NEXTera ENERGY SEABROOK

Februry 28, 2013

SBK-L-13027
Docket No. 50-443

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

Seabrook Station
<u>Response to Confirmatory Action Letter</u>

References:

1. NRC letter to NextEra Energy Seabrook, CAL No. 1-2012-002, Confirmatory Action Letter (CAL), Seabrook Station, Unit 1 – Information Related to Concrete Degradation Issues, dated May 16, 2012. (ML121254172)
2. NextEra Energy Seabrook Letter to NRC, SBK-L-12257, Response to Confirmatory Action Letter, dated December 13, 2012. (ML12362A323)
3. NRC letter to NextEra Energy Seabrook, Revision to Confirmatory Action Letter, Seabrook Station, Unit 1 – Information Related to Concrete Degradation Issues, dated January 14, 2013. (ML13014A555)

In Reference 1, the NRC-issued Confirmatory Action Letter (CAL) No. 1-2012-002 which confirmed commitments NextEra Energy Seabrook, LLC (NextEra Energy Seabrook) made regarding planned actions to address alkali silica reaction (ASR) in certain structures at Seabrook Station, and required NextEra Energy Seabrook to notify the NRC Region 1 Administrator if, for any reason, NextEra Energy Seabrook cannot complete any of the actions or commitments within the specified schedule and to advise the Administrator in writing of the modified schedule.

In Reference 2, the NextEra Energy Seabrook requested deletion of CAL action 7, as the results of the Mortar Bar Expansion Testing obviated the need for the long term expansion testing; and requested that CAL action 11 be changed to be consistent with the approach taken with CAL action 8, i.e., NextEra Energy Seabrook is to submit the technical details of the anchor test program planned at the contracted research and development facility by February 28, 2013.

In Reference 3, the NRC approved the changes to the CAL requested in Reference 2.

In accordance with Reference 3, NextEra Energy Seabrook is submitting, in Enclosure 1 of this letter, the technical details of the anchor test program planned at the contracted research and development facility.

Enclosure 2 of this letter contains an explanatory white paper which provides an overview of the testing process.

The Enclosures contain information proprietary to NextEra Energy Seabrook, therefore, NextEra Energy Seabrook has provided redacted versions of the anchor test program and the explanatory white paper.

NextEra Energy Seabrook will provide the proprietary versions of the anchor test program and white paper along with a request for withholding from public disclosure and accompanying affidavit in accordance with the provisions of 10 CFR 2.390 at its earliest convenience not later than March 15, 2013.

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

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

Sincerely,

NextEra Energy Seabrook, LLC

Kevin T. Walsh
Site Vice President

cc:

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Enclosure 1 to SBK-L-13027

Specification for Strength Testing of Attachments in ASR-Affected Concrete

MPR
ASSOCIATES INC.
ENGINEERS

Specification for Strength Testing of Attachments in ASR-Affected Concrete

0326-0058-26

Revision 4

February 26, 2013

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

Prepared by: Robert J. Vayda

Reviewed by: James E. Moroney

Approved by: John W. Simons

Prepared for

NextEra Energy Seabrook LLC
P.O. Box 300
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Revision Description Sheet

Revision Number	Sections Revised	Revision Description
0	Initial Issue	Initial Issue
1	All Sections	Revised specification to reflect changes in the test scope and to reflect changes in the philosophy for the Block tests (i.e., blocks to be representative of Seabrook rather than Bridge Girders). Also, made minor editorial changes/clarifications throughout.
2	All Sections	Revised specification to separate the two phases of anchor testing into separate appendices. Added clarifying information on the second phase of anchor testing that consists of preparation of new concrete specimens.
3	Section 3.0	Revised Section 3.0 of specification to reflect changes in schedule.
	Appendix B	Revised Appendix B of specification to increase the concrete compressive strength range and lengthen the time for recording crack indices in the test specimens. The revised concrete compressive strength range still falls within the range of normal strength concrete at Seabrook Station and the revised length of time for recording crack indices was based on observed crack growth rates in the test specimens.
4	All Sections	Revised specification to incorporate miscellaneous editorial clarifications throughout. Also, added specific year/editions for general ASTM specifications and ACI Code citations.

Table of Contents

1.0 SCOPE OF WORK

1.1 This Specification provides the requirements for testing of attachments in concrete affected by Alkali-Silica Reaction (ASR). The test results will be used to evaluate the extent of structural capacity reduction for attachments at Seabrook Station in the vicinity of concrete affected by ASR.

1.2 Vendor shall perform the following scope of work:

- Prepare detailed test procedures that will govern specimen preparation, calibration, conduct of testing, and documentation of results.
- Develop and maintain a quality system manual, based on ISO standards, that is suitable for interfacing with other relevant quality systems for anchor research.
- Procure all necessary equipment for the scope of testing.
- Procure all necessary services to support the scope of testing (e.g. calibration services).
- Execute girder test series. This effort includes the following:
  - Provide ASR-affected girders from the "boneyards" for testing.
  - Provide a concrete slab, unaffected by ASR, to serve as a control for the girder tests.
  - Conduct the tests in accordance with Appendix A to this specification. Two separate tests are required of the Vendor. These tests shall include the following:
    - Pullout tests of anchors in concrete
    - Breakout tests of anchors in concrete
  - Specific activities to support conduct of these tests include the following:
    - Characterization of the extent of ASR degradation in girders to be used in testing
    - Extraction of cores for petrographic examinations that will be performed by the Purchaser
    - Installation of expansion and undercut anchors in concrete specimens
  - Prepare a test report documenting the test results.

Details regarding the above activities are provided in Appendix A.

- Execute block test series. This effort includes the following:

  - Prepare specimens for the tests in accordance with Appendix B to this specification. This involves fabricating the specimens from purchased cement, aggregate, and reinforcing steel and driving ASR degradation in the identified concrete specimens.

  - Conduct the tests in accordance with Appendix B to this specification. Two separate tests are required of the Vendor. These tests shall include the following:

    - Unconfined tension tests of anchors installed in concrete prior to ASR degradation

    - Unconfined tension tests of anchors installed in concrete with existing ASR

  Specific activities to support conduct of these tests include the following:

    - Preparation of concrete blocks and beams

    - Preparation of cylinders for compressive strength testing

    - Extraction of cores for compressive strength testing, and for petrographic examinations that will be performed by the Purchaser

    - Characterization of the extent of ASR degradation in the concrete specimens

    - Performance of compression strength testing to establish the 28-day strength and the compressive strength at the time of testing

    - Installation of expansion and undercut anchors in concrete specimens

  - Prepare a test report documenting the test results.

  Details regarding the above activities are provided in Appendix B.

2.0 DEFINITIONS

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

3.0 SCHEDULE

All test activities shall be completed by December 31, 2014; the final test report shall be submitted within four weeks of the completion of testing. The Vendor shall verify its ability to meet target dates. If procurement constraints delay any listed delivery dates, the Vendor shall notify the Purchaser as soon as possible. The Purchaser's contact is John Simons, (703) 519-0258.

4.0 TESTING REQUIREMENTS

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

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

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

4.4 All measurement and test equipment which requires calibration and which is used by the Vendor in the scope of work shall be in current calibration prior to use. The calibration records for all such equipment shall be provided by the Vendor to the Purchaser prior to use for the scope of work.

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

5.0 SUBCONTRACTING

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

6.0 DOCUMENTATION

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

6.2 The required test results specified in Appendices A and B shall be documented by the Vendor in certified test reports. A separate report shall be submitted for each test series (i.e., girder test series, and block test series). Each test report shall be provided to the Purchaser for review and approval prior to formal submittal to the purchaser. The test reports shall contain, at a minimum, the following documentation:

- an unmarked copy of the procedures used,
- pictures or other documentation depicting the test set-up and conditions,
- test data recorded and results,
- the names of the individuals conducting the test,
- records demonstrating test personnel were trained to the applicable procedures,
- the date the testing was performed,
- calibration records of the equipment used, and
- a listing of the measuring and test equipment used for each test (identified by equipment ID) and the associated calibration records.

The test report shall include a statement indicating conformance to the requirements of this specification and the Vendor's project-specific quality system manual—see Section 13.

7.0 HOLD POINTS

The Vendor shall notify the Purchaser seventy-two (72) hours prior to performing any specimen preparation or testing activity. The Purchaser will notify the Client of these hold points upon notification from the Vendor. Once notified, the Purchaser will provide a written response indicating the Purchaser's desire to witness the activity.

8.0 RIGHT OF ACCESS

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

9.0 MEASURING AND TEST EQUIPMENT CALIBRATION

Pre- and post-use calibration of Measuring and Test Equipment (M&TE) is required. M&TE shall either be calibrated and certified in accordance with an ISO 17025 accredited program or calibrated against standards that were calibrated and certified in accordance with an ISO 17025 accredited program. Calibration records are required for the M&TE used. Calibration records shall identify the person performing the calibration, procedure used, standards used, and the as-found and as-left results.

10.0 Out-of-Tolerance Conditions

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

11.0 Nonconformances

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

[redacted]

13.0 Certificate of Conformance

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

14.0 PO RECEIPT CONFIRMATION

The Vendor shall provide confirmation within 5 days of purchase order date that this purchase order was received and accepted including confirmation that the terms of this PO can be satisfactorily adhered to.

For revisions to this specification, the Vendor shall provide confirmation within 5 days of receipt of the revised specification that the requirements of the revised specification can be met.

15.0 REFERENCES

1. Not used.

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

3. Seabrook Drawing No. 9763-F-101842, "Concrete General Notes & Reinforcing Splice Length," Rev. 14, October 21, 1983.

4. Seabrook Drawing No. 9763-F-111342, Revision 5, June 9, 1981.

5. Seabrook Drawing No. 9763-F-101345, Revision 7, December 30, 1982.

6. ASTM C42-11, "Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete."

7. ASTM E488-10, "Standard Test Methods for Strength of Anchors in Concrete Elements."

8. ACI 355.2-07, "Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary."

9. ASTM C192-07, "Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory."

10. ASTM C39-11a, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens."

Appendix A – Girder Test Series

A1. Purpose

The purpose of the testing described herein is to assess the impact of ASR on the capacity of post-installed expansion and undercut anchors covering a range of cracking indices. ASR may have reduced the structural capacity of the attachments (expansion anchors, undercut anchors, and embedments) in concrete at Seabrook. The results from these tests will be compared against post-installed anchors installed in concrete with similar mechanical properties that is unaffected by ASR to establish if ASR affects the structural capacity of attachments.

A2. Test Overview

The following information will be developed by the testing to assess the impact of ASR on the capacity of the attachments:

1. Pullout Strength of Expansion Anchors - determine the extent to which the pullout capacity of expansion anchors in concrete has been affected by ASR. The pullout testing will assess the pullout strength of the anchors in concrete as a function of the level of ASR degradation and installation effort. Pullout testing will be performed in concrete with similar mechanical properties that is unaffected by ASR, to develop a baseline for data comparison.

2. Breakout Strength of Undercut and Expansion Anchors - determine the extent to which the breakout capacity of undercut and expansion anchors in concrete has been affected as a function of ASR degradation. Breakout testing will be performed in concrete with similar mechanical properties that is unaffected by ASR, to develop a baseline for data comparison.

A3. Test Specimens

A3.1. Description

The following is a description of the concrete test specimens that will be used for testing.

- ASR-affected Concrete (Bridge Girders) – ASR-affected Bridge Girders available in the "boneyards" at the Ferguson Structural Engineering Laboratory.

- Existing Concrete without ASR (Control Slab) - existing concrete slab available at the Ferguson Structural Engineering Laboratory. The Control Slab has similar concrete mechanical properties and reinforcement layout as the ASR-affected Bridge Girders.

From walkdown inspections at Seabrook, combined cracking indices (average of horizontal and vertical) of up to 2.5 mm/m have been measured. The range of cracking indices used for testing in the Bridge Girders shall overlap and extend beyond the cracking indices observed at Seabrook. The data collected from the control specimen (Control Slab) shall be used as a baseline for data comparison.

The cracking index is a quantitative method to measure the total width of cracking per unit length, along the horizontal and vertical sides of 20" squares (Reference 2). For anchor testing at Ferguson Structural Engineering Laboratory, it is permitted to modify the method by reducing the dimensions of the square since the cracking index is a relative measurement of expansion.

A3.2. Characterization of ASR Degradation

Objectives:

- Confirm the presence of ASR.
- Characterize the extent of degradation to support identification of areas for anchor testing.

Applicable ASTM Test Procedure(s): ASTM C42-11

Summary of Test Elements:

- Each specimen (Bridge Girders, Control Slab) shall be surveyed and cataloged by marking and numbering the suitable areas with appropriate-size grids that are consistent with the influence area of the anchor. The cracking index in each grid shall be recorded for the ASR-affected specimens.
- The cracking index shall be determined for the Bridge Girders following the procedures outlined above in Section A3.1.
- One cylindrical core shall be extracted in accordance with ASTM C42-11 (Reference 6) from each Bridge Girder used in testing. The extracted cores shall be provided to Purchaser for petrographic examinations.

Reporting of Test Results:

The cracking indices for the concrete specimens shall be documented to support identification of areas for anchor testing.

A4. Testing

A4.1 Pullout Testing (Test ID No. 1)

Objectives:

- Determine if there is a correlation between the pullout capacity of expansion anchors and the degree of ASR as measured during petrographic examinations or the degree of observed surface cracking.

- Determine if there is a relationship between pullout capacity and installation effort of anchors.

Applicable ASTM Procedure(s): ASTM E488-10

Summary of Test Elements:

- Post-install [redacted] expansion anchors per manufacturer's specifications, except embedment depth shall be adjusted such that the anchor fails by pullout. The nominal embedment depth should be in the range of [redacted] The expansion anchors shall be installed in each of the following types of concrete specimens:

  - Bridge Girders

  - Control Slab

  Each anchor shall be given unique identification marks or numbers.

- Approximately [redacted] expansion anchors shall be installed in the Bridge Girders and approximately [redacted] expansion anchors shall be installed in the Control Slab. The number of tests in the Bridge Girders may be reduced if concrete quality considerations limit the portion of the Girders that are suitable for testing.

- The expansion anchors in the Bridge Girders shall be installed in areas of concrete with a range of cracking indices that overlaps and extends beyond the range of cracking indices observed at Seabrook. At least [redacted] levels of cracking indices shall be tested.

- A sufficient number of expansion anchors shall be installed with a [redacted] installation effort to simulate the relaxation of concrete under load.

- The expansion anchors shall be installed such that the spacing and edge distances do not influence the failure load. In addition, the anchors shall not cut through the reinforcing steel during installation.

- Confined pullout tests shall be conducted on the post-installed expansion anchors.

The above testing shall use ASTM E488-10 (Reference 7) and ACI 355.2-07 (Reference 8) as guidance.

Reporting of Test Results:

Comparisons of the pullout capacity of the anchors in ASR-affected concrete (Bridge Girders) to the pullout capacity of the anchors in similar concrete unaffected by ASR (Control Slab) shall be developed as a function of the level of ASR degradation and installation effort.

A4.2. Breakout Testing (Test ID No. 2)

Objective:

- Determine if there is a correlation between the breakout capacity of undercut anchors and the degree of ASR as determined by petrographic examinations of ASR or the degree of observed surface cracking.

- Determine if the breakout capacity of expansion anchors in ASR degraded concrete is more limiting than the pullout capacity of expansion anchors in similar concrete.

Applicable ASTM Procedure(s): ASTM E488-10

Summary of Test Elements:

- Post-install [redacted] undercut anchors per manufacturer's specifications, except embedment depth shall be adjusted such that the anchor fails by breakout. The nominal embedment depth should be in the range of [redacted] The undercut anchors shall be installed in each of the following types of concrete specimens:

  - Bridge Girders

  - Control Slab

  Each specimen shall be given unique identification marks or numbers.

  Approximately [redacted] undercut anchors shall be installed in the Bridge Girders and approximately [redacted] undercut anchors shall be installed in the Control Slab. The number of tests in the Bridge Girders may be reduced if concrete quality considerations limit the portion of the Girders that are suitable for testing.

- Post-install [redacted] expansion anchors per manufacturer's specifications, except embedment depth shall be adjusted such that the anchor fails by breakout. The nominal embedment depth should be in the range of [redacted] The expansion anchors shall be installed in each of the following types of concrete specimens:

  - Bridge Girders

  - Control Slab

Approximately [redacted] expansion anchors shall be installed in the Bridge Girders and [redacted] expansion anchors shall be installed in the Control Slab. The number of tests in the Bridge Girders may be reduced if concrete quality considerations limit the portion of the Girders that are suitable for testing

- The anchors in the Bridge Girders shall be installed in areas of concrete with a range of cracking indices that overlap and extend beyond the range of cracking indices observed at Seabrook. At least [redacted] levels of cracking indices shall be tested.

- The anchors shall not cut through any reinforcing steel during the installation process.

- Unconfined breakout tests shall be conducted on the post-installed undercut and expansion anchors.

The above testing shall use ASTM E488-10 (Reference 7) and ACI 355.2-07 (Reference 8) as guidance.

Reporting of Test Results:

- Comparisons of the breakout capacity of the undercut anchors in ASR-affected concrete (Bridge Girders) to the breakout capacity of the undercut anchors in similar concrete unaffected by ASR (Control Slab) shall be developed as a function of the level of ASR degradation.

- Comparisons of the breakout capacity of the expansion anchors in ASR-affected concrete to the pullout capacity of expansion anchors in ASR-affected concrete with similar cracking indices shall be developed.

Appendix B – Block Test Series

B1. Purpose

The purpose of the testing described herein is to assess the impact of ASR on the capacity of post-installed expansion and undercut anchors covering a range of cracking indices. ASR may have reduced the structural capacity of the attachments (expansion anchors, undercut anchors, and embedments) in affected concrete at Seabrook. The results from these tests will be compared against post-installed anchors installed in concrete with similar mechanical properties that is unaffected by ASR to establish the affect of ASR on the structural capacity of attachments.

B2. Test Overview

The following information will be developed by the testing to assess the impact of ASR on the capacity of the attachments:

1. Anchors Installed in Concrete Subsequently Affected by ASR – determine the extent to which the capacity of anchors installed in concrete prior to ASR has been affected as a function of the level of ASR degradation. Testing will be performed in concrete with similar mechanical properties that is unaffected by ASR, to develop a baseline for data comparison.

2. Anchors Installed in Concrete with Existing ASR – determine the extent to which the capacity of anchors installed in concrete with existing ASR has been affected as a function of the level of ASR degradation. Testing will be performed in concrete with similar mechanical properties that is unaffected by ASR, to develop a baseline for data comparison.

B3. Test Specimens

B3.1. Description

The concrete specimens used for testing will have similar concrete mechanical properties and reinforcement layout as the walls at Seabrook Station made with highly reactive aggregate and high alkali cement. The concrete specimens will be in the following forms:

- Concrete Blocks

- Concrete Beams

Control tests and testing at degraded levels of ASR will be performed on the specimens. Control testing will be performed in concrete after the test specimen has gained sufficient strength, but before ASR has progressed to deleterious levels.

From walkdown inspections at Seabrook, combined cracking indices (average of horizontal and vertical) of up to 2.5 mm/m have been measured. The range of cracking indices used for testing in the Concrete Beams/Blocks shall overlap and extend beyond the cracking indices observed at Seabrook. The data collected from the control tests shall be used as a baseline for data comparison.

The cracking index is a quantitative method to measure the total width of cracking per unit length, along the horizontal and vertical sides of 20" squares (Reference 2). For anchor testing at Ferguson Structural Engineering Laboratory, it is permitted to modify the method by reducing the dimensions of the square since the cracking index is a relative measurement of expansion.

B3.2. Preparation of Test Samples

Applicable ASTM Procedure(s): ASTM C39-11a, C42-11 and C192-07

Requirements:

- [redacted] Concrete Blocks and [redacted] Concrete Beams shall be prepared and cast in accordance with ASTM C192-07 (Reference 9).
- The Concrete Blocks shall be approximately [redacted] thick, [redacted] high, and [redacted] long.
- The Concrete Beams shall be approximately [redacted] thick, [redacted] high, and [redacted] long.
- The concrete mix design shall provide a concrete compressive strength of approximately [redacted] which is within the range of normal strength concrete used at Seabrook Station. [redacted]
- The reinforcement of concrete blocks shall be similar to the walls at Seabrook Station. Bi-directional reinforcement shall be used on both sides of the blocks with a [redacted] concrete clear cover (Reference 3). The reinforcement shall be [redacted] bars at [redacted] spacing (Reference 4 & 5). [redacted]
- Accelerated ASR degradation shall be driven in the Concrete Blocks/Beams per procedures developed by Vendor to obtain a range of cracking indices for testing that overlaps and extends beyond the range of cracking indices observed at Seabrook. At least [redacted] levels of cracking indices shall be tested.
- Cylinders shall be cast at the time the concrete specimens (Concrete Blocks and Beams) are cast in accordance with ASTM C192-07 (Reference 9). Compressive strength testing shall be performed in accordance with ASTM C39-11a (Reference 10) to establish the 28-day compressive strength of each test specimen.

- Cores shall be taken each time a concrete specimen is used for anchor testing. Cores shall be taken in accordance with ASTM C42-11 (Reference 6). Compressive strength testing shall be performed in accordance with ASTM C39-11a (Reference 10) to establish the compressive strength of each specimen at the time of testing.

- A core taken from the concrete specimens shall be provided to Purchaser at each stage of anchor testing (control stage and at each level of ASR-degradation) for petrographic examinations [redacted] (See Section B3.3).

Source of Test Samples:

Test samples shall be provided by the Vendor.

Reporting of Test Results:

The compressive strength of the concrete cylinders and cores shall be documented.

B3.3. Characterization of ASR Degradation

Objectives:

- Confirm the presence of ASR.

- Characterize the extent of degradation to determine when testing shall be conducted.

Applicable ASTM Test Procedure(s): ASTM C42-11

Summary of Test Elements:

- Each specimen (Concrete Blocks, Concrete Beams) shall be surveyed and cataloged by marking and numbering the suitable areas with appropriate-size grids. The layout of anchor locations shall be consistent with the influence area of the anchor.

- The cracking index in each grid shall be determined for the Concrete Blocks/Beams following the procedures outlined above in Section B3.1. The crack indices of record shall be taken no more than [redacted] prior to the start of testing at a given ASR level. This period of time is sufficient based on observed crack growth rates.

- Up to [redacted] concrete specimens (cores) shall be provided to Purchaser for petrographic examinations. The [redacted] petrographic specimens will be representative of the condition of the test blocks/beams at the time a series of anchor tests is performed: control plus [redacted] levels of ASR degradation. Cores shall be taken in accordance with ASTM C42-11 (Reference 6).

Reporting of Test Results:

The cracking indices for the concrete specimens shall be documented to determine when testing should be conducted in the Concrete Blocks/Beams.

B4. Testing

Objectives:

- Determine the reduction in the capacity of anchors at different levels of ASR degradation as determined based on the degree of observed surface cracking.

- Determine if the installation of the anchors in concrete prior to, or after ASR degradation affects the capacity of the anchors.

Applicable ASTM Procedure(s): ASTM E488-10

Summary of Test Elements:

- One test set includes [redacted] anchors of each combination listed in [redacted] by anchor type, diameter, and embedment depth. Post-install these anchors per manufacturer's specifications, in the Concrete Blocks and Concrete Beams.

[redacted]

  Each anchor shall be given unique identification marks or numbers.

- With the mutual agreement of both Vendor and Purchaser, the scope of testing may be adjusted based on insight gained from testing.

- The anchors shall be installed such that the anchor spacing and edge distances do not influence the failure load. In addition, the anchors shall not cut through the reinforcing steel during installation.

- Each level of ASR degradation at which testing is performed shall be approved by Purchaser prior to testing.

- Control Tests – Unconfined tension tests shall be conducted with one (1) test set after the test specimen has gained sufficient strength, but before ASR has progressed to deleterious levels.

- Tests with Anchors Installed Pre-ASR – Unconfined tension tests shall be conducted with [redacted] test sets, one at each level of ASR degradation. The anchors in all [redacted] test sets shall be installed after the test specimen has gained sufficient strength, but before ASR has progressed to deleterious levels.

- Tests with Anchors Installed Post-ASR – Unconfined tension tests shall be conducted with [redacted] test sets, one at each level of ASR degradation. The anchors in each test set shall be installed in the test specimen once it has reached the desired level of ASR degradation.

The above testing shall use ASTM E488-10 (Reference 7) and ACI 355.2-07 (Reference 8) as guidance.

Reporting of Test Results:

Comparisons of the capacity of the anchors in ASR-affected concrete to the capacity of the anchors in similar concrete unaffected by ASR shall be developed as a function of the level of ASR degradation and whether the anchors were installed before or after ASR degradation developed.

Enclosure 2 to SBK-L-13027

Testing of Anchors in ASR-Affected Concrete – A Test Plan Overview

MPR
ASSOCIATES INC.
ENGINEERS

Testing of Anchors in ASR-Affected Concrete – A Test Program Overview

0326-0058-156
Revision 0

February 26, 2013

Prepared by: [signature]
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MPR ASSOCIATES INC. ENGINEERS

Testing of Anchors in ASR-Affected Concrete – A Test Program Overview

1. Objective

The objective of the Anchor Test Program is to provide a quantitative assessment of the impact of alkali-silica reaction (ASR) on anchor performance using an approach that is consistent with the current design basis for anchors at Seabrook Station. The program must provide sufficient technical rigor and documentation to support using the results as a design input to Seabrook Station design calculations. Specific goals of the testing are:

- Support a long-term assessment of the impact of ASR on anchor capacity relative to the design basis.
- Systematically quantify the relative impact of ASR on anchor capacity by comparison of anchor tests at various levels of ASR degradation to control tests (i.e., tests performed prior to the development of ASR degradation).

We currently envision applying the results to the anchors at Seabrook Station in the form of a reduction factor to the current design capacities. The factor would be determined from the testing and applied to the design capacity of the anchor. This approach maintains the safety factor of four on the tested capacity as required by the Seabrook Station response to NRC IE Bulletin 79-02 (Reference 1).

2. Background

MPR has been supporting Seabrook Station in assessing the structural impact of ASR on safety-related, reinforced concrete structures at the plant, including the capacity of anchors embedded in ASR-affected concrete. Due to the lack of available data on the impact of ASR on embedded anchors (e.g., expansion and undercut anchors), MPR initiated a test program at the Ferguson Structural Engineering Laboratory (FSEL) at the University of Texas at Austin in late 2011. The Anchor Test Program consists of two series as outlined below.

- Girder Series—The initial test series was aimed at determining if ASR significantly affects the performance of anchors embedded in concrete. This test series used ASR-affected girders that were available at FSEL. These tests covered a single embedment depth and used both expansion anchors and undercut anchors. The girders were useful for studying the effects of ASR on anchors, but were not representative of the concrete components at Seabrook Station. The Girder Series, which is documented in MPR-3722, Revision 0 (Reference 2), provided sufficient insights to support our interim assessment of ASR on structures at Seabrook Station (MPR-3727, Revision 1; Reference 3).

- Block Series—The second test series is a systematic quantification of the effect of ASR on expansion anchors using specimens representative of Seabrook Station, performed in a manner consistent with the design basis testing program. This test series uses specimens (concrete blocks or beams) manufactured by FSEL to closely represent the concrete components at Seabrook Station. These tests will systematically determine the effect of ASR on anchor capacity covering: (1) a variety of embedment depths with both expansion anchors and undercut anchors; (2) multiple levels of ASR degradation; and (3) anchors set both prior to and after the development of ASR. The Block Series is currently underway.

The remainder of this document will focus on the Block Series, which is intended to support a long-term assessment of the impact of ASR on anchor capacity relative to the design basis. The Girder Series was performed only to understand the potential effects of ASR on anchors and support operability.

3. Summary

The Block Series of the Anchor Testing Program is designed to quantify the impact of ASR on anchor capacity as a function of the severity of ASR degradation, systematically varying the size and embedment depth of the anchors. The overall approach of the test program and the testing method are consistent with the original anchor qualification testing that established the anchor design capacities for Seabrook Station, with one notable exception. The exception is that the concrete test specimens will be more representative of the concrete structures at Seabrook Station than the generic specimens used in the qualification testing. Further, the current vision for applying the results maintains the current safety factors per NRC IE Bulletin 79-02.

All Block Series specimens have been manufactured and are undergoing accelerated aging. Based on current degradation rates, anchor tests at the first ASR degradation level are targeted for later this year.

4. Discussion

4.1. Seabrook Design Basis

The design basis for the capacity of concrete anchor bolts at Seabrook Station is based on NRC IE Bulletin 79-02, Revision 2 (Reference 1).[1] This document requires the capacity of concrete expansion anchors to be based on test results (mean failure loads) and incorporate a safety factor of 4 for wedge type anchors. The Seabrook Station UFSAR states (Reference 4, Section 3.9(B), Page 40):

> *Component supports are connected to concrete walls and slabs by either welding to embedded plates, or by bolting to the concrete with either concrete expansion anchors (wedge type) or concrete inserts. The response to the NRC's IE Bulletin No. 79-02, [Reference 2], was used as a guide for the design of the concrete expansion anchors. The maximum allowable design loads for the concrete expansion anchors for ASME Class 1, 2, and 3 supports were developed using the*

[1] The design basis for concrete Seismic Category I structures other than Containment, ACI 318-71, does not address the capacity of concrete anchor bolts.

manufacturer's ultimate loads and a safety factor of 4 for worst case loading (normal and upset or faulted loads).

The test results supporting the Seabrook Station expansion anchor design basis were furnished by the expansion anchor vendor, Hilti (Reference 5). The qualification testing was not specific to Seabrook Station. Instead, the qualification testing was intended to support use of Hilti expansion anchors throughout the industry. The testing was performed in generic concrete slabs using limestone aggregate (3/4-inch) with specified compressive strengths of 2,000, 4,000 and 6,000 psi. Slab thicknesses varied based on the anchor diameter tested. Tensile (i.e., pullout) testing was performed using a three-legged reaction frame (i.e., a tripod). The frame distributed the anchor reaction to outside of area of influence for an anchor: 24-inch diameter circle for anchor diameters of 3/4-inch or less, and a 30-inch diameter circle for anchor diameters of 1-inch and larger. The design capacity for a given expansion anchor is the mean failure load reduced by a safety factor of four. For concrete specified compressive strengths other than those tested, design capacities were determined by linear interpolation.

The generic qualification testing is supplemented by site-specific testing on Hilti Kwik Bolt expansion anchors performed at Seabrook Station by Hilti (References 6 and 7). This testing focused on the minimum torque applied to the nut of the expansion anchor to ensure adequate performance; it was not intended to define anchor capacity. The testing program was performed in the Unit 2 Primary Auxiliary Building (Hilti Kwik Bolt 1) and Tank Farm (Hilti Kwik Bolt Super), Seismic Category I (safety-related) reinforced concrete structures with a specified compressive strength of 3,000 psi.

4.2. Overview of Block Series

The Block Series is a systematic quantification of the effect of ASR on expansion anchors. The tests will be conducted consistent with the original qualification, but with specimens that are representative of Seabrook Station and have varying levels of ASR degradation. The relative impact of ASR on anchor capacity will be determined by comparison of anchor capacity at different levels of ASR degradation to control tests conducted prior to development of ASR.

The Block Series includes tests of expansion anchors that have been installed both before significant ASR has developed and after the desired extent of ASR degradation has occurred (see Section 4.2.2). By testing anchors that were installed before and after the development of ASR, the Block Series inherently accounts for any loss of torque/pretension due to ASR.[2]

4.2.1. Specimen Design

The concrete blocks and beams have been manufactured to closely represent the reinforced concrete components at Seabrook Station. The representativeness to concrete to Seabrook Station exceeds that of the specimens used in the original qualification testing.

[2] The Girder Series assessed the impact of reduced anchor torque on anchor capacity at multiple levels of ASR degradation. Comparison of anchor capacities at full-torque and reduced torque (50%) showed that reduced anchor torque had no measurable effect on ultimate capacity (Reference 3, Figure 7-1). This suggests that there should not be a difference in anchor capacity for anchors installed prior to ASR and those installed after ASR.

- The concrete mix used for these specimens was consistent with that used at Seabrook Station for the attributes that are important for anchor performance: 28-day compressive strength (between [redacted] and coarse aggregate nominal size [redacted].

- The two-dimensional reinforcement mats used reflect typical plant details such as rebar strength [redacted] size [redacted] spacing [redacted] and interior clear cover [redacted] Providing reinforcement mats and clear cover consistent with the plant is important with regard to applying similar confinement of the ASR expansion and correlating cracking in the cover of the specimens to that at Seabrook Station.

4.2.2. *Scope of Block Series*

The Block Series consists of three types of tests as described below.

- Control Tests—The control tests provide a baseline by which to judge potential reductions in anchor capacity due to ASR. These tests will be performed after the test specimens have gained sufficient strength but before ASR has progressed to deleterious levels as determined from the Combined Cracking Index (CCI).

- Post-Installed Tests—These tests will quantify the impact of ASR on the capacity of post-installed anchors for at least [redacted] levels of ASR degradation. The anchors will be installed in the concrete test specimen at the time of testing. These results reflect the scenario where anchors are installed after ASR cracking has occurred.

- Pre-Installed Tests—These tests will be similar to the post-installed tests, except the anchors will be installed prior to development of deleterious levels of ASR, but not tested until the ASR degradation has progressed to the level of ASR degradation as determined using the CCI. These results are applicable to anchors that were installed during original construction or early in plant life. Results from the pre-installed tests will be compared to results from the post-installed tests to assess whether the impact of ASR on anchor capacity is different if ASR developed after the anchor was installed.

A total of [redacted] test sets will be performed: one set for the control tests and one set for each of pre- and post-installed tests at [redacted] levels of ASR degradation. Each test set consists of [redacted] replicates [redacted] of [redacted] anchor bolt types/embedment depths. [redacted] lists the [redacted] anchor bolts selected [redacted] expansion anchors [redacted] and [redacted] undercut anchors [redacted].

[redacted]

The ASR degradation in the test specimens will be correlated to degradation levels at Seabrook Station using the CCI, an approximate measure of expansion based on visible cracking in a unit area. The CCI will be measured in a unit area centered about each tested anchor prior to testing. Additional information regarding the test specimens will be generated. The compressive strength of each test specimen will be determined at the time of testing from drilled cores. Petrography will be performed on a drilled core representative of each level of ASR degradation. The petrographic examinations will assess ASR degradation using the damage rating index (DRI) and the visual assessment rating (VAR) to facilitate comparison to petrographic examination of cores from Seabrook Station.

4.3. Evaluation of Test Results

Application of Test Results to Anchors at Seabrook Station

The current vision for applying the results from the Block Series is a capacity reduction factor that maintains the IE Bulletin 79-02 safety factors. The reduction factor would be determined relative to the control tests for each anchor type/embedment depth and vary with CCI. Figure 1 shows an example (mock-up) of potential test results for one anchor type/embedment depth assuming five tests at each of three levels of ASR degradation (plus the control). A trend line through the data illustrates a reduction factor curve based on a best fit of the data. The reduction factor begins at 1.0 with the control tests and decreases as CCI increases. Based on the results from the Girder Series, significant reduction factors (significantly less than 1.0) are not expected until CCI becomes quite large (about 6 mm/m).

Equation 1 shows example equations that could be used to determine and implement the reduction factor. Since the reduction factor for ASR is applied to the design capacity of the anchor, the safety factor of four inherent in the design capacity is maintained.

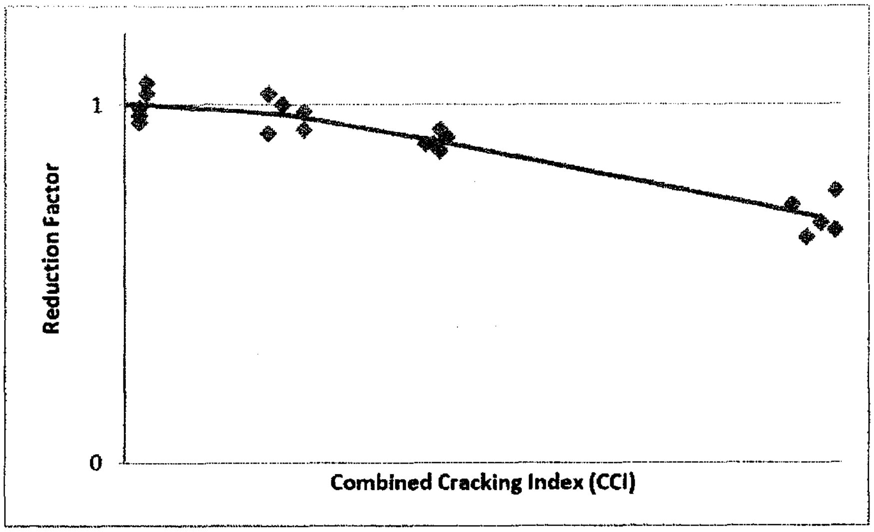

Figure 1. Example of Potential Test Results and Reduction Factor

$$AL_{Anchor1;\, CCI=X} = DB\ AL_{Anchor1} * RF_{Anchor1;\, CCI=X} \qquad \text{Equation 1}$$

Where: AL = Allowable Load accounting for ASR at a CCI of X
DB = Design Basis
RF = Reduction Factor

The undercut anchor tests will provide insights into the behavior of cast-in-place embedments in ASR-affected concrete. Cast-in-place embedments are designed such that ductile failure of the steel shank limits the capacity. This design practice results in a concrete breakout capacity that is usually significantly greater than that of the steel shank. Before ASR degradation would affect the rated capacity of the embedment, the concrete breakout capacity would need to be reduced below that of the steel shank. Thus, the reduction in rated capacity would only be proportional to the loss in concrete breakout capacity, below the point at which the embedment capacity began to be limited by concrete breakout. Results from the undercut anchor tests will be used to estimate the degree of ASR degradation where the concrete breakout capacity begins to limit the rated capacity of embedments over the steel shank.

Comparison to Concrete Capacity Method

The concrete capacity (CC) method is the modern standard for the design of concrete attachments (expansion anchors, cast-in-place embedments, etc.). This method is used by the latest editions of ACI 318 and ACI 349 to calculate the capacity of attachments for concrete failure modes (breakout, pryout, etc.). The development of the CC method was partially empirical—theoretical equations fine-tuned with historical test data. NUREG/CR-5563 (Reference 8) describes the CC method and other concrete attachment design methods in greater detail. The CC method includes different factors for uncracked concrete and cracked concrete.

Results from the Block Series results will be compared to the CC Method to assess whether behavior of anchors in ASR-affected concrete is similar to that in concrete cracked by other mechanisms such as external loads (flexure, shear, etc.) or restrained shrinkage.

4.4. Current Status of Block Series

The manufacture of all Block Series specimens is complete. All specimens are undergoing accelerated aging in the new environmental curing facility. The control tests were performed in late 2012. Based on current expansion rates pre- and post-installed tests for the first ASR degradation level are expected later this year.

5. References

1. Public Service Company of New Hampshire letter, dated Jan. 4, 1980, to NRC Region I, Office of Inspection and Enforcement (response to NRC IE Bulletin 79-02, "Pipe Support Base Plate Designs Using Concrete Expansion Anchor Bolts," Revision 2, November 8, 1979).

2. MPR-3722, "Strength Testing of Anchors in Concrete Affected by Alkali-Silica Reaction," Revision 0 (Seabrook FP No. 100718).

3. MPR-3727, "Seabrook Station: Impact of Alkali-Silica Reaction on Concrete Structures and Attachments," Revision 1 (Seabrook FP No. 100716).

4. Seabrook Station Updated Final Safety Analysis Report, Revision 14.

5. Seabrook Foreign Print 44412, "Hilti Anchor and Fastener Design Manual," Revision 0.

6. Seabrook Foreign Print 44132, "Torque vs. Pretension Test for Hilti Kwik-Bolt Concrete Expansion Anchors performed at Seabrook Station in Seabrook, New Hampshire on February 12, 13, 16, 1979; March 15, 1979; and March 10, 11, 12, 13, 1981," Revision 0.

7. Seabrook Foreign Print 47369, "Torque vs. Pretension and Pullout Test of Hilti Super Kwik-Bolt Concrete Expansion Anchors performed at Seabrook Station in Seabrook, New Hampshire on June 17, 18, and 19, 1981," Revision 0.

8. NUREG/CR-5563, "A Technical Basis for Revision to Anchorage Criteria," March 1999.