Alice
Sent:	Tuesday, January 29, 2013 2:30 PM
To:	Marshall, Michael
Cc:	Sheikh, Abdul; Thomas, George; Graves, Herman
Subject:	Revised ACI 318-71
Attachments:	Assessment of ACI 318-71.docx
Follow Up Flag:	Follow up
Flag Status:	Completed
Categories:	Review

Michael,

I've attached the revised version of the ACI 318 paper. I merged the comments that I received from Bill Cook and Niklas Floyd and you can see the changes I made in response to the comments in track changes. For the comments that did not result in revisions, I provided a comment to explain why. I haven't discussed these revisions with Bill or Niklas yet, but would like to share why I made the changes that I did. Please provide me any comments or feedback so we can send it to OGC for review and comments.

Abdul, George, and Herman,

If you have any additional comments or revisions to see necessary, please let me know and I'll be happy to discuss.

Thanks,

Alice Erickson
General Engineer
Office of Nuclear Reactor Regulation
Division of License Renewal
Aging Management of Structures, Electrical, and Systems Branch

Mail Stop: O-11F1
Phone: (301) 415-1933
Email: Alice.Erickson@nrc.gov

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January 29, 2013

MEMORANDUM TO: ASR Working Group

FROM: Michael Marshall, Branch Chief

SUBJECT: POSITION PAPER: ASSESSMENT OF ACI 318-71 AS DESIGN BASIS FOR CATEGORY 1 CONCRETE STRUCTURES AFFECTED BY ALKALI-SILICA REACTION AT SEABROOK STATION

The purpose of this paper is to document the staff's position regarding the applicability of American Concrete Institute (ACI) 318-71, "Building Code Requirements for Structural Concrete," and understanding of the guidance provided in Chapter 20 of ACI 318-71 as it relates to the Seabrook Station current licensing basis.

The staff has performed a thorough review of the relevant regulatory requirements, guidance documents, industry codes and standards, and Seabrook Station UFSAR and has determined that a distinction should be made between the method of evaluation relied upon for design considerations, i.e. the strength design method of ACI 318-71, and methods of evaluation for existing structures. The Seabrook Station UFSAR clearly documents the strength design method of ACI 318-71 along with NUREG-0800, "Standard Review Plan as the design bases for the Category I Structures, with the exception of primary containment. However, the method of evaluation for existing structures is not clearly defined in the UFSAR.

Enclosure: Assessment of ACI 318-71 as Design Basis for Category 1 Concrete Structures Affected by Alkali-Silica Reaction at Seabrook Station

CONTACT: Alice Erickson, NRR/DLR/RASB
301-415-1933

Assessment of ACI 318-71 as Design Basis for Category I Concrete Structures Affected by Alkali-Silica Reaction at Seabrook Station

Written By:

Alice K. Erickson

Peer Reviewed By:

Abdul Sheikh

Herman Graves

George Thomas

~~November 9, 2012~~January 29, 2013

BACKGROUND

Historically, Seabrook Station has experienced groundwater infiltration through below grade portions of concrete structures. In the early 1990's, an evaluation was conducted to assess the effect of groundwater infiltration on the serviceability of concrete walls and concluded that there would be no deleterious effect, based on the design and placement of the concrete and on the non-aggressive nature of the groundwater. However, in 2009, NextEra tested seasonal groundwater samples to support the development of the License Renewal Application (LRA) and the results showed that pH values were between 5.8 and 7.5, chloride values were between 19 ppm and 3900 ppm, and sulfate values between 10 ppm and 100 ppm, indicating that the groundwater had become aggressive [pH < 5.5, chlorides > 500 ppm, or sulfates > 1500 ppm]. Subsequently, in conducting a comprehensive review of the possible effects on concrete structures, in early to mid-2010, the licensee performed in-situ penetration resistance testing (PRT) and compression testing of concrete cores from the affected areas in the "B" electrical tunnel of the control building. The results showed a reduction in compressive strength and modulus of elasticity of the affected concrete. In September 2010, the applicant confirmed the presence of Alkali-Silica Reaction (ASR) through petrographic examination of samples taken from the concrete cores of the "B" electric tunnel.

The licensee has made two prompt operability determinations (PODs) to address the effects of this issue for potentially affected structures. The first addresses the ~~reduced concrete properties~~reduction in concrete compressive strength and modulus of elasticity below grade in the "B" electrical tunnel exterior wall, and the second addresses the reduced concrete modulus of elasticity below grade in the containment enclosure building (CEB), residual heat removal (RHR) equipment vaults, emergency feedwater (EFW) pumphouse, diesel generator fuel oil tank rooms, and some additional other Cate~~r~~gory I Structures. These additional Category I structures, identified as having the potential presence of ASR as a result of an extent of condition survey, include the condensate storage tank enclosure, control building makeup air intake, service water cooling tower, "A" electrical tunnel, fuel storage building, east pipe chase, west pipe chase, pre-action valve room, primary auxiliary building, service water pump house, mechanical penetration area, and waste process building. Except for the primary containment structure, the Seabrook concrete structures that have been identified thus far as affected or potentially affected by ASR generally fall under the classification of "Other Category 1 Structures" described in UFSAR Section 3.8.4. As of June 2012, both PODs conclude that the ASR-affected structures are *operable but degraded*, and *below full qualification*. NUREG-1430, "Standard Technical Specifications," defines *operable/operability* as "…capable of performing its specified safety function." RIS 2005-20, Revision 1, which includes NRC Inspection Manual Part 9900 as an attachment, defines *degraded condition* as "one in which the qualification of an SSC or its functional capability is reduced." It further defines *full qualification* of an SSC as one that "conforms to all aspects of its CLB, including all applicable codes and standards, design criteria, safety analyses assumptions and specifications, and licensing commitments." Based on the definitions provided in Inspection Manual Part 9900, the "below full qualification" aspect of Seabrook Station's operability determination suggests that Seabrook Station is not meeting some aspect of its CLB. The licensee will have to resolve the current PODs with respect to the CLB, in accordance with its procedures for operability determinations and functionality assessments, as part of its action plan to comprehensively address and manage the ASR degradation issue at the site.

Comment [n1]: What were these concrete properties? (e.g. what makes these properties different vs. the reduced elasticity modulus mentioned in the next sentence)

This paper is not intended to cover all requirements that must be met for compliance with the CLB, but to focus on understanding the applicability of American Concrete Institute (ACI) 318-

71, "Building Code Requirements for Structural Concrete," to which the affected structures were designed.

ACI 318-71 DOCUMENTED AS DESIGN BASIS

Seabrook Station's Updated Final Safety Analysis Report (UFSAR) Section 3.8, "Design of Category I Structures," identifies the 1971 version of American Concrete Institute 318 (ACI 318-71), "Building Code Requirements for Reinforced Concrete (with Commentary)" as the applicable Construction Code for Category I structures, exclusive of the containment structure. UFSAR Subsection 1.8, "Conformance to NRC Regulatory Guides" indicates that although compliance with Regulatory Guide 1.142, "Safety-Related Concrete Structures for Nuclear Power Plants (Other Than Reactor Vessels and Containments)" was not required and that ACI 349-76, "Code Requirements for Safety-Related Structures" was not used as a design and construction standard, the design and construction of the structures do fulfill the intent of the requirements set forth in the publication and in Regulatory Guide 1.142. Further, UFSAR Subsection 1.8 clearly indicates that the "loads and load combinations were taken directly from the USNRC Standard Review Plan and ACI 318[-71]" and that "structural analysis and design were consistent with the requirements of the [USNRC] Standard Review Plan (SRP) [NUREG-0800] and ACI 318[-71]."

The Seabrook Station UFSAR clearly documents the [ultimate] strength design method of ACI 318-71 Code along with the NUREG-0800 SRP as the design basis for the Category I Structures, except the primary containment. The basic load combinations considered in the design basis of each seismic Category 1 structure are given in UFSAR Table 3.8-16. Therefore, demonstration that those structures now affected by ASR still meet the strength design requirements of ACI 318-71 under design basis loads and load combinations in the UFSAR, should be sought for compliance with Seabrook Station's current licensing basis (CLB).

DISCUSSION ON ACI 318-71

ACI 318-71 is a Construction Code written in the context of new design and construction. The empirical relationships between concrete compressive strength and other material/mechanical properties (such as tensile strength, shear strength, bond, modulus of elasticity etc.), defined in this Code and relied upon for design, are based on performance and test data of normal concrete. These equations do not account for the effects of ASR; and therefore, should not be relied upon to demonstrate that the Code requirements are satisfied, unless proven otherwise. The technical basis for establishing design adequacy of reinforced concrete structural systems with ASR degradation is not covered by the ACI 318-71 Code. However, ACI 318-71 Chapter 20, "Strength Evaluation of Existing Structures" does provide guidance for structural assessments when doubt develops concerning the safety of a structure. ~~Although ACI 318-71 is a Construction Code, a review of this Code identified two sections as being useful in considering NextEra's approach to demonstrating that the ASR-affected structures continue to meet the intent of ACI 318-71.~~

Comment [w2]: Although we believe this statement is correct, it may not be, in that, it may be dependent upon the degree of ASR expansion and/or confinement. If we understand NextEra' expectation for testing large-scale specimens, they intend to show by testing that the Code relationships are being maintained, even in ASR-affected structures.

Alice: We know that the relationships are based on the performance and test data of normal concrete which is stated in the prior sentence. The "unless proven otherwise" is intended to communicate that they may be able to demonstrate the relationships still remain valid for ASR-affected concrete.

Comment [n3]: This is a slightly repetitive statement since the two sections identified are discussed in the next two paragraphs. I recommend deleting it.

ACI 318-71 Chapter 1, Section 1.4, "Approval of Special Systems of Design or Construction," states that "[t]he sponsors of any system of design or construction within the scope of this Code, the adequacy of which has been shown by successful use or by analysis or test, but which does not conform to or is not covered by this Code, shall have the right to present the data on which their design is based to a board of examiners appointed by the Building Official. This board shall be composed of competent engineers and shall have the authority to investigate the data so submitted, to require test, and to formulate rules governing the design and construction of such systems to meet the intent of this Code. These rules when approved by the Building Official and promulgated shall be of the same force and effect as the provisions of this Code." Section 1.2.3 of the Code defines the Building Official as "the officer or other designated authority charged with the administration and enforcement of this Code, or his duly authorized representative." By law, the NRC has the regulatory jurisdiction over commercial nuclear power plants in the US. Concrete structures important-to-safety have been licensed by the NRC to ACI 318-71 for several earlier plants. Therefore, in the context of the Code, the NRC would logically be considered the Building Official in this situation. Also, even though ACI 349 "Code Requirements for Nuclear Safety-Related Concrete Structures" was not published until after Seabrook Station's design was completed, Section 1.4, which is equivalent to Section 1.4 in ACI 318-71, replaced the term "building official" with "authority having jurisdiction." This is because the ACI 349 Code adapted and applied most of its provisions from ACI 318 specifically for nuclear safety-related structures (with exception of containment) and, therefore, explicitly identifies the NRC as having this authority in the definitions section of the Code. Regardless, it is important to note that the commentary for ACI 318-71, Section 1.4, clarifies that the provisions of this section do not apply to strength evaluation of existing structures under Chapter 20.

ACI 318-71 Chapter 20, "Strength Evaluation of Existing Structures," Section 20.1 states that "if doubt develops concerning the safety of a structure or member, the Building Official may order a structural strength investigation by analysis or by means of load tests, or by a combination of these methods." The general requirements for analytical investigations provided for in Section 20.2 states that "a thorough field investigation shall be made of the dimensions and details of the members, properties of the materials, and other pertinent conditions of the structure as actually built." This means that the data relied upon in the analytical investigation must be based on measured properties of the in-situ conditions of the structure. Section 20.3 provides general requirements for load tests on the built structure and Section 20.4 provides requirements for load test on flexural members. ~~The provisions of Chapter 20, especially the load tests, are generally in the context of acceptability of concrete quality of the as-built structure at the time of original construction. Never the less~~However, load tests on the as-built structure does not seem like a practicable approach for the Seabrook Station ASR issue, especially for the affected below-grade structures and for performance assessment in shear, bond and anchorages for embeds and supports.

INTENT OF TESTING BEING CONDUCTED

In a public meeting held on April 23, 2012 to discuss the plans and schedule regarding concrete degradation due to ASR, NextEra presented several statements in their slides that provide some insight as to the intent of the testing being conducted at the University of Texas. The following statements indicate that the testing will be used to support resolution of the PODs and to provide some basis for demonstrating that the effects of aging will be adequately managed for license renewal:

- Ongoing full scale testing is expected to validate assumptions and identify additional margin.
- Testing is anticipated to show that the performance of ASR-affected concrete structures is not compromised.

Comment [n4]: Is this true? I could not find any commentary for ACI 318-71. I do know that ACI 318-11 does say this though. I recommend delete if not true.

Alice: This is true. We had a copy of the 1971 version with commentary in the library, but it has since turned up missing.

Comment [w5]: Discussion in this paragraph pertaining to the Building Official is good, but I would prefer to have this last sentence in the next paragraph as a lead-in to the Chapter 20 discussion.

Alice: I decided to keep it in this paragraph because this statement is in Section 1.4 of the ACI code, not Chapter 20.

Comment [n6]: I disagree. Chapter 20 as it reads in the 1971 and 2011 revisions is for existing structures and is directly applicable to the current ASR degradation issue. The time frame is indefinite.

Alice: A timeframe is not mentioned in the Code or Commentary so I decided to delete this sentence.

Comment [w7]: I do not believe this statement is accurate and it is not supported by later versions of ACI 318, (reference ACI 318-2011 and commentary in Sections 5.6.5/R5.6.5, and 20.1/R20.1. I strongly believe that Chapter 20 of the 1971 revision applies and that 2011 revision and commentary makes it clearer.

Comment [n8]: Should also discuss the other option which is a strength investigation by analysis. This is still not an option until NextEra fully understands the material properties of the concrete in place.

Alice: I briefly described the strength investigation at the beginning of this paragraph.

Comment [w9]: Agree that a load test is not practical. But, this does not mean that Chapter 20 does not apply. The Building Officer has a responsibility to determine (or judge) what may be an appropriate analysis under Chapter 20.

Alice: I don't want to imply that Chapter 20 does not apply. I don't completely agree that the building official has a responsibility to determine what may be an appropriate analysis. If by the same logic that I used to conclude that the NRC is the building official, then the engineer may order a strength evaluation, as stated in the equivalent section of ACI 349, Chapter 20.1. Not the regulatory authority.

Comment [n10]: Add bullets or numbering for the list of 5 intentions.

- Design parameters for ASR affected concrete [derived from ASR-affected and control beams] will be compared to ACI Construction Code requirements and reconciled with Seabrook design basis calculations.

- AMP criteria and frequency will be revised as the full-scale concrete beam test program develops.

- Ongoing testing programs are expected to identify additional structural margin.

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Based on this information, the staff understands that the testing being conducted at the University of Texas will be used in the resolution of the PODs. However, the details as to how the testing will support the resolution of the PODs remain unclear to the staff. The staff also understands that the testing will no longer serve as a basis for the development of their aging management program; however, the results of the testing may inform certain elements of the program that NextEra is currently proposing.

ASSESSMENT

As was stated earlier, Seabrook Station's UFSAR clearly indicates that the Seismic Category I concrete structures, exclusive of the containment structure, were designed to meet the strength design requirements of ACI 318-71. As such, this Code is applicable in that it is the Construction Code-of-Record that forms the current licensing design basis for the Category I structures.

The intent of this paper is to communicate that the strength design provisions of ACI 318-71 must be satisfied in order for Seabrook Station to demonstrate that the ASR-affected concrete structures will perform their intended safety function within the CLB; however, unless proven otherwise, the empirical relationships in the design provisions of the Code should be treated with caution and should not be relied upon for strength evaluation because those empirical relationships do not account for the effects of ASR. Additionally, because ACI 318-71 does not provide a technical basis for establishing the design adequacy of ASR-affected reinforced concrete structural systems using its strength design provisions, ~~and because NextEra's approach to demonstrating Code compliance is not consistent with the guidance described in Chapter 20 for strength evaluations,~~ the technical basis by which NextEra demonstrates the ability of the ASR-affected structures to perform their intended safety function may require a change to the current licensing basis in the resolution of the current PODs. However, it is the licensee's responsibility to make this determination by evaluating its proposed approach in establishing the long-term design adequacy of ASR-affected structures with respect to the ACI 318-71 code and the regulatory requirements contained in 10 CFR 50.59 "Changes, tests and experiments."

At this time, it does not seem necessary to seek clarification from the American Concrete Institute because, as presented in this paper, the staff has a generally agreed upon position and understanding of the ASR issue as it relates to the ACI 318-71 Code requirements.

Comment [w11]: Substitute "may not"

Alice: Decided not to change because relationships were based on data of normal concrete.

Comment [n12]: The testing that NextEra is doing is outside of the ACI 318-71 code requirements for Chapter 20 and therefore, they must request approval from the building official (aka NRC). This should be explicitly stated. Their plan to perform large-scale model testing to prove strength is not an analysis (as the material properties are not well understood and it's not an exact replica of Seabrook's existing structures) or a load test as described in the code.

Alice: As you stated, the material properties are not well understood. In section 20.1.3, it states "if the effect of the strength deficiency is not well understood or if it is not feasible to establish the required dimensions and material properties by measurement, a load test shall be required..." We already know that the load test is not practicable, therefore, it may be appropriate to pursue and alternate method to show that the structures remain within their design basis. I also note, although I'm not entirely sure how much weight this carries, that the Code states "the Code and Commentary cannot replace sound engineering knowledge, experience, and judgement."

Comment [w13]: I believe we need to be stronger in the language we use in this section/conclusion. Specifically, NextEra is not currently adhering to the methods for evaluating the strength of existing structures in Chapter 20, therefore they are pursuing an approach that is not recognized by ACI 318-71 and are outside their CLB. They will have to seek NRC (Building Official) approval before resolving the ASR issue at Seabrook Station. Accordingly, they proceed at their own risk and without NRC approval of the approach they are taking.

Alice: I decided to delete the discussion for the method of evaluation. I don't believe we have enough information and a clear understanding as to what they are planning to do with the results of that testing. I don't think we can say the method of evaluation alone is outside the CLB.

From:	Lamb, John (n/r/c
To:	Khanna, Meena
Cc:	Ennis, Rick; Hughey, John; Chernoff, Harold
Subject:	Response to Request - Reg Process Outline - Seabrook ASR
Date:	Monday, February 04, 2013 12:50:35 PM
Attachments:	seabrook asr outline Reg Process - Rev 1.docx
Importance:	High

Meena,

Attached, as requested, is the regulatory process outline for Seabrook ASR for the conference call with Region I on Wednesday, February 6, 2013. I would like to thank Harold Chernoff for providing the outline in the midst of his other high priority work.

Thanks.
John

B/88

Seabrook ASR – Regulatory Process Overview and Approach

1. Seabrook submitted evaluation/analysis in accordance with Item 7 of the CAL on 5/25/2012.
    1.1. Evaluation of impact of ASR on Seabrook constitutes an analysis performed at NRC request.
    1.2. 10 CFR 50.71(e) requires the FSAR to be updated with "...all analyses of new safety issues performed by or on behalf of the applicant or licensee at Commission request."
    1.3. The FSAR update must, "...assure that the information included in the report contains the latest information developed. This submittal shall contain all the changes necessary to reflect information and analyses submitted to the Commission by the ... licensee ..."
2. Seabrook is required to incorporate this information into the FSAR in accordance with 10 CFR 50.71(e)(4).
    2.1. Based on the 5/25/2012 submittal, this FSAR update must be submitted by 11/17/2013.
    2.2. The change to the FSAR must be evaluated in accordance with 10 CFR 50.59 to determine if NRC approval is required prior to incorporation into the FSAR update.
3. The 10 CFR 50.59 evaluation of the FSAR update will likely trigger a request for amendment pursuant to 10 CFR 50.90.
    3.1. Amendment process provides a strong regulatory framework to document NRC staff review of the licensee evaluation/analysis of ASR.
    3.2. Amendment process provides a structured opportunity for public involvement.
4. Licensee final disposition of the degraded/nonconforming condition will likely require additional modification to the facility as described in the FSAR.

Buford, Angela

From: Buford, Angela
Sent: Monday, February 11, 2013 11:29 AM
To: Cook, William
Cc: Conte, Richard; Trapp, James
Subject: Comments RE: SMP Position Paper Rev6 AB.docx
Attachments: SMP Position Paper Rev6 AB.docx

Bill, some comments for your consideration, mostly on the wording used to describe GALL and its reference to ACI 349.3R. I also suggested a rework of one of the paragraphs.

Overall I think this is a great paper that covers all of the key messages and staff issues regarding SMP.

If you'd like, please give me a call to discuss.

Angie

February 8, 2013 (revision 6)

Memorandum To: ASR Working Group

From: William A. Cook, ASR Team Lead, Region I

Through: Richard Conte, ASR Project Manager, Region I

Subject: Position Paper: "ASR Working Group Recommendation to Address the Adequacy of NextEra's Seabrook Station Structures Monitoring Program (SMP)."

The purpose of this position paper is to provide the ASR Working Group and inspection team with a basis to assess the adequacy of NextEra's current SMP (Revision 2, dated July 12, 2012) revised to identify and monitor ASR in reinforced concrete structures at Seabrook Station. Further, the paper provides the basis for a recommendation to NextEra to commit to ACI 349.3R, in order to provide an enhanced technical basis to evaluate and monitor ASR-affected structures at Seabrook Station.

Under 10CFR50, the NRC has not specifically endorsed an applicable code or standard for modeling an appropriate structures monitoring program, regardless of whether or not the structures are impacted by ASR. Although 10CFR50.65, the Maintenance Rule, uses Regulatory Guide 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," that, in turn, endorses Nuclear Management and Resources Council (NUMARC) 93-01, "Industry Guidelines for Monitoring Effectiveness of Maintenance at Nuclear Power Plants," neither of these documents specifically addresses the essential elements of a structures monitoring program. Both documents address the fundamentals of a structures monitoring program (periodic inspection/examination) and the broad actions to be taken in the event of the identification of degradation mechanisms (reference Regulatory Guide 1.160, Rev 2 March 1997, Section 1.5; and NUMARC 93-01, Rev 4 May 2007, Sections 9.4.2.4 and 10.2.3.) However, both of these documents fall short of endorsing any available code or industry standard.

In contrast, under 10CFR54, the License Renewal rule, the NRC uses the guidance contained in technical report NUREG 1801, "Generic Aging Lessons Learned (GALL) Report," which provides recommendations for modeling a structures monitoring aging management program (AMP). The GALL Report recommends using the guidance in technical report ACI 349.3R, "Evaluation of Existing Nuclear Safety-Related Concrete Structures," as part of the basis for developing a structures monitoring aging management program. By this memo, it is acknowledged that NUREG 1801 provides guidance and does not endorse ACI 349.3R, such as would typically be the case through the Regulatory Guide process. This position paper recommendation (and accompanying discussion points) outlines for the inspection team the technical guidance for assessing the overall adequacy of the licensee's corrective actions to

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Comment [A1]: Bill, I changed the wording here to make it a little bit more precise. For your consideration.

address ASR, a condition adverse to quality. The NRC's review of NextEra's revised SMP is in accordance with CAL Item #9 and per NextEra's compliance with 10CFR50, Appendix B, Criterion XVI.

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NextEra's reaction to this position paper will determine the follow-on regulatory options. Options potentially available to the NRC staff include, but are not limited to: 1) NextEra voluntarily committing to ACI 349.3R (via 50.59 process); 2) NextEra voluntarily commits to ACI 349.3R, but takes exception to elements of the standard; 3) Management meeting conducted with NextEra to determine the appropriate regulatory approach/outcome, potentially leading to an amended Confirmatory Action Letter or Order to Show Cause; 4) issuance of a Notice of Violation or NCV via our second inspection report involving the failure to satisfy Appendix B, Criterion XVI for ineffective corrective action to address a condition adverse to quality; or, 5) if NextEra submits a license amendment request, a license condition could be imposed to ensure appropriate ASR monitoring methods are implemented by the licensee.

Copy to:

James Trapp, William Raymond, Suresh Chaudary, Angela Buford, George Thomas

Position Paper: "Adequacy of NextEra's Revision (2) to the Seabrook Structures Monitoring Program (SMP) to Address ASR", Revision 1

Recommendation: This position paper supports an ASR Working Group recommendation that NextEra commit to ACI 349.3R, in whole, for the Seabrook SMP, and incorporate specific actions to appropriately establish a well informed baseline assessment and effective monitoring of the progression of ASR to ensure continued operability of affected structures.

Background:

This position paper originated from an effort to draft separate ASR Working Group position papers for steel reinforcing bar (rebar) examinations and core sampling of structures at Seabrook Station that are impacted by ASR. Initial NRC oversight of the ASR issue prompted NextEra to agree to update the Maintenance Rule required Structures Monitoring Program (SMP) to include additional requirements to address the identification and monitoring of ASR in affected reinforced concrete structures. This commitment was documented in CAL No. 1-2012-002, Confirmatory Action Letter, Seabrook Station Unit 1- Information Related to Concrete Degradation Issues, dated May 16, 2012, CAL Item No. 9 and implemented per a revision (Revision 2) to Structural Engineering Standard 36180, "Structural Monitoring Program," dated July 12, 2012.

Based upon a preliminary review of NextEra's Revision 2 to the Structures Monitoring Program, the CAL follow-up team identified that NextEra did not elect to implement some parts of ACI 349.3R that provide guidance to address ASR-affected structures. Instead, NextEra has only used the three-tiered visual inspection criteria, outlined in Sections 5.1 through 5.3 of ACI 349.3R. NextEra has augmented the visual inspection criteria to incorporate structural evaluation thresholds based upon combined crack indexing (CCI) results. The CCI monitoring, performed at 26 selected locations (including containment) on various station structures at six-month intervals, was implemented based upon NextEra's partial adoption of Federal Highway Administration (FHWA) structures monitoring guidance. The inspection team has observed that NextEra has selected specific elements of both of these guidance documents, but has not incorporated the guidance in total. Some of the additional guidance/recommendations not included would have NextEra more fully investigate the current extent of ASR progression in affected structures and more thoroughly evaluate the operating environment contributing to ASR. From an Appendix B, Criterion XVI perspective, the CAL follow-up team concluded that NextEra's corrective actions appear to fall short of the ACI 349.3R and/or FHWA guidance for evaluating structures impacted by conditions such as ASR.

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The CAL follow-up inspection team observed that the key elements of Revision 2 to the SMP are: 1) the addition of Federal Highway Administration (FHWA) document FHWA-HIF-09-004, "Report on the Diagnosis, Prognosis, and Mitigation of Alkali-Silica Reaction (ASR) in Transportation Structures," as a reference document; 2) the performance of crack indexing on selected structure locations (26) to collect quantitative information on the progression of ASR expansion/degradation; and, 3) additional active individual crack width and CCI measurement criteria and associated evaluation thresholds, as developed in NextEra's interim structures operability assessment (reference Foreign Print 100716, "Impact of ASR on Structures.").

The following sections provide a brief overview of the guidance and recommendations in ACI 349.3R and FHWA-HIF-09-004 that are pertinent to monitoring reinforced concrete structures and, in particular, to assess the impact of cement-aggregate reactions, such as ASR.

ACI 349.3R Review

As discussed in Chapter 1, ACI 349.3R provides evaluation guidance for the periodic review/examination of existing concrete nuclear structures with the purpose of determining physical condition and functionality of the structures. The purpose and scope of a plant-specific evaluation procedure is defined by the plant owner and responsible governmental agency (NRC). Per Chapter 2, the general condition survey practices using visual inspection criteria should be supplemented by additional testing or analysis, as required. The scope of the recommended evaluation criteria are outlined in Chapter 3; and in addition to the periodic visual inspection activities, both non-destructive and destructive testing methods are specified. Also, Chapter 3 recommends assessing the condition and aggressiveness of the operating environment. Chapter 4 addresses the concrete degradation mechanisms, including specific discussion of cement-aggregate reactions, chemical attacks, leaching, and potential corrosion of carbon steel reinforcements and embedments. As mentioned above, Chapter 5 outlines the periodic three-tiered visual inspection criteria. Chapter 6 discusses the frequency of structural evaluations and emphasizes that the frequency should be based upon the aggressiveness of environmental conditions and the physical condition of plant structures. For below grade structures, the monitoring of soils and ground water chemistry is recommended and should be used to support changes in the frequency of structural monitoring, as necessary.

With respect to core sampling (destructive evaluation), ACI 349.3R suggests this technique be used, but limited, to minimize any adverse impact on structural performance. Section 3.5.3 states that destructive testing provides "information needed to determine the remaining durability of the cover concrete, structural concrete, and reinforcing steel system via testing of exposed or removed samples.....The removal of core samples from a structure may allow the determination of strength via testing, the use of petrographics, mechanical and chemical property determination, tests for carbonation depth, and inspection of material consistency and physical condition." ACI 349.3R refers to ASTM C42, C823, and C856 for further sampling and petrography guidance, noting the importance of proper sampling and testing accuracy. Further, "destructive testing provides especially useful and accurate data for assessing the ultimate impact of degradation and provides a baseline for comparison in any future testing."

As stated in the GALL Report, the evaluation and acceptance criteria established in ACI 349.3R is derived, in part, from the original design and construction standard ACI 318 (reference NUREG-1801, XI.S6, "Structures Monitoring," Section 6, "Acceptance Criteria"). The recommended material property testing of core samples (reference ACI 349.3R-96, Section 3.5.3) provides a means to directly assess the impact of ASR on the affected reinforced concrete structure. This type of analysis is also referenced in ACI 318-71 (and later revisions). Per Section 20.2, "If the strength evaluation is by analytical means, a thorough field

Comment [A2]: When referencing GALL, we usually always say "the GALL Report"

Comment [A3]: Instead of leading with this sentence, consider using the sentence in Program Element 6, Acceptance Criteria, of GALL Report which states that "The criteria are derived from design bases codes and standards" and then go on to discuss the ACI 318 Chapter 20 discussion, although in that case, the paragraph would not have anything to do with ACI 349.3R and you may want to consider moving it to a different section of the paper

Comment [A4]: Program Element, not Section

Comment [A5]: This is not how I read Program Element 6, Acceptance Criteria, of the GALL Report. GALL Report states that acceptance criteria for the Structures Monitoring AMP should be based on design bases codes, such as ACI 349.3R, ACI 318, ANSI/ASCE 11, etc., and consider industry and plant operating experience. The argument can be made that ACI 349.3R is not a design basis code for Seabrook, so the GALL recommendation that acceptance criteria should be based on the design codes still applies. I would consider deleting this sentence, and moving the entire reference to NRC position documented in the GALL Report to a new paragraph. In that new paragraph, I might say something similar to the following sentences:

1. "As documented in the GALL Report, the NRC position is that ACI 349.3R should be incorporated into the licensing basis for evaluation of concrete structures excluding containment."
2. "The GALL Report recommends that ACI 349.3R be used to identify and establish criteria for evaluating aging effects of concrete."
3. The sentence you currently have at the end of this paragraph, beginning with "Lastly...", except remove the word "Lastly" and use "In addition", or "Further", or a similar word

Comment [A6]: If we are making the correlation between the sentence in GALL that recommends licensees use their own design codes to establish criteria, then this sentence does not belong, since ACI 349.3R is not in the CLB investigation shall be made of the dimensions and details of the members, properties of the materials, and other pertinent conditions of the structure as actually built." The material property data would provide a baseline assessment of the current level of degradation, may be used to assess ASR progression, and support an ongoing operability assessment, absent any ASR mitigation actions. However, it is important to acknowledge the limitations of core sample testing by conventional means, and as likely intended by ACI 318. Specifically, current research suggests that in-situ ASR-affected concrete performance (confined) may significantly differ from unconfined core sample testing results. Large-scale specimen performance testing may provide better insights to the affects of ASR. Accordingly, analytical investigation as prescribed by ACI 318 may not be practical and, therefore, warrant development of an alternative method, consistent with seeking Building Official (NRC) review and approval per ACI 318 and 10CFR50.59. The GALL Report also states that "Applicants who are not committed to ACI 349.3R and elect to use plant-specific criteria for concrete structures should describe the criteria and provide a technical basis for deviations from those in ACI 349.3R."

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Comment [A7]: Consider moving this statement to a new paragraph, see Comment A2 above. Note that this statement in GALL Report applies specifically to the acceptance criteria program element of the SMP

FHWA Review

Report No. FHWA-HIF-09-004, "Report on the Diagnosis, Prognosis, and Mitigation of Alkali-Silica Reaction (ASR) in Transportation Structures," dated January 2010, outlines a three-level investigation program implemented by the FHWA to address ASR impact on transportation structures. The investigation program includes: Level 1 – Condition Survey; Level 2 – Preliminary Studies for Diagnosis of ASR; and Level 3 – Detailed Studies for the Diagnosis/Prognosis of ASR; and uses a combination of visual examination criteria (extent of cracking and measurement) and sampling/laboratory investigation methods (petrography, mechanical and chemical testing). As stated in Section 4.2. crack indexing is used in combination with petrographic examination of cores to provide decision-making criteria for further investigation. Section 4.3 addresses the core sampling program and includes guidance ranging from the nature and extent of sampling to the type and size of samples. Section 4.4 addresses petrographic examination and the importance of understanding and interpreting the examination results. Section 5.0 discusses Level 3 activities and emphasizes the need to understand the impact of ASR on mildly reinforced structural members and the effects of the environment on service life of the affected structures. In short, the FHWA guidance does not advocate crack indexing as the only method of monitoring reinforced concrete structures. The FHWA guidance suggests that both the degree of deterioration and a quantitative determination of the rate of degradation due to ASR are important to assess the service life and/or remediation actions of ASR-affected structures, if warranted.

The adequacy of NextEra's current Crack Indexing methodology, as recommended by the FHWA, for monitoring ASR progression is addressed by a separate position paper (reference "In Situ Monitoring of ASR-affected Concrete").

Additional Considerations/Recommendations

Based upon the CAL follow-up team's first inspection and detailed review of NextEra's interim assessment of ASR impact on reinforced concrete structures, some additional monitoring and/or evaluation attributes may be considered for inclusion in NextEra's SMP, in addition to ACI 349.3R:

1) NextEra qualitatively credited ASR expansion pre-stressing of the reinforcing steel for improved structural performance. In addition to the monitoring of rebar for potential corrosion mechanisms (reference ACI 349.3R, Section 4.2.8 and 4.3.1), NextEra should attempt to quantify the assumed ASR-expansion strain on rebar, consistent with construction/design pre-stressing methods and monitoring practices (reference Section 3.2.9 of IR 05000443/2012009).
2) NextEra should incorporate an enhanced water chemistry program to measure and monitor ground water infiltration chemistry (to look for leaching or corrosion products) and to monitor changes in aggressive chemicals in the environment. (ACI 349.3R, Section 3.5.1 and 3.5.3)
3) The SMP should more clearly discriminate between types of structures and degree of ASR impact (i.e., above grade versus below grade, concrete wetting due to water infiltration versus environmental cyclic wetting and drying). Reference FHWA -HIF-09-004, Section 4.3.1 for further discussion of the "nature and extent of sampling.")
4) Phase 3 ASR walkdown schedule should be completed in a timely manner, consistent with ACI 349.3R guidance and prior to the completion of testing, to ensure the testing appropriately bounds all known (full extent of condition) station ASR-affected structures. (reference Section 7.2 of IR 05000443/2012009)
5) In addition to the baseline core sampling suggested by ACI 349.3R, periodic representative core sampling should be performed to monitor ASR progression. Reliance on periodic combined crack indexing alone warrants validation of the representativeness of this technique for nuclear station reinforced concrete structures.

<u>NextEra's Position (Preliminary Response)</u> - Based upon team discussions the week of January 21, 2013, NextEra agreed to consider the following revisions to their SMP (to potentially be captured in Revision 3):

- Commitment to 349.3R
- Reevaluate the adequacy of current ASR baseline, after reviewing additional ACI-349.3R guidance.
- Tier II structural inspection actions need to be added to SMP, specifically the 2.5 year inspection frequency and the "CCI-like" evaluation.
- Consider incorporation of details, discussion, and scope of deep pins usage for in-situ monitoring of through wall (z-direction), for correlation of test data to affected station concrete structures.
- Consider incorporation or reference to current water chemistry and groundwater monitoring program, as an integral part of the SMP (reference ACI-349.3R environmental monitoring)
- Consider incorporation of plans for periodic petrographic examinations for correlation of UT-Austin test program CCI testing results and additional structural monitoring.

- Update the SMP (following completion of testing at UT-A) reflecting proposed revised CCI thresholds and actions to be taken.
- Consider any additional insights from the Phase 3 walkdowns into the revised SMP

Buford, Angela

From:	Buford, Angela
Sent:	Monday, February 11, 2013 4:20 PM
To:	Cook, William
Subject:	Revised Crack Indexing Paper - Please Review Format Change
Attachments:	In-situ Monitoring of ASR Paper Rev 3 2-11-13(2).docx

Bill,

I made mostly minor revisions to the crack monitoring paper, but pretty major changes in terms of format. Can you take a look and tell me if I captured your comment on format or if I missed the mark? I want to make sure we are still conveying the messages we intended in a digestible way.

Thanks,

Angie

February 11, 2013

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Memorandum To: ASR Working Group
From: Angela R. Buford
Through: Richard Conte, ASR Project Manager, Region I
Subject: Position Paper: In-situ Monitoring of ASR-affected concrete: A study on crack indexing and damage rating index to assess the severity of ASR and to monitor ASR progression

The purpose of this position paper is to provide the ASR Working Group and inspection team with a basis to assess the adequacy of using crack indexing and damage rating index to determine severity of ASR and monitor its progression of degradation in reinforced concrete structures at Seabrook Station. Further, the paper provides the basis for a recommendation that using the method of combined crack indexing alone to characterize the extent of ASR damage to-date and monitor the progression is not adequate, and that additional measures should be taken to provide a baseline understanding of the ASR affect on structures before combined cracking index can be correlated to anticipated structural performance.

Key Messages:

1. Surface cracking may not be indicative of the conditions of the concrete through the full section of the concrete member, and crack indexing measurements may not consistently indicate the level of ASR severity from one structure to another. For each group of similar (i.e., reinforcement detail, size, environmental conditions) structures, additional examinations are necessary to correlate crack measurements to severity of ASR degradation.

2. Crack mapping results should be correlated to actual strains (and therefore stresses) in the concrete and rebar in order to accurately represent the effect of ASR-induced stresses in engineering evaluations for structural behavior.

3. Damage Rating Index (DRI) is a more accurate measure of ASR severity than crack indexing, and alleviates many of the pitfalls of the crack indexing method. DRI should be considered as a method to assess damage related to ASR. However, since there is no standard on performing the DRI, one would need to be developed to ensure consistency.

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Copy to:
James Trapp, William Raymond, Suresh Chaudary, Angela Buford, George Thomas

Position Paper: In situ Monitoring of ASR-affected Concrete: A study on crack indexing and damage rating index to assess the severity of ASR and to monitor ASR progression

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Recommendation: Using the method of combined crack indexing alone to characterize the extent of ASR damage to-date and monitor the progression is not adequate. Additional measures should be taken to provide an understanding of the ASR affect on structures before combined cracking index can be correlated to anticipated structural performance.

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Key Messages:

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1. Surface cracking may not be indicative of the conditions of the concrete through the section, and crack indexing measurements may not consistently indicate the level of ASR severity from one structure to another. For each group of similar (i.e., reinforcement detail, size, environmental conditions) structures, additional examinations are necessary to correlate crack measurements to severity of ASR degradation.

2. Crack mapping results should be correlated to actual strains (and therefore stresses) in the concrete and rebar in order to accurately represent the effect of ASR-induced stresses in engineering evaluations for structural behavior.

3. Damage Rating Index (DRI) is a more accurate measure of ASR severity than crack indexing, and alleviates many of the pitfalls of the crack indexing method. DRI should be considered as a method to assess damage related to ASR.

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Alkali-Silica Reaction (ASR)

ASR is a chemical reaction that occurs in concrete between alkali hydroxides dissolved in the concrete pore solution and reactive silica phases in the aggregates. The product of the reaction is an expansive gel around the aggregate particles, which imbibes water from the pore fluid, and, having much larger volume than the reacting components, triggers a progressive damage of the material (Winnicki and Pietruszczak 2008). The pressures imparted by the gel onto the concrete can exceed the tensile strength of the aggregates and the cement paste and cause microcracking and macrocracking in the aggregate and surrounding paste. With the presence of moisture, the gel expands and can cause destructive cracking and deleterious expansion of the concrete. The extent of the concrete deterioration depends on aggregate reactivity, high levels of alkalinity, availability of moisture, temperature, and structural restraint (Williams, Choudhuri, and Perez 2009). Concrete expansion and cracking can lead to serious operational and serviceability problems in concrete structures (Rivard et al. 2002).

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Surface Cracking and Expansion

The Federal Highway Administration (FHWA) Report on the Diagnosis, Prognosis, and Mitigation of Alkali-Silica Reaction in Transportation Structures states that "in concrete members undergoing internal expansion due to ASR and subject to wetting and drying cycles (cyclic exposure to sun, rain, wind, etc.), the concrete often shows surface cracking because of induced tension cracking in the 'less expansive' surface layer (because of variable humidity conditions and leaching of alkalis) under the expansive thrust of the inner concrete core (with more constant humidity and pH conditions)." Cracks first form as three or four-pronged star patterns resulting from expansion of the gel reacting with the aggregate. If the concrete is not subject to directional stress, the crack pattern developed forms irregular polygons, commonly referred to as map cracking (Swamy 1992). This cracking is usually enough to relieve the pressure and accommodate the resulting volume increase (Figg 1987; reported by Farny et al. 2007).

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Map cracking is one of the most commonly reported visual signs associated with ASR. The pattern and severity of cracking vary depending on the type and quantity of reactive aggregate used, the alkali content of the concrete, exposure conditions, distribution of stresses, and degree of confinement in the concrete (Smaoui et al. 2004). ASR can also be characterized by longitudinal cracking, surface discoloration, aggregate pop-out, and surface deposits (gel or efflorescence) (Williams, Choudhuri, and Perez 2009). Although pattern cracking is a characteristic visual indication that ASR may be present in the concrete, ASR can exist in concrete without indications of pattern cracking. Newman (2003) noted that "while superficial cracking patterns can often be reminiscent of ASR, it is important to be aware that reliable diagnosis can never be adequately based on the appearance of surface cracking alone." This is also emphasized by Hobbs (as reported by Bensted and Barnes, 2001), whose research cites examples where cracking from other mechanisms was diagnosed as ASR, and also examples in which ASR gel and associated cracked aggregate particles were found in concrete that was uncracked. In addition, in ASR-affected structures with reinforcement close to the surface or in heavily reinforced structures, surface cracking may be suppressed while internal damage exists throughout the section. The presence and extent of surface cracking is not a conclusive indication that ASR is present, nor is it a conclusive measure of concrete degradation due to ASR. Conversely, the absence of surface cracking does not conclusively indicate the absence of ASR.

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Crack Mapping/Indexing Review

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In order to determine the effect of ASR on the performance of a concrete structure, it is important that there be an understanding of current concrete condition (ASR damage reached to-date) and the rate of ASR expansion. Crack indexing is a method that is proposed to measure crack widths and expansion of cracks over time. For this type of visual examination individual crack widths are measured over a defined grid and the total amount of cracking is quantified. The examination is repeated at regular intervals and the results are compared over time, with a goal of establishing a rate of ASR progression. The Institute of Structural Engineers (ISE 1992) proposed a method for crack mapping that consists of measuring the ASR crack widths along five parallel lines that are each 1 m long. Lines are traced directly onto the concrete structure. The total width of intersecting cracks along each line is summed and divided by the length over which they were measured, to determine the severity of ASR cracking, and then over time to determine the rate of expansion. Another method, suggested by Laboratoire Central des Ponts et Chaussees (LCPC 1997), consists of measuring the widths of all cracks intersecting two perpendicular 1m lines originating from the same point and their two diagonals 1.4 m long. The total crack index is determined as a value in millimeters per meter and compared to criteria that correspond to action levels.

Summary of General Discussion on Crack Mapping

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It is stated throughout published ASR research that crack mapping is somewhat limited in its applicability to understanding ASR degradation in concrete. Saint-Pierre et al. (2007) note that compared to other non-destructive methods developed for assessing the damage induced by ASR, the semi-quantitative surface methods like crack mapping appear to be less effective. It is generally agreed that while results of crack indexing can potentially give some indication of how ASR is progressing over time, establishing an absolute trend that directly correlates expansion levels to ASR progression may not be a reliable practice. Much of the published ASR research also indicates that using crack measurement alone to characterize the current state of ASR degradation would not be advised, since the practice relies on the assumption that the surface cracking on the face of a structure is wholly congruent to ASR severity. In the 2010 Addendum to its report titled "Structural Effects of Alkali-Silica Reaction - Technical guidance on the Appraisal of Existing Structures," ISE stated that the crack summation procedures for estimating expansion to date work well in directions where there is little restraint from structural stress, reinforcement, or prestress. This suggests that in structures with higher restraint, this would not be the case. In addition, crack mapping is limited in that it can only give data on two-way crack measurements and does not capture cracking in the out-of-plane direction. It is suggested that further activities be carried out for assessing current condition of the concrete and current expansion rate, as well as correlating the expansion to structural integrity.

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In addition, crack indexing evaluation criteria should not be universally applied to all structures because surface cracking may not give a reliable indication of the ASR degradation to the structure. Due to variability in size, location, environment, reinforcement detailing, and relative severity of ASR damage, it may be necessary to obtain an understanding of the ASR effects for each individual structure or group of structures with similar physical properties and environments. Indeed, Newman (2003) stated "it is important to relate cracking patterns variously to structural geometry and/or design, apparent concreting sequence, localized detailing (especially where cracking may be coincident with water leakage) and both environmental and in-service conditions." Deschenes et al. (2009) also state that research into the method highlighted that a number of factors (size and shape of member, restraint present, depth of cover, etc.) leading to poor correlation between crack indexing and measured expansions.

Surface Cracking vs. Internal ASR Damage

The correlation between surface cracking and ASR deterioration may be closer to unity for specimens used in the laboratory that are only allowed to deteriorate due to ASR conditions. However, for concrete in the field, the surface indications sometimes poorly correlate to the extent of ASR degradation within the concrete. Since conditions are so variable from one region to another, and even from one location to another in the same structure, poor correlations are often observed between the severity of surface cracking and the presence of the internal signs of ASR (i.e., reaction products, micro-cracking, and expansion) (Nishibayashi et al. 1989 and Stark 1990 reported by Smaoui et al. 2004). Development of cracking on the surface depends strongly on the amount of reinforcement close to the surface (Smaoui et al. 2002) and also depends on external environmental conditions such as wetting-drying, freezing-thawing, and exposure to saline solutions (Smaoui et al. 2002). Two examples of situations in which external conditions can affect the surface cover concrete such that the surface features are not indicative of the actual ASR degradation of the structure are presented here for consideration. In one case, presence and extent of surface cracking can depend on the pH of the surface which can be affected by leaching and carbonation. As such, wetting-drying cycles can affect the features of ASR, as conditions at the surface layer could be less favorable to the development of ASR, due to the [lower] humidity during the drying periods and the leaching of alkalis during the wetting periods (Poitevin 1983 and Swamy 1995, reported by Smaoui et al. 2004). In other words, if the outer surface layer of concrete is exposed to conditions that would cause the ASR severity or development to be lower, but conditions inside the concrete remain conducive to ASR development (i.e., high relative humidity); surface conditions would not be representative of the ASR within the concrete section. Crack indexing efforts would incorrectly characterize the level of ASR degradation as minor, when within the section the ASR degradation might be more severe.

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Another example in which environmental conditions have caused surface conditions to be different than conditions within the concrete is the subject of a study done by Berube et al. (2002). In this study, an attempt was made to correlate ASR expansion with type of exposure to moisture. Results showed that specimens exposed to wetting-drying cycles saw more surface cracking but less actual expansion than specimens that were always exposed to humidity. In this case, the larger amount of surface cracking evident in the specimens exposed to wetting-drying cycles did not show to correlate well to the actual expansion due to ASR, with the ASR expansion being less severe than the cracking would indicate. Conversely, the specimens that showed less surface cracking saw a greater expansion due to ASR, which shows that visual examination of surface cracking alone may not be adequate.

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Smaoui et al. (2004) state that although the intensity of surface cracking on ASR-affected concrete in service can help to assess the severity of ASR, quantitative measurement of this intensity [i.e., crack mapping] [could] lead to values that generally underestimate the true expansion attained, except maybe when the surface concrete layer does not suffer any ASR expansion at all. If the concrete surface layer undergoes ASR expansion that is less than that of the inner concrete, according to Smaoui et al. (2004), "the measurement of surface cracking will tend to give expansion values lower than the overall expansion of the concrete element under study." This research indicates that the degree of correlation between surface cracking and actual ASR expansion or degradation tends to vary with the level of exposure, which means that crack indexing over a number of structures with varying environmental conditions may not conclusively measure the extent or severity of ASR degradation.

ASR-induced Stresses

The ISE (2010) noted that for some structures exposed to ASR, internal damage occurs through the depth [of the section] but visible cracking is suppressed by heavy reinforcement. In reinforced concrete structures, expansion of ASR cracks generates tensile stresses in the reinforcing steel while also causing compressive stresses in the concrete surrounding the rebar (this phenomenon is often likened to prestress in the concrete and noted to temporarily improve structural behavior). According to Smaoui et al., 2004, the most useful information in the structural evaluation of an ASR-affected concrete member is the state of the stresses in the concrete, but more importantly in the steel reinforcement. The ASR-induced stresses increase the structural demand on the steel and concrete, but this new design load has likely not been accounted for in the original design or in further structural evaluations. According to Multon et al. (2005), "assessment models have to take into consideration the property of stresses to modify ASR-induced expansions and their effect on the mechanical response of ASR-damaged structures..." The expansion reached to date, the current rate of expansion, and the potential for future expansion of the concrete are particularly critical pieces of information to determine whether or not the reinforcing steel has reached or will at some point reach its plastic limit, thus creating risk of structural failure (FHWA 2010).

Crack mapping alone to determine ASR effects on the structure does not allow for the consideration of rebar stresses. Visual examination and measurement of crack growth need to be correlated to strain measurements taken of ASR-affected concrete and the reinforcing steel. In similar structures, then, the visual indications of expansion due to ASR can relate to stresses in the concrete and reinforcing steel in order to apply ASR-induced stress as an additional load in structural evaluations. Smaoui et al., 2004 propose that if it is not possible to do a destructive examination (i.e., exposing the rebar or taking deep cores) of the structure in question, "an indirect method is based on the expansion accumulated to date...Assuming that this expansion corresponds to that of the reinforcement steel, the stresses within the reinforcement and the concrete could thus be determined from the modulus of elasticity of the steel and the corresponding sections of the concrete elements under investigation." For determining added stresses in in situ structures, once correlation has been made with respect to size and rebar configuration between the in situ structure and a test specimen, it would be appropriate to use crack mapping as a measure of ASR degradation when introducing the additional ASR-induced stresses on concrete and reinforcing steel in structural evaluations.

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Discussion on Applicability of Crack Indexing

This report is not intended to present the position that crack indexing and resulting data should not be part of a structural monitoring program to assess the ongoing effects of ASR in concrete. In fact, crack indexing is recommended by the Federal Highway Administration (FHWA 2010) "to obtain a quantitative rating of the 'surface' deterioration of the structure as a whole" (it should be noted that in the FHWA document, the word "surface" is emphasized with quotation marks, which implies recognition that crack indexing measurements alone provide information limited only to what is occurring at the concrete surface). NRC staff position is that crack mapping can only be useful once there is an understanding of how the conditions inside the concrete, (i.e., relative humidity, presence and severity of cracking, and added stresses in the concrete, reinforcing detail) correlate to the cracking observed at the surface. The FHWA (2010) document agrees, indicating that to obtain an understanding of the current state of ASR degradation and in order to correlate the surface cracking to the actual effects of ASR-induced expansion on the structure, other investigations of the in-situ structure are necessary. In addition to crack indexing, some FHWA recommendations for transportation structures that can be appropriately applied to nuclear structures include taking stress [strain] measurements in reinforcing steel, obtaining temperature and humidity readings, and performing non-destructive testing such as pulse velocity measurements (the recommendation to use pulse velocity measurements is in agreement with the experimental findings of Saint-Pierre et al. 2007). The Institution of Structural Engineers (ISE 2010) suggests that expansion to date and severity of ASR should be evaluated using examination and testing of cores for changes in modulus of elasticity and development of hysteresis (stiffness deterioration). It is also proposed that strain sensors be used as a method of monitoring ASR progression in order to monitor and quantify out-of-plane expansion.

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In addition to provisions for monitoring (or predicting) progression of ASR, it is recommended that each structure or group of similar structures undergo petrographic analysis to determine the current state of ASR damage, in order to provide an accurate baseline from which to understand the current severity level and monitor ASR progression.

Damage Rating Index Review

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The damage rating index (DRI) was developed by Grattan-Bellew and Danay in 1992 (Reported by Smaoui et al. 2004) as a method to determine the extent of internal damage in concrete affected by ASR (Rivard et al. 2002). The DRI is a method for quantifying both qualitative and quantitative observations and determining severity of ASR using petrographic analysis of polished sections of concrete. It is based on the recognition of a series of petrographic features that are commonly associated with ASR (Rivard et al. 2002). The DRI accounts for defects observed in the concrete, such as the presence and distribution of reaction products, existence of internal microcracking, and location of microcracking (within the aggregate vs. through the cement paste) by assigning a weighting factor to each and quantifying overall damage. When the factors are normalized to an area of 100 cm^2, the resulting number is the DRI. Rivard et al. (2000) noted that the abundance of individual defects and the overall DRI values increased with regularity with increased ASR expansion. It should be noted that the specimens used by Rivard et al. were comprised of reactive aggregates with different reaction mechanisms, but ASR expansion indeed correlated with DRI measures of ASR severity.

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Smaoui et al. (2004) performed damage rating indexing on specimens from five concrete mixes using different reactive aggregates to determine if there was a reliable and accurate correlation between ASR damage determined by DRI and ASR expansion measurements. They noted that there exists a potential error in estimating expansion of ASR concrete in the field and establishing a DRI-expansion relationship with laboratory testing. In some of the lab specimens, relatively similar DRI values were obtained for very different expansion levels for cylinders which had been cast with the same concrete mix (and progressed ASR over time). The tests indicated that expansion levels (of in situ structures compared to laboratory specimens) may not be the best indication of ASR degradation. For example, the presence of air bubbles in the proximity of reactive aggregates [in field concrete] usually has the effect of reducing the expansion due to ASR (Landry 1994, Reported by Smaoui et al. 2004). In other words, air bubbles that exist in the in situ concrete structure could result in a smaller expansion of the structure as concluded under crack mapping activities while more severe ASR damage could be present in the structure because ASR features have "room" to grow inside the existing structure before extensive cracking is notable on the concrete surface. Smaoui et al. (2004) concluded that "for evaluating the expansion attained to date by ASR-affected concrete, it may be necessary to reconsider the relevant defects and their respective weighting factors and take into account a certain number of factors such as the presence or absence of entrained air and preexisting cracks and alteration rims" to assess the severity of ASR in structures. It is notable that the research done by Rivard et al. (2000) showed that DRI correlated well with actual ASR expansion, while subsequent work done by Smaoui et al. (2004) proposed that in some cases lack of gross expansion did not correlate to low ASR degradation, and that air bubbles prevented macro-level expansion even though ASR effects were severe. Crack indexing would not have identified this severe ASR progression since that method only measures expansion of surface cracks,

Rivard et al. noted a possible limitation of the DRI method: that weighting factors assigned to each defect may not universally apply to all types of reactive aggregates (reported by Smaoui et al. 2004) and that weighting factor adjustments may be needed depending on the type of reactive aggregate being examined. In other words, DRI results (and their correlation to concrete expansion) should not be applied universally between concretes with different aggregates (with different types of siliceous materials), However, the FHWA (2010) notes that the DRI method can be useful for quantitative assessment of ASR damage for concretes with the same constituents (i.e., same type of reactive aggregate and cement mix design), and can provide useful relative information when cores are taken and a damage rating developed for each structure by the same experienced technician.

Conclusion/Recommendations

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In order for the effects of ASR on concrete to be assessed, the parameters that need to be understood are (1) the amount of cracking inside the concrete, (2) ASR-induced expansion-to-date and rate of expansion, and (3) effects of ASR on concrete and rebar stresses. To understand the affects of ASR on structural behavior, the effects of ASR damage inside the

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rebar cage should be applied to engineering analyses or laboratory testing of an equivalent structure for each group of similar structures.

Visual examination of the concrete surface, without any other information about the concrete beneath the surface, is not recommended for either determining the current level of ASR degradation or projecting the future effects of ASR in concrete. Crack indexing would be an adequate and reasonable method of monitoring ASR progression once surface cracking can be correlated to actual ASR degradation, including cracking, expansion, and corresponding stresses (strains) in the concrete and rebar. Laboratory and in-situ testing must be performed to correlate surface cracking with loss of mechanical properties because cracking patterns may vary for different structural geometry and/or design, apparent concreting sequence, localized detailing (especially where cracking may be coincident with water leakage) and both environmental and in-service conditions (Newman et al. 2003).

At a minimum, for each set of structures with the same environmental conditions (e.g. chronically wetted, exposed to freeze-thaw action, constant wetting/drying) and section properties (e.g. wall thickness, rebar layout), an initial petrographic analysis should be done to establish the current state of ASR degradation. The severity of ASR damage on the inside of the structure should be correlated to the surface cracking found on the face of the concrete. The expansion measured by subsequent periodic crack indexing can then be assessed on a structure by structure basis depending on that correlation. Also, depending on the correlation between the surface and interior indications for each set of structures, it may be appropriate to adjust the individual crack width and CCI acceptance criteria for different groups of structures. An added benefit to doing an initial petrographic analysis is that the cores removed from the structure could be studied for subparallel microcracking that would not be detected from crack mapping efforts, which only show cracks on the surface face. This is the minimum effort that should be undertaken to gain at least a more informed understanding, for each set of similar structures (physical attributes and environmental conditions), of the ASR expansion reached to date and rate of expansion. The ability to correlate in situ conditions with laboratory testing would strengthen the reliability of the crack indexing method.

A recommended approach to monitoring ASR progression would be the use of embedded strain gauges and other sensors in the concrete to provide a measure of expansion in the concrete. This would provide the most accurate measure of expansion due to ASR and would provide the benefit of understanding expansion due to cracking in the third direction. The application of strain instrumentation would also be able to quantify strains (stresses) on the rebar and concrete in order to apply the additional demand due to ASR to a structural engineering evaluation. Finally, this method would help to establish a rate of expansion in the concrete, and could provide insights into understanding the ASR degradation mechanism, including relating environmental conditions specific to a structure to the rate of change of ASR progression, in order to characterize the potential and extent of continued degradation over time. The data could also be used in engineering analyses to predict the effects of ASR on structural behavior.

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The DRI method has been shown to be an effective method for assessing the damage level of ASR-affected structures. However, due to the limitation of this method in being able to apply weighting factors consistently between various types of aggregates, practical implementation of this method would mean that site-specific criteria for severity ratings and weighting factors for ASR indications may need to be established in accordance with the reactivity of the aggregate used on site. Also, since there is no standard test procedure available and thus the DRI method results could be variable from one petrographer to another, it would be important to ensure quality and consistency in the implementation of the method. If consistency could be ensured through quality of the technician performing the initial examination and subsequent examinations, the DRI would provide a beneficial and useful understanding of current ASR degradation and degradation over time.

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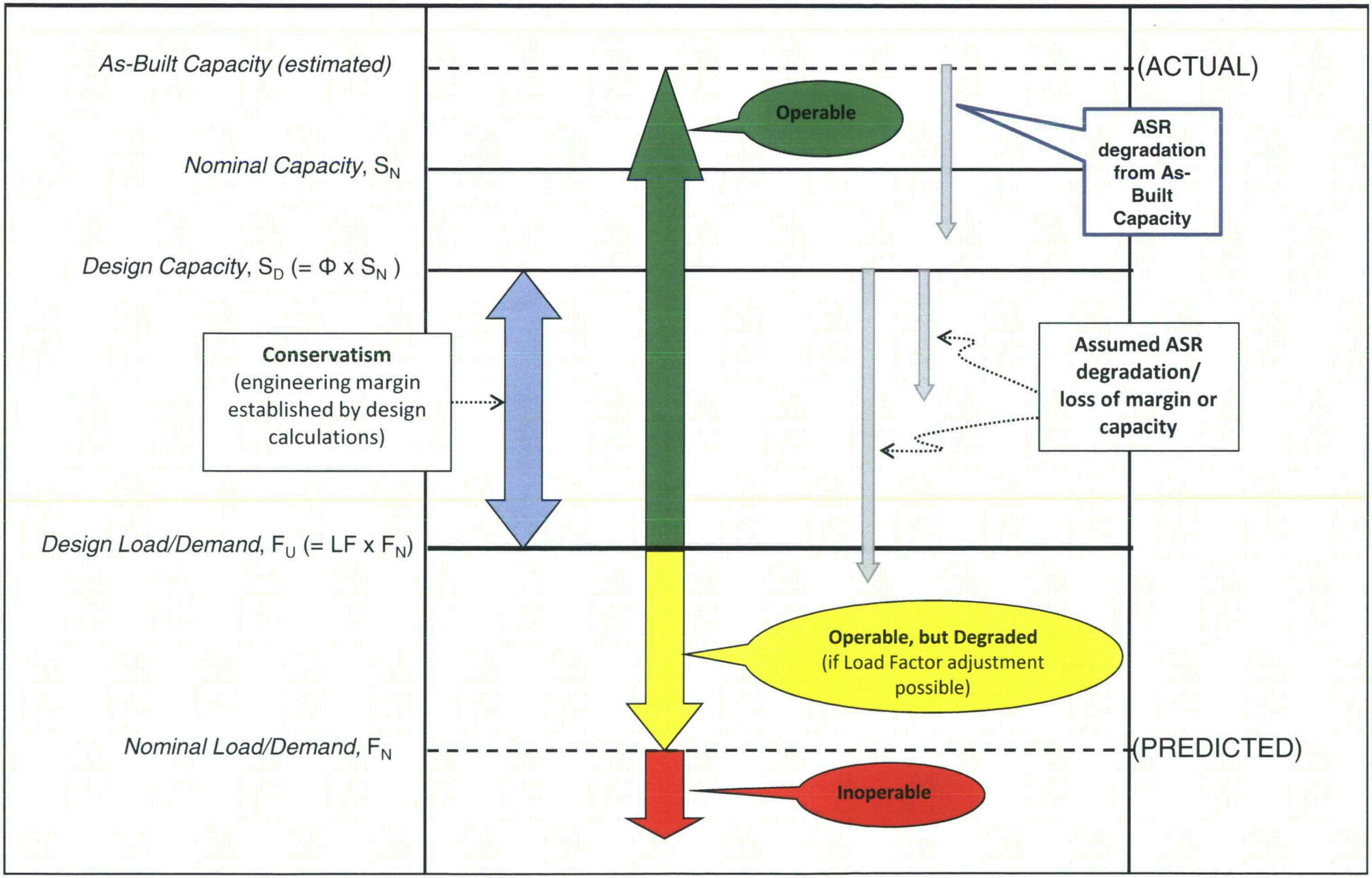
NextEra Crack Rating Chart

Assessment of Severity of ASR in Hardened Concrete by Petrographic Examination

This rating system is based on a modified "best practice" procedure initially developed at tehe Building Research Establishment (BRE) in the United Kingdom, using ASR identification critieria first set out in the British Concrete Association report titled "The Diagnosis of Alkali-Silica Reaction," (1992).

Rating	Description
0	No cracking detected
1	Very slight cracking (no evidence of deleterious ASR)
2	Slight cracking (minor or trace evidence of deleterious ASR)
3	Moderate cracking (moderate evidence of deleterious ASR)
4	Severe cracking (severe evidence of deleterious ASR)
5	Very severe ASR-related cracking
6	Heavily fractured ASR-related damage

Prompt Operability Determination - Margins Approach



Thomas, George

From: Thomas, George
Sent: Wednesday, February 13, 2013 7:19 AM
To: Conte, Richard; Marshall, Michael
Cc: McMurtray, Anthony; Manoly, Kamal
Subject: RE: Request for Input forUpdate of ASR 1-pager in preparation for the RIC 2013
Attachments: Alkali Silica Reaction (ASR) in Concrete_RIC2013 2-13-13.docx

Mike/Rich,

Thanks for the prompt input from R-I/DLR on the subject one-pager. I have combined and condensed the two inputs in the attached file. Please do a final review and provide any additional comments by COB today, the objective being to make it shorter and not longer.

Thanks.
George

From: Conte, Richard
Sent: Tuesday, February 12, 2013 4:30 PM
To: Thomas, George; Marshall, Michael
Cc: Trapp, James; Raymond, William; Cook, William; Dentel, Glenn; Schroeder, Daniel
Subject: RE: Request for Input forUpdate of ASR 1-pager in preparation for the RIC 2013

I thought the one pager was grossly out of date being dated for June 2012 for Part 50 issues. I reformatted and reorganized and tried to still keep it 1 page, goes onto the next page. You can do a file comparison but it might look like a piece of swiss cheese.

I defer to MM on an statements related to license renewal.

From: Thomas, George
Sent: Tuesday, February 12, 2013 10:45 AM
To: Conte, Richard; Marshall, Michael
Subject: Request for Input forUpdate of ASR 1-pager in preparation for the RIC 2013

Rich/Mike,

I have been asked to update this one-pager on the ASR issue for NRC management in preparation for RIC 2013 – so I need your help. Could you please update the attached (using track changes) with the latest status/information on the issue from your respective office/branch. Please provide your input by COB tomorrow (2/13), if possible.

Thanks for your help.
George

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Seabrook - Alkali Silica Reaction in Concrete

February 2013

Goals:

With an operability review of ASR-affected concrete structures satisfactorily completed, NRC staff continues efforts to complete the technical review of alkali silica reaction (ASR) concrete degradation issues identified at Seabrook Station and incorporate insights into (i) the need for a license amendment review, and (ii) the ongoing review of the license renewal application.

Status:

Reactor Oversight

- NextEra (the licensee) continues with detailed large-scale testing, crack monitoring and evaluations to comprehensively address and manage the Seabrook ASR-issue in the long-term.
- NextEra completion of CAL commitments were documented in letters dated May 25, 31, June 8, 21, 28, 2012.
- The CAL follow-up inspection began June 18, 2012, and was completed in December 2012 NRC Inspection Report No. 050004432012009 and it was accompanied by a meeting with the public on the ASR issue on December 11, 2012.
- In response to a NextEra request, dated December 13, 2012 to change two CAL items: 1) delete No. 7 to do a prism test as being unnecessary; and, 2) change CAL item No.11 related to anchor testing at the research and development facility, the NRC in a letter dated January 14, 2013 accepted the changes. The licensee now commits to submit technical details on the anchor test program by February 28, 2013.
- The NRC staff is currently conducting a second CAL followup inspection to verify actions related to the Structures Monitoring Program and the testing of specimens to reconcile the ASR issue with the design and licensing basis along with open issues identified in the first CAL followup report.
- The NRC's review of this issue to date has determined that there are no immediate safety concerns due, in part, to existing safety margins, the localized and slow nature of the ASR, and ongoing crack monitoring. This review includes a review of the NextEra's operabilitiy determinations for various structures affected by ASR and the results of the staff's review was documented in the above noted NRC inspection report.

License Renewal Application (LRA): (accepted for review June 2010)

- The discovery of ASR concrete degradation at Seabrook Station is a concern for the ongoing license renewal review because the effects of ASR on the affected safety-related structures may be different in character and/or magnitude after the term of the current operating license, and the effects have not been explicitly identified and evaluated by the licensee for the period of extended operation.
- On May 31, 2012, the NRC staff sent NextEra a letter to inform the applicant that the review schedule for the Seabrook LRA was being changed. The last two public

.milestones (i.e., issuance of final SER and ACRS full committee meeting) have been changed to TBD, because the supplemental information on the actions to applicant plans to manage the aging effects due to ASR was not provided in March 2012 as discussed in a letter to NextEra, dated July 12, 2011, and the supplemental information provided in May 2012 included a significantly new program that warrants additional staff resources to review. The ACRS subcommittee occurred on July 9, 2012 with no specific action on schedule for another subcommittee review.

- To date, after several rounds of RAI responses, the applicant has not provided a sufficient technical basis to support the adequacy of the proposed actions to manage the aging effects of ASR. The staff position is that the aging effects of ASR that need to be managed are: (1) changes of mechanical properties of concrete, (2) cracking of concrete, and (3) loss of anchorage capacity.
- A public meeting is planned for late February 2013 for the NRR/DLR staff and the applicant to discuss and develop a shared understanding of the specific aging effects that need to be managed and the information that needs to be provided to support the applicant's proposed plant-specific, first-of-kind ASR aging management program.

Background/Additional Information:

- ASR is a slow chemical process that can occur over time in hardened concrete and adversely impact the mechanical properties of concrete and has the potential to affect structural performance. The reaction requires reactive aggregate, high alkali content in cement, and adequate moisture to form a gel that expands and results in a network of microcracks.
- In August 2010, during a license renewal assessment, Seabrook reported the presence of ASR degradation of concrete in below-grade walls of several Category 1 structures with groundwater intrusion. Seabrook is the first plant to report ASR degradation in the U.S. nuclear power industry. Initial testing of core samples indicated a reduction in compressive strength and elastic modulus properties.
- Seabrook continued with detailed testing, crack monitoring and evaluations to comprehensively address and manage the issue in the short- and long-term. Following the public meeting with NextEra on April 23, 2012, the NRC staff issued a confirmatory action letter (CAL No. 1-2012-002) to NextEra on May 16th to confirm licensee commitments to address the issue. These actions were focused on assuring operability of the structures pending a review a formal root cause analysis, short-and long- term monitoring action while research and development occurred in order to address a final operability determination and corrective actions.