



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

December 6, 2013

David Wright, PhD  
Co-Director and Senior Scientist  
Global Security Program  
Union of Concerned Scientists  
Cambridge, Massachusetts 02138

Dear Dr. Wright:

Thank you for your letter dated November 4, 2013, highlighting Dr. Paul Brown's commentary on NRC Inspection Report 0500443/2012010 and outlining his recommendations for addressing the alkali-silica reaction (ASR) impacting the reinforced concrete structures at Seabrook Station. We appreciate your interest and Dr. Brown's independent assessment of the impact of ASR on reinforced concrete structures at Seabrook nuclear power plant. We welcome Dr. Brown's feedback and hope that we may continue our dialogue with him and other interested members of the public as NextEra and the NRC gain a better understanding of the effects of ASR on Seabrook safety-related structures. The NRC staff is holding a public meeting near Seabrook on December 18, 2013, at which the staff will discuss the ASR issue with NextEra managers and then respond to questions from the public. We would welcome further discussion with you there.

We have provided a response to Dr. Brown's specific comments in an enclosure to this letter. Our enclosure also addresses similar comments provided in the summary document prepared by the Union of Concerned Scientists and the C-10 Foundation.

The NRC continues its efforts to better understand the impact of ASR on reinforced safety-related structures at the Seabrook Station. Our inspections and assessments to date have determined the ASR-affected structures at Seabrook Station remain capable of performing their intended safety functions with margin from initial design and construction. Long-term resolution of this issue will require a thorough understanding of the effects of ASR and additional testing, monitoring and potential compensatory actions by NextEra. The NRC will continue to carefully assess NextEra's actions to resolve this issue and conduct inspections at Seabrook Station to ensure corrective actions are effective.

D. Wright

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Please feel free to contact Mr. Melvin Gray (610-337-5209) or Mr. William Cook (610-337-5074) of my staff should you have any further questions or comments to share with us.

Sincerely,

**/RA/**

William M. Dean  
Regional Administrator

Enclosure:  
NRC Response to Dr. Paul Brown's Commentary

cc w/encl: Distribution via ListServ

D. Wright

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## Enclosure

### NRC Response to Dr. Paul Brown's Commentary

#### Background

NRC closure of our Confirmatory Action Letter (CAL) 1-2012-002 (ADAMS Accession No. ML13274A670) represents the agency's assessment by in-office review and direct inspection of the specific commitments (eleven numbered CAL items) made by NextEra pertaining to their actions to address ASR-affected reinforced concrete structures at Seabrook Station. Closure of the CAL represents NextEra having: 1) successfully established a reasonable assurance of current operability for ASR-affected, safety-related structures; and, 2) implemented an appropriate corrective action plan to monitor and resolve this non-conforming condition, consistent with the current state of knowledge of ASR and 10CFR50, Appendix B, Criterion XVI, "Corrective Action Program."

As documented in NRC Inspection Reports 05000443/2012009 (hereafter referred to as Report 1 - ML12338A283) and 05000443/2012010 (hereafter referred to as Report 2 - ML13221A172), the NRC summarized extensive reviews and hundreds of hours of detailed inspections, meetings and internal deliberations to understand and ensure a clear engineering and safety basis had been established by NextEra for the current structures' operability determination. These prompt operability determinations were based upon detailed structural evaluations that are independent of the large-scale specimen testing being conducted by NextEra per the ASR Project Corrective Action Plan. As documented in our cover letter for NRC Report 1, the NRC determined that NextEra's methods for assessing operability of ASR-affected reinforced concrete structures were reasonable and generally comprehensive. NextEra conducted a margins analysis, using bounding ASR-affected concrete properties derived from research data, to demonstrate that Seabrook structures remained operable. As documented in Report 2, Section 9.6, the NRC understands that the resolution of the ASR non-conforming condition currently awaits NextEra's completion of the large scale testing at the University of Texas – Austin, Ferguson Structural Engineering Laboratory (FSEL). Upon completion of the testing, NextEra may submit a license amendment request pursuant to 10CFR50.59 and 50.90. It is understood that should the testing program be unsuccessful, any revisions to NextEra's ASR Project Corrective Action Plan would be appropriately communicated to the NRC. The NRC plans to periodically inspect NextEra's ASR monitoring program and testing activities at FSEL. NextEra is required, consistent with their Part 50 license, to maintain reasonable assurance of operability of Seabrook Station ASR-affected structures, as ASR insights are developed from the ongoing FSEL testing and the Seabrook Structures Monitoring Program (SMP).

The NRC acknowledges that the ASR issue is a complex and challenging phenomena because the onset, progression and impact of ASR on nuclear power plant structures is not fully understood or directly measureable nor are there established methodologies for assessing and monitoring ASR-affected reinforced concrete structures from either a materials property or structural performance standpoint (or a combination of these approaches). Accordingly, the NRC plans to carefully and deliberately review and assess the ongoing efforts of NextEra to address the Seabrook Station ASR issue.

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## **Commentary Review**

The specific commentaries numbered below are quoted or paraphrased from Attachment 1, "Commentary on NRC Inspection Report 05000443/2012010." We have structured our response to parallel Dr. Brown's commentary and have included, where appropriate, any additional considerations addressed in Attachment 2, "Continuing Problems with Monitoring Concrete Damage at Seabrook."

**Commentary 1) (pg.1):** The first area of concern is that CCI is not a well-established basis for reliably measuring ASR damage in highly reinforced concrete. Our response also addresses Attachment 2, Section (1) "Continuing Use of an Unjustified Measure of ASR," that reiterates this concern.

**NRC Response:** The NRC agrees with Dr. Brown's comment that the use of combined crack indexing (CCI) is not a well-established basis for monitoring the progression of ASR or measuring ASR impact on reinforced concrete. For this reason, NextEra's ASR-affected safety-related reinforced concrete structures' operability determinations are currently independent of this monitoring method. NextEra has provided reasonable assurance of operability for the Seabrook ASR-affected structures using appropriate engineering-based structural evaluations (reference ADAMS Accession No. ML12151A396 and ML12151A397 for Enclosure 2). The evaluations assessed structural design attributes using bounding values for assumed ASR degradation derived from concrete industry test data. These evaluations were informed using the material property testing results from core samples (47) taken from various Seabrook ASR-affected and non-affected structures. In addition, the structural evaluations assumed the structural members of interest were uniformly and entirely impacted by ASR, whereas the comprehensive walkdown of Seabrook structures has identified only localized areas of ASR degradation on the surface of the structures. The limited number of six-month CCI measurements recorded, to date, (18 months of data) has not yielded any noteworthy data trends. Likewise, no significant change in any individual CCI values has been observed.

As documented in Section 7.0 of Report 2 - "The crack growth monitoring provides a visual indication of the progression of ASR within a reinforced concrete structure. The relative width and number of visible cracks may be correlated to the overall progression of ASR and may be used to evaluate ASR impact on structural performance. However, ASR cracking and crack propagation is closely associated with the specific reinforcement design and structural loading. Accordingly, the adequacy of CCI measurement as a long-term structures monitoring methodology for Seabrook structures is being further evaluated by NextEra as part of the UT-Austin FSEL testing program." In addition, as documented in Section 9.5 of Report 2, the inspectors summarized the "reasonable assurance" rationale for CCI interim use in the Structures Monitoring Program (SMP) and stated that longer term use may warrant further NRC review.

**Commentary 2) (pg. 1):** A second area of concern is the lack of predictive capability of CCI. Attachment 2, Section (1) "Continuing Use of an Unjustified Measure of ASR," reiterates this concern.

**NRC Response:** The NRC agrees with Dr. Brown's comment on the lack of predictive capability of CCI. As discussed in Section 9.5 of Report 2, NextEra acknowledges the need to correlate CCI values to ASR progression in the large test specimens, and eventually to the station structures. Accordingly, NextEra has initiated efforts to install deep pins, or some comparable through-wall monitoring device(s), to measure ASR expansion in the out-of-plane direction. Measurement in the through-wall (Z-direction) is intended to complement the X-Y-direction monitoring obtained by CCI. The NRC understands that the testing program is intended to determine the adequacy of the CCI monitoring method, and to enhance or develop additional methods, as appropriate.

**Commentary 3) (pg. 1):** The third area of concern is that there is presently no generally accepted technology to mitigate the effects of ASR within an existing concrete structure.

**NRC Response:** The NRC agrees with Dr. Brown's statement that there "is presently no generally accepted technology to mitigate the effects of ASR within an existing concrete structure." As outlined in NextEra's large specimen testing program (ML13151A328), should structural remediation of the ASR-affected buildings be necessary, additional large specimens may be used to research, develop, and test remediation methods.

**Commentary Section 1.0 (pg. 2):** NextEra document, FP100716, discusses the use of lower bound values for structural capacity. It is not clear in the report how these values were applied. This lower bound would have a significant impact on the integrity of lap splices and anchorage capacity in particular.

**NRC Response:** Section 1.0 of Report 2 is an abbreviated background summary of the efforts undertaken by NextEra to address ASR, including the initial operability determination bases. The NRC documented the review of the operability determinations (ODs) in Section 3.0 of Report 1. Lower bound values used in the ODs were obtained from research test data gathered over several decades by numerous research facilities and testing laboratories, based upon small scale test specimens. These lower bound values were applied to existing design basis structural calculations to ensure, assuming worst case ASR degradation of the most sensitive limit states (out-of-plane shear capacity, lap splice length, and anchorage capacities) the available margin between design structural capacity and assumed loading conditions was not compromised. These calculations demonstrated that the affected structures were still operational assuming reasonable, worst-case ASR degradation.

**Commentary 3.0 (pg. 2):** No systematic analysis of the corrosion of rebar due to potentially aggressive water migration through the concrete. Attachment 2, Section (5) "Lack of Information on Corrosion of Steel Reinforcing Bars at Seabrook," reiterates this concern.

**NRC Response:** Dr. Brown is correct that no detailed or exhaustive analysis was conducted to assess the impact of ground water infiltration on rebar. However, the NRC has reasonable assurance that corrosion of the rebar is not occurring because generally, the alkali environment within the concrete inhibits corrosion and no surface indications of corrosion have been observed. In addition, the rebar samples taken by NextEra and examined, to date, do not show any evidence of corrosion. However, should the two to three-inch cover concrete start to severely degrade, further analysis and examination of the rebar would be prudent due to the increased vulnerability of the embedded rebar to oxidation mechanisms. Further, if rebar corrosion is or were to occur, additional visual indications such as staining and spalling would be evident. Reference Section 9.4 of Report 2 for additional inspection detail concerning this issue.

**Commentary 4.0 (pg. 3):** Closure of CAL Item 4 does not appear consistent with the corrective action plan being a “living document.”

**NRC Response:** The term “living document” implies that the corrective actions being taken by NextEra to address ASR may change as more information from either the SMP or the FSEL testing program is learned about Seabrook structural response to ASR. Because ASR remains a non-conforming condition, NextEra’s corrective action plan remains in effect until, and potentially after, this condition is resolved in accordance with the plant’s current operating license. The closure of CAL Item 4 was based upon NextEra having met their commitment to submit the ASR Project Corrective Action Plan to the NRC. NRC inspections will be conducted to determine the adequacy of NextEra’s corrective actions in the long-term resolution of this issue.

**Commentary 5.0 and 6.0 (pg.3):** Statements of fact, no concerns or recommendations expressed.

**Commentary 7.0 (pg. 3):** “There is no existing standard that correlates crack displacement in a reinforced structure to the extent of ongoing ASR within that structure.” Attachment 2, Section (1) “Continuing Use of an Unjustified Measure of ASR,” reiterates this concern.

**NRC Response:** The NRC agrees with Dr. Brown. The combined crack indexing (CCI) thresholds established in the Seabrook SMP were developed by NextEra using input from ACI 349.3R-96, “Evaluation of Existing Nuclear Safety-Related Structures;” Federal Highway Administration FHWA-HIF-09-004, dated January 2010, “Report on the Diagnosis, Prognosis, and Mitigation of Alkali-Silica Reaction in Transportation Systems;” Institution of Structural Engineers, July 1992, “Structural Effects of Alkali-Silica Reaction: Technical Guidance on the Appraisal of Existing Structures;” and ONL/NRC/LRT-95/14, “In-Service Inspection Guidelines for Concrete Structures in Nuclear Power Plants, December 1995. These CCI thresholds were incorporated into the SMP, consistent with available industry guidance, to prompt additional engineering evaluations upon identification of structural anomalies consistent with ASR progression. The use of CCI as a long-term surrogate for monitoring ASR progression is being evaluated by NextEra through their FSEL testing program.

**Commentary 7.0 (pg. 4):** “The report does not provide any detail as to this program (ground water chemistry monitoring).”

**NRC Response:** Other than committing to ACI 349.3R in the Seabrook SMP and the associated recommendation for environmental sampling of ground water on a periodic basis, outlined therein, NextEra does not have a detailed ground water chemistry analysis program specific to the ASR monitoring program. At the conclusion of the Report 2 inspection, NextEra was evaluating a new initiative and available methods to chemically analyze and compare ground water to collected infiltrated water. Ground water sampling for environmental monitoring purposes has been implemented to meet other regulatory commitments. NextEra actions to address this issue will be assessed during future NRC inspections.

**Commentary 8.0 (pg. 4):** There are no details in the inspection report pertaining to the anchor bolt and large specimen shear and lap splice testing programs. Attachment 2, Section (3) “Problems with Applying Results of “Replica Testing” to Seabrook,” reiterates this concern.

**NRC Response:** The details of these two testing programs were provided to the NRC by NextEra with a proprietary and non-proprietary version (Anchor - ML13088A218 and Shear/Lap splice - ML13151A328). The NRC reviewed these testing programs to gain an understanding of the methodology, expected results and proposed application of the same. These testing programs can be likened to confirmatory or research-related testing initiatives, not currently subject to NRC review or approval.

The NRC will conduct inspections of NextEra’s corrective actions to resolve the non-conforming condition related to ASR-affected structures documented in their corrective action program. This includes inspections of NextEra’s planned corrective actions involving anchor bolt and large-scale specimen testing. The results of our inspections will be documented in publically available reports. If NextEra staff determines these test results provide a technical basis to resolve the non-conforming conditions related to ASR, then the NRC will complete inspections to ensure NextEra staff properly implements the regulatory processes described in 10CFR50.59 and 50.90. Should preliminary testing results indicate a potential problem with Seabrook ASR-affected structures, the NRC would expect NextEra to evaluate that information in accordance with their corrective action program similar to other operating experience and assess the impact on Seabrook Station.

**Commentary 9.1 (pg.4):** “The present report does not provide the criteria for defining what constitutes an excessive crack, nor does it provide any detail as to this program.”

**NRC Response:** The CCI threshold (1.0 mm/m or greater) and individual crack width (1.0 mm or greater) documented in the Seabrook Station Structures Monitoring Program (SMP) are used for determining the need for a structural evaluation. These thresholds were developed by NextEra using available industry guidance. See Commentary 7.0 (pg. 3) and the NRC Response above for additional details regarding the industry reports and guidance used by NextEra.



Section 3.2.1 of Report 1 identified a minor performance deficiency associated with an SMP program requirement. Section 9.1 of Report 2 documents the inspection team's follow-up to this performance deficiency. A clarifying excerpt from Section 3.2.1 is provided below and identifies the genesis of this inspection issue.

"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. CCI is an ASR expansion monitoring method that sums the crack widths measured along a fixed rectangular grid line. The sum of the crack widths is then divided by the length (perimeter) of the grid to obtain the index value. 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...."

**Commentary 9.2 (pg. 5):** "It is well understood that drilled cores are extracted from an existing structure and have been subjected to the service environment associated with the structure. This in no way invalidates the results of the testing. The NextEra preposition misuses the cautionary language of ASTM C42 and appears to be an attempt to avoid accumulating data which might be regarded as problematic." Also, the report does not provide any details regarding any future drilled cores. Attachment 2, Section (2) "Failure to Adequately Use Core Testing" and Section (3) "Problems with Applying Results of 'Replica Testing' to Seabrook" reiterate these concerns.

**NRC Response:** The use of drilled cores to assess ASR impact on the concrete is not being challenged by either NextEra or the NRC staff. The use of that core test data alone, to assess structural performance, is being challenged by NextEra. The misuse of the cautionary language of ASTM C42 is improperly attributed to NextEra. That restatement of the ASTM C42 caution in the inspection report was added by the inspection team to highlight the introduction of uncertainties associated with extracting a drilled core and directly applying the test results, which may be adversely impacted for the stated reasons. No additional information pertaining to future drilling of cores was documented in the report because the number and location of future cores is dependent upon the FSEL testing program and unspecified future correlation needs, as determined by NextEra staff.

The NRC recognizes the merits of the testing and associated research that is being done in order to better understand the structural impact of ASR on non-triaxial reinforced concrete structures and to develop better methods to monitor ASR-affected concrete degradation. As stated in the background section above (and NRC response to Commentary 8.0), the NRC has reviewed and gained an understanding of the FSEL testing program and anticipated results, but not provided regulatory approval of the same. The "problems" or concerns expressed by Dr. Brown with applying test results to Seabrook Station have been identified and discussed between the NRC inspectors and NextEra staff. NextEra has outlined the methods to be used to correlate specimen test data to Seabrook structures in the test specifications submitted to the NRC per the CAL. The adequacy of that methodology has not yet been confirmed, but may be subject to NRC review, if used by NextEra pursuant to the 10 CFR 50.59 and 50.90 processes.

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**Commentary 9.3 (pg. 5):** This section states that ASR causes chemical prestressing. Such a statement indicates a misunderstanding of prestressing.

**NRC Response:** The report documents “chemical” pre-stressing in quotes to acknowledge that this term is being used to characterize the impact of the expansion of the ASR gel on the surrounding concrete matrix and rebar. The use of this term was to communicate a condition of the ASR-affected reinforced structures and not to imply actual pre-stressing similar to fabrication of pre-stressed concrete members.

**Commentary 9.4 (pg. 5):** Statement of fact, no concern or recommendation expressed.

**Commentary 9.5 (pg. 5):** “An assessment of the probability of mid-wall cracking should also be carried out on the actual in-place concrete. Attachment 2, Section (4) “Misunderstanding of the Structural Role of Concrete in Layered Construction,” also addresses this concern.

**NRC Response:** The NRC agrees with Dr. Brown’s statement and this issue is being considered by NextEra staff. See Commentary 9.2 (pg. 5) and the associated NRC Response above for additional detail. The NRC is not aware of any core samples taken at Seabrook that were found to have evidence of mid-wall cracking.

**Commentary 9.6 (pg. 5):** This section indicates that NRC staff finds the use of the CCI as an acceptable method of conditional assessment. This is unfortunate because it does not encourage NextEra to apply NDE techniques or other (assessment) techniques to quantify conditional analyses.” Attachment 2, Section (1) “Continuing Use of an Unjustified Measure of ASR,” reiterates this concern.

**NRC Response:** The NRC does not discourage the use of additional NDE assessment methods. Visual examination is recognized in the concrete industry as an effective means to detect ASR. However, petrographic examination is used to confirm the presence of this concrete degradation mechanism. Monitoring ASR progression through measurement of surface crack growth (at specified time intervals) may be effective, but remains to be validated. The NRC continues to follow industry research activities to improve NDE techniques related to ASR. Also see Commentary 1) and 2) and the associated NRC Response documented above.

**Commentary 9.6 (pg. 6):** The inconsistencies between pin expansion data and the CCI data show the complexity of interpreting the results of the analyses being conducted.

**NRC Response:** The NRC agrees with this statement. See our responses to Commentaries 1, 2, 7.0 and 9.6, above.

**Commentary 12 (pg. 6):** “The assumption that aircraft impact will not transfer stresses to ASR compromised concrete is unfounded.”

**NRC Response:** As stated in the Report 2, ASR has not been identified in the containment areas presumed to be impacted by the postulated aircraft impact. Secondly, areas of the containment identified as having ASR are: 1) localized; 2) below grade; and 3) in heavily reinforced sections. As such, there is reasonable assurance that the containment structure's aircraft impact analysis is unaffected. However, as stated in Report 2, if upon closer visual examination of the containment dome areas during the 2014 ASME IWL exam, evidence of ASR is identified, a re-evaluation of the structural design analysis may be warranted.