Enclosure 3 to SBK-L-15107

MPR-4153

Seabrook Station

Approach for Estimating Through-Thickness Expansion from Alkali-Silica Reaction

MPR Associates, Inc., Alexandria, VA, 2015

(Non-Proprietary)

MPR

MPR-4153
Revision 1
(Seabrook FP # 100918)
June 2015

Seabrook Station - Approach for Determining Through-Thickness Expansion from Alkali-Silica Reaction

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 for

NextEra Energy Seabrook, LLC
P.O. Box 300, Lafayette Rd., Seabrook, NH 03874

MPR

Seabrook Station - Approach for Determining Through-Thickness Expansion from Alkali-Silica Reaction

MPR-4153
Revision 1
(Seabrook FP # 100918)

June 2015

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: C W Bagley
C. W. Bagley

Reviewed by: John W. Simons
John W. Simons

Approved by: [signature]
James E. Moroney

Additional Contributors

K. Mulvaney
D. Bergquist
A. Card
M. Saitta
R. Vayda

Prepared for

NextEra Energy Seabrook, LLC
P.O. Box 300, Lafayette Rd., Seabrook, NH 03874

RECORD OF REVISIONS

Revision	Affected Pages	Description
0	All	Initial Issue
1	Body of Report, Appendix A	Included corrected data for expansion of FSEL test specimens in the through-thickness direction. Also made minor editorial changes throughout the body of the report.

Executive Summary

This report recommends a methodology for determining the extent of through-thickness expansion of reinforced concrete structural members at Seabrook Station. Quantifying through-thickness expansion will enable NextEra Energy to apply the results of the ongoing structural testing programs to Seabrook Station based on the condition of existing plant structures.

Data from the structural testing programs have shown that expansion in the in-plane direction plateaus at low expansion levels, while expansion in the through-thickness direction continues to increase. Accordingly, the test programs will provide results correlating structural performance to expansion in the through-thickness direction.

NextEra plans to install instruments in concrete structures at Seabrook Station to measure expansion in the through-thickness direction (i.e., extensometers). This approach will enable measuring expansion for a given concrete structural member from the time the extensometer is installed. To calculate total expansion, NextEra will need to determine expansion from original construction until the time the extensometer is installed.

MPR recommends the following approach for determining total ASR-induced through-thickness expansion at each instrumented location at Seabrook Station. The recommended method determines the pre-instrument expansion based on the reduction in modulus of elasticity.

1. Determine the current elastic modulus of the concrete by material property testing of cores removed from the structure. Elastic modulus testing requires companion compressive strength testing, so MPR recommends obtaining a minimum of four test specimens at each proposed monitoring location. Two test specimens are for compressive strength testing and two test specimens are for subsequent elastic modulus testing.

2. Establish the original elastic modulus of the concrete by either (1) using the ACI 318-71 correlation to calculate elastic modulus from 28-day compressive strength records or (2) obtaining cores from representative ASR-free locations and testing for elastic modulus.

3. Calculate the reduction in elastic modulus by taking the ratio of the test result from the ASR-affected area to the original elastic modulus.

4. Determine through-thickness expansion from original construction to the time the extensometer is installed using the correlation developed in this report. The correlation relates reduction in elastic modulus with measured expansion from beam specimens used during the large-scale ASR structural testing programs.

5. Calculate total expansion levels by adding the extensometer measurements to the expansion at the time of instrument installation.

Contents

Figures

1

Introduction

1.1 PURPOSE

This report recommends a methodology for determining the extent of through-thickness expansion of reinforced concrete structural members that are affected by alkali-silica reaction (ASR) at Seabrook Station. Quantifying through-thickness expansion of existing plant structures is necessary to relate the extent of ASR in a given structure to the results of the structural testing programs at Ferguson Structural Engineering Laboratory (FSEL).

1.2 BACKGROUND

1.2.1 Overview of Alkali-Silica Reaction

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

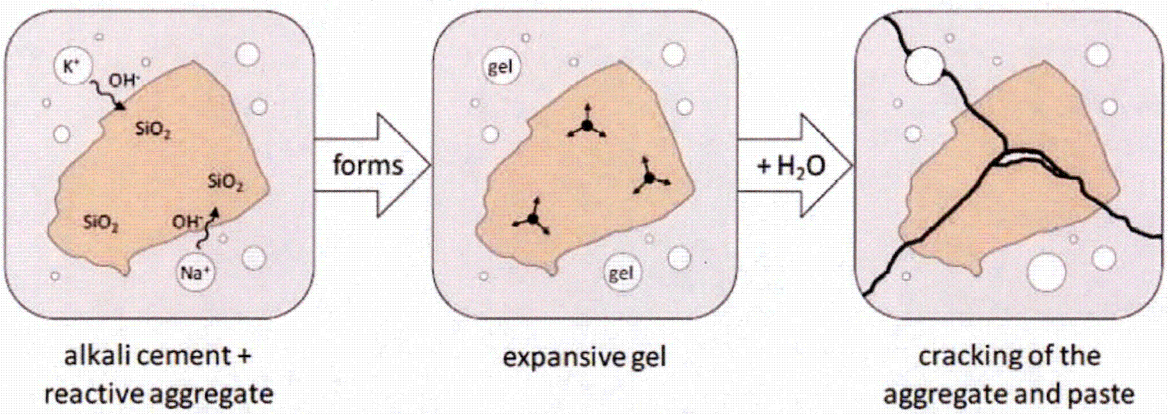

Figure 1-1. ASR Expansion Mechanism

Several publications indicate that the cracking may degrade the material properties of the concrete (References 1, 2, and 3). The concrete properties most rapidly and severely affected are the elastic modulus and tensile strength. Compressive strength is also affected, but less rapidly and less severely.

While development of ASR causes a reduction in material properties, there is not necessarily a corresponding decrease in structural performance. As discussed in previous MPR reports on ASR at Seabrook Station and the approach for the FSEL test program (References 4 and 5), cores removed from a reinforced ASR-affected structure are no longer confined by the reinforcement and do not represent the structural context of the in-situ condition. Therefore, material properties obtained from cores have limited applicability for evaluating the capacity of a structure.

1.2.2 ASR at Seabrook Station

NextEra Energy has identified ASR in multiple safety-related, reinforced concrete structures at Seabrook Station (Reference 6). To evaluate this condition, MPR performed a structural assessment (Reference 4) of selected ASR-affected structures. Based on the low level of observed cracking and the apparent slow rate of change, MPR concluded that these structures are suitable for continued service for at least an interim period (i.e., at least several years).

A follow-up evaluation will assess the long-term adequacy of the concrete structures at Seabrook Station. This evaluation will incorporate the results of large-scale test programs currently being performed at FSEL using test specimens that were specifically designed and fabricated to represent reinforced concrete at Seabrook Station.

1.2.3 Test Programs at FSEL

MPR is sponsoring four test programs at FSEL to support NextEra's efforts to resolve the ASR issue at Seabrook Station. Three of the test programs focus on the structural performance data necessary to complete the final structural assessment of ASR-affected structures. The fourth test program evaluates instruments for monitoring expansion of Seabrook Station. A brief overview of each program is provided below.

- Anchor Test Program—This program evaluates the impact of ASR on performance of anchors installed in the concrete. Tests will be performed at multiple levels of ASR degradation.

- Shear Test Program—This program evaluates the impact of ASR on shear performance of reinforced concrete beams. The test scope includes tests at multiple levels of ASR degradation and, if necessary, tests of retrofits for restoring the shear capacity.

- Reinforcement Anchorage Test Program—This program evaluates the impact of ASR on reinforcement anchorage using beams that have reinforcement lap splices. The test scope includes tests at multiple levels of ASR degradation and, if necessary, tests of retrofits.

- Instrumentation Test Program—This program evaluates instruments for the measurement of through-thickness expansion. Insights gained from this program will be used to select which instrument to use at Seabrook Station and refine installation procedures.

As part of the test programs, FSEL monitors development of ASR. For the shear, reinforcement anchorage, and instrumentation test programs, FSEL both measures expansion of the test specimens and determines the effect on material properties of concrete, which are related to ASR development. Using this information, this report recommends a methodology for determining the extent of ASR-induced expansion at Seabrook Station. (Similar data were not obtained as part of the Anchor Test Program, so this report does not utilize expansion data from the Anchor Test Program.) Quantifying the extent of ASR development will enable comparison of the test data to the condition of existing structures at Seabrook Station.

Testing is being conducted under FSEL's project-specific quality system manual with quality assurance oversight from MPR. MPR is commercially dedicating the testing services performed by FSEL. Commercial grade dedication of services from the test program relevant for this report is documented in References 22, 23, and 24.

2 Expansion Behavior in Test Specimens

This section discusses expansion behavior observed in the test specimens thus far in the test program and the implications for monitoring ASR development in structures at Seabrook Station. An overview of test specimen design is included to provide context for understanding the observed expansion behavior.

2.1 OVERVIEW OF TEST SPECIMENS

2.1.1 Reinforcement Pattern

The test program specimens are large, reinforced concrete beams. Most test specimens are [redacted] feet-[redacted] inches long, [redacted] inches wide, and [redacted] inches thick (References 7.1 and 7.2). The test specimens were designed to represent the configuration of reinforced concrete structural members at Seabrook Station. In particular, the test area of each specimen includes two-dimensional reinforcement mats on two opposite faces, which is the same reinforcement detailing used for most reinforced concrete buildings at Seabrook Station (e.g., walls that have reinforcement mats on the interior and exterior faces). Figure 2-1 provides a schematic of the reinforcement pattern in an example shear test specimen (Reference 7.3). The reinforcement anchorage and instrumentation test specimens have some design differences (e.g., [redacted], but all test specimens contain two-dimensional reinforcement mats consistent with the example in Figure 2-1 (References 7.4 and 7.5).

[redacted]

Figure 2-1. Example Reinforcement Pattern in Shear Test Specimen (Reference 7.3)

2.1.2 Embedded Rods

FSEL tracks the progression of ASR by measuring the distance between rods that were embedded in the concrete during specimen fabrication. Each specimen contains [redacted] rods perpendicular to the reinforcement mats and [redacted] rods parallel to the reinforcement mats. As ASR occurs, the concrete between a given set of rods expands, which increases the distance between the rods.

FSEL measures the distance between each set of expansion rods shortly after fabrication to provide an initial value. The cumulative expansion at a given point in time is the difference between the initial value and the measurement at a given time (Reference 8). Figure 2-2 and Figure 2-3 show the configuration of the embedded rods.

[redacted]

Figure 2-2. Plan View of Embedded Rods (Reference 7.6)
(Embedded Reinforcement [redacted] also Shown)

[redacted]

Figure 2-3. Elevation View of Embedded Expansion Rods (Reference 7.6)
(Embedded Reinforcement [redacted] also Shown)

The instrumentation specimen has [redacted] rods perpendicular to the reinforcement mats, but does not have rods parallel to the reinforcement mats. For this specimen, through-thickness expansion is monitored using a depth gage inserted into small bore holes that go completely through the specimen.

2.2 EXPANSION IN REINFORCED CONCRETE

2.2.1 Test Specimens

Expansion of the test specimens is significantly more pronounced in the through-thickness direction (i.e., perpendicular to the reinforcement mats) than the in-plane direction (i.e., on the faces of the specimens parallel to the reinforcement mats). Expansion in the in-plane direction plateaus at low levels, while expansion in the through-thickness direction continues to increase. This behavior can be seen in Figure 2-4, which is a plot of expansion for Specimen [redacted] based on monitoring the distance between the embedded rods[1]. Expansion behavior in this test specimen is representative of other test specimens.

[redacted]

Figure 2-4. Expansion Trends in Example Test Specimen

The difference between in-plane expansion and through-thickness expansion is due to the reinforcement detailing and the resulting difference in confinement between the in-plane and through-thickness directions. The reinforcement mats confine expansion in the in-plane direction. Through-thickness expansion, on the other hand, is not confined because there is no

[1] Figure 2-4 is for illustrative purposes only. Periodic monitoring of expansion is considered for information only, whereas the measurements at the time of testing are formal test measurements.

reinforcement in that direction. Therefore, expansion occurs preferentially in the through-thickness direction.

For specimens with higher ASR levels, a large crack on the concrete surface formed on each specimen face that is between the reinforcement mats, as shown in Figure 2-5. This crack was also between the embedded pins used to measure through-thickness expansion.[2]

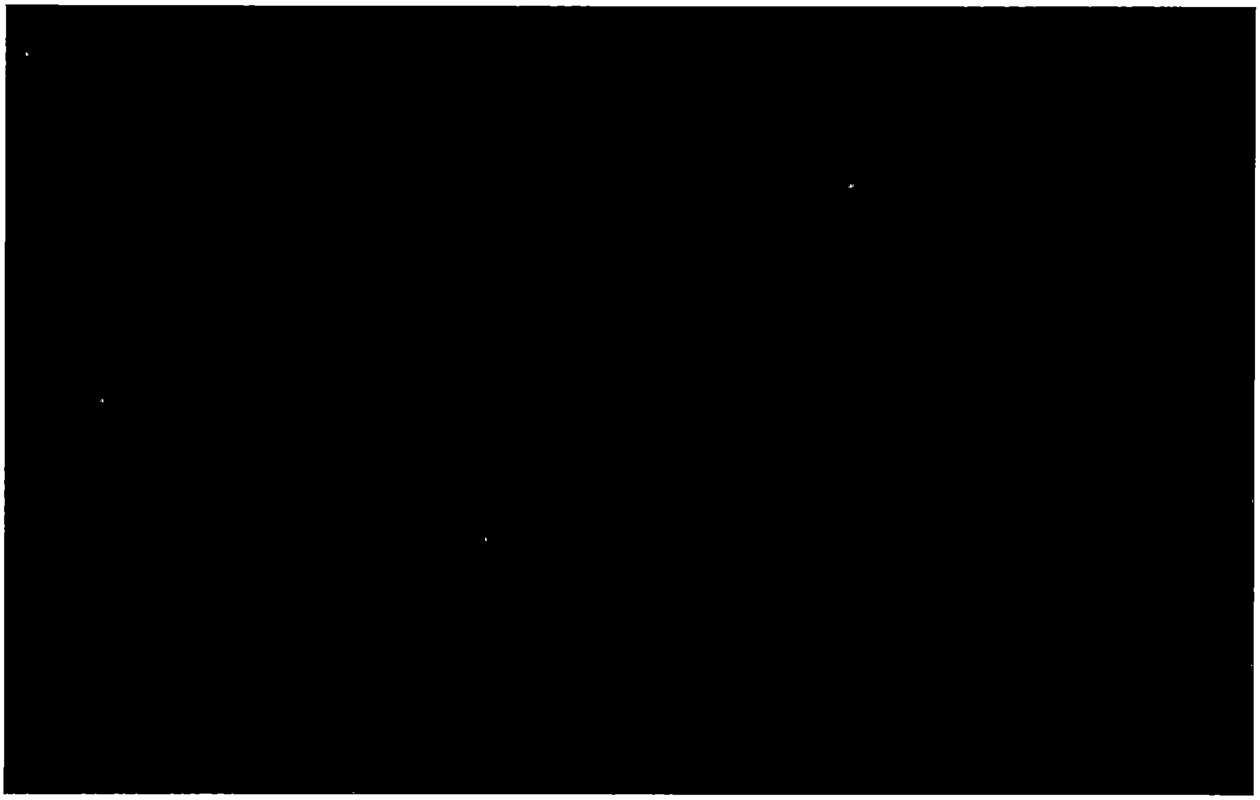

Figure 2-5. Crack in Through-Thickness Direction of Example Test Specimen

Once the large crack forms, expansion measured using the embedded rods is governed by the increase in crack width. Expansion in the regions outside of the embedded rods remains relatively unchanged. Therefore, expansion must be calculated based on the total width of the beam, rather than the distance between the embedded rods, to appropriately characterize expansion of the specimen. FSEL provided a correlation to relate expansion measurements from the embedded rods to through-thickness expansion over the total beam width. (Reference 21)

2.2.2 Literature Review

The observed preferential expansion in the through-thickness direction is consistent with literature on expansion caused by ASR (References 2, 9, and 10). Literature suggests that when reinforcement is present to restrain the tensile force exerted by ASR expansion, an equivalent compressive force develops in the concrete, which creates a prestressing effect. If tensile loads

[2] Concentration of expansion in the large crack is believed to be an edge effect of the test specimens that is not representative of Seabrook Station, where the concrete is in its full structural context. There is no evidence of this type of cracking at Seabrook Station at this time.

are applied to the structure, the compressive stresses in the concrete from prestressing must be overcome before there is a net tensile stress. Cracking in confined concrete would not occur until a net tensile stress is applied.

2.3 IMPLICATIONS FOR MONITORING ASR AT SEABROOK

Based on the expansion behavior observed in the test specimens, expansion in the through-thickness direction is the best indicator of ASR development in the test specimens and at Seabrook Station. In-plane expansion is a readily available parameter that can be used to assist with diagnosis of ASR-affected reinforced concrete. However, the test data suggest that through-thickness measurement is a more sensitive parameter for characterizing ASR-induced expansion at Seabrook Station in the long term. Accordingly, the results of the structural testing program will be correlated to expansion in the through-thickness direction.

NextEra is expanding its ASR monitoring efforts to include through-thickness expansion. Specifically, NextEra plans to install instruments (i.e., extensometers) in concrete structures at Seabrook Station to monitor expansion in the through-thickness direction. The current plan includes installing instruments in ASR-affected areas and some areas unaffected by ASR. The instruments in areas unaffected by ASR will provide a reference measurement to gauge effects, such as thermal expansion, that could influence the ASR expansion measurements.

The instruments measure through-thickness expansion that occurs after the instrument is installed. To determine the cumulative expansion since original construction, this expansion measurement must be added to the expansion up to the time the instrument is installed. The subsequent sections of this report provide a methodology for determining the pre-instrument expansion.

3 Determining Pre-Instrument Expansion from Elastic Modulus

This section describes the technical basis and methodology for using the reduction in elastic modulus to determine the total ASR-induced expansion in the through-thickness direction prior to instrument installation. The methodology depends on determining the elastic modulus at the time of instrument installation from cores and establishing the original elastic modulus to provide a point of reference. The original elastic modulus may be determined by testing reference cores from concrete without symptoms of ASR or by using original construction data with an ACI correlation that relates compressive strength to elastic modulus.

Specific topics discussed in this section include:

- Evaluation of changes in material properties to indicate ASR-induced expansion,
- Development of the correlation between expansion and elastic modulus based on test data from the large-scale ASR testing programs, and
- Determination of the original elastic modulus at Seabrook Station, which is used as the point of reference for determining reduction in elastic modulus.

The discussion in this section relies on test results obtained to date from the ongoing large-scale ASR testing programs at FSEL. After all test data are available, MPR will revisit this evaluation and provide updates, as appropriate.

3.1 Material Properties of Test Specimens

As part of the large-scale structural testing programs, FSEL has been obtaining material property data on the beam specimens at different levels of ASR expansion. The difference between the 28-day material property result and the material property result at the time of testing may be used to quantify development of ASR.[3]

3.1.1 Material Property Testing during FSEL Structural Testing Programs

During fabrication of the beam specimens, FSEL prepares cylinders (approximately 8 inches in height and 4 inches in diameter) using the same batch of concrete as the specimens (Reference 11). A subset of these cylinders are tested 28 days after fabrication to provide initial values for the material properties of the specimen, including compressive strength, elastic

[3] The FSEL test results on elastic modulus are material tests of removed cores that no longer exhibit the structural context of the beam specimen. Load test results of beam specimens show that the reduction in elastic modulus of the cores does not correlate to a corresponding reduction in stiffness of the beam from which the cores were taken.

modulus, and splitting tensile strength (Reference 12). At the time of load testing a shear or reinforcement anchorage specimen, FSEL obtains cores from the specimen and performs testing for material properties. For the instrumentation specimen, FSEL obtains cores and performs material property testing at selected expansion levels.

3.1.2 Compressive Strength and Elastic Modulus

Figure 3-1 is a plot showing the normalized values for compressive strength and elastic modulus as a function of expansion (Reference 13). A normalized material property is the ratio of the property at the time FSEL obtained the expansion measurement divided by the material property obtained from testing a cylinder 28 days after fabrication.

[redacted]

Figure 3-1. Material Properties as a Function of Expansion from Test Data (Reference 13)

Key observations from Figure 3-1 include the following:

- Normalized elastic modulus follows a trend where elastic modulus decreases sharply at expansion levels less than about [redacted]%. The trend indicates a more gradual decrease at higher expansion levels.

- Normalized compressive strength shows a general decreasing trend with increasing expansion levels; however, compared to elastic modulus, there is lower sensitivity with expansion (i.e., the slope is shallower) and there is more data scatter.

Literature data indicate that trends for normalized material properties are consistent with the material property results from the test programs (References 1 and 2). In particular, the literature concludes that reduction in elastic modulus is more sensitive to ASR development than compressive strength.

3.1.3 Splitting Tensile Strength

Figure 3-2 is a plot showing the splitting tensile strength values as a function of expansion. Normalized splitting tensile strength results (which require a 28-day value) are not currently available because the test program did not start obtaining these results until after FSEL had fabricated many of the specimens.

[redacted]

Figure 3-2. Splitting Tensile Strength as a Function of Expansion from Test Data (Reference 13)

Data from higher expansion levels have approximately the same splitting tensile strength values as data from low expansion levels. Even if normalized data were available, sensitivity with expansion would be low (i.e., shallow slope). Accordingly, MPR concludes that a correlation to expansion using normalized tensile strength is unlikely to be more sensitive than a correlation using normalized elastic modulus.

3.2 DEVELOPMENT OF CORRELATION BETWEEN MODULUS AND EXPANSION

3.2.1 Data from Test Program

Figure 3-3 includes a plot of the test data for reduction in modulus of elasticity and the corresponding expansion measurements (Reference 13; Appendix A). The plot uses a normalized modulus value that is the ratio of the elastic modulus at the time the expansion measurement was obtained (E_t) divided by the 28-day elastic modulus (E_o).

[redacted]

Figure 3-3. Elastic Modulus as a Function of Expansion from Test Data (Reference 13)

Results of calculations using the data from Figure 3-3 include the following:

- The correlation shown in Figure 3-3 has the following equation determined by [redacted] least-squares regression (Reference 13):

  [redacted] [Equation 1]

- The correlation fits well with the data and therefore supports use of a [redacted] formulation. The coefficient of determination (R^2) is [redacted] (Reference 13). MPR performed scoping evaluations of several different forms of the equation for the correlation and determined that a [redacted] formulatio[redacted] provided the best fit.

3.2.2 Data from Literature

As part of the Reference 13 calculation, MPR compared the relationship developed from the FSEL test data against data available in literature (References 14, 15, and 16). The literature data reflect small specimens that were cast and cured as unconfined concrete.

[redacted]

Figure 3-4. Comparison of Derived Relationship with Literature Data (Reference 13)

Overall, the trend from the literature data compares favorably with the correlation generated from the FSEL data. Accordingly, the comparison to literature data corroborates application of the experimentally-determined correlation at Seabrook Station.

3.2.3 Applicability of Correlation to Seabrook Station

The correlation developed from the FSEL data relating expansion to reduction in elastic modulus is applicable to reinforced concrete structures at Seabrook Station. The test data used to generate the correlation were obtained from test specimens that were designed to be as representative as practical of the concrete at Seabrook Station, including the reinforcement detailing. Additionally, comparison against literature data shows that the correlation follows a trend that is consistent with other published studies which cover a range of concrete mixtures.

3.3 ESTABLISHING ORIGINAL ELASTIC MODULUS AT SEABROOK

The correlation shown in Figure 3-3 and provided in Equation 1 uses the 28-day elastic modulus as an input for determining expansion. However, consistent with typical construction practices, material property testing of concrete used at Seabrook Station verified only the 28-day compressive strength; the elastic modulus was not measured. This section describes two approaches for establishing the 28-day elastic modulus for concrete at Seabrook Station.

3.3.1 Approach 1: Code Equation Based on Compressive Strength

ACI 318-71 (Reference 17) provides the following equation for the elastic modulus of concrete (E_c) calculated based on compressive strength (f_c') and the density of concrete in lb/ft^3 (w_c):

$$E_c = 33 \times w_c^{1.5} \times \sqrt{(f_c')} \qquad \text{[Equation 2]}$$

The equation presented in ACI 318-71 is based on fitting a curve to publicly available information on compressive strength and elastic modulus of various concrete specimens. The data used cover a range of concrete mixtures from lightweight concrete to normal weight concrete.

Confirmation of Code Equation for FSEL-Generated Data

Using data from the test program for 28-day compressive strength and elastic modulus for a concrete mix design that represented Seabrook Station, MPR confirmed that the ACI equation is applicable (Reference 18; Appendix B). ACI 318-71 states that the actual elastic modulus is expected to be within ±20% of the calculated value. As shown in Figure 3-4, [redacted] of [redacted] data points ([redacted]%) obtained from the test program met this criterion.

[redacted]

Figure 3-5. Comparison of Test Data to ACI Equation (Reference 18)

MPR concludes that the ACI 318-71 equation is applicable for concrete at Seabrook Station for the following reasons:

- The FSEL data are consistent with the equation from ACI 318-71 and the stated variance of ±20%.

- The concrete test specimens fabricated by FSEL are designed to be representative of the concrete used at Seabrook Station and therefore better represent the concrete at Seabrook than the range of mixtures used to generate the code equation.

Original Compressive Strength

Using original construction records for compressive strength tests and the ACI 318-71 correlation, NextEra could establish the 28-day elastic modulus.

NextEra has retrieved records for concrete fabrication from original construction for selected buildings. For convenience, MPR Calculation 0326-0062-CLC-02 (Reference 19; Appendix C) summarizes the currently-available 28-day compressive strength test results and the buildings associated with those results. For structural assessment of particular concrete members, application of values from Reference 19 will need to be evaluated on a case-by-case basis to determine whether the available data are sufficiently representative of the concrete being evaluated. NextEra may need to retrieve additional original construction records to implement this approach.

In addition, NextEra has statistical analysis of over 5,000 compressive strength specimens representing 12 mix classes used during original construction (Reference 20). These data could be applied if NextEra can identify the mix class used for a particular concrete surface.

3.3.2 Approach 2: Reference Cores

An alternative approach for determining the original elastic modulus is to obtain and test reference cores for elastic modulus from concrete at Seabrook Station that is not affected by ASR. The elastic modulus determined using the reference cores would then be applied as equivalent to the 28-day elastic modulus.

NextEra plans to install through-thickness expansion monitoring instrumentation in "control" locations where ASR has not affected the concrete. NextEra would test the cores obtained during installation to obtain elastic modulus results.

To implement this approach, NextEra would need to justify that the reference cores were representative of original construction concrete for the location in question. Petrographic examination of the cores (potentially after elastic modulus testing) would conclusively determine that the reference core is not affected by ASR. The original construction data discussed in Appendix C indicate that there are differences in material properties among the buildings at Seabrook Station. NextEra should evaluate selection of a representative reference core on a case-by-case basis.

3.3.3 Selection of an Approach for Determining Original Elastic Modulus

Approach 1 and Approach 2 are both valid approaches. The approach should be selected based on specific considerations of the area being evaluated. If both approaches are feasible, both approaches may be used to validate the results using two independent means.

4 Recommended Approach

4.1 Overview of Approach

MPR recommends the following approach for determining ASR-induced through-thickness expansion for instrumented locations at Seabrook Station.

1. Determine the current elastic modulus of the concrete by testing of cores removed from the structure. Elastic modulus testing requires companion compressive strength testing, so MPR recommends obtaining a minimum of four specimens. Two test specimens are for compressive strength testing and two test specimens are for subsequent elastic modulus testing.

2. Establish the original elastic modulus of the concrete by one of the following methods:

   – Using the ACI 318-71 correlation to calculate elastic modulus from 28-day compressive strength test results.

   – Obtaining cores from ASR-free locations and testing for elastic modulus.

3. Calculate the reduction in elastic modulus by finding the ratio of the test result from the ASR-affected area to the original elastic modulus.

4. Determine through-thickness expansion from original construction to the time the extensometer is installed using the correlation developed in this report. The correlation relates reduction in elastic modulus with measured expansion from beam specimens used during the large-scale ASR structural testing program.

5. Calculate the total expansion by adding the extensometer measurement to the expansion at the time of instrument installation.

4.2 Uncertainty

The recommended methodology relies on the correlation between through-thickness expansion and normalized elastic modulus. For normalized elastic modulus greater than [redacted], the correlation indicates a relatively narrow range of expansion values from [redacted]% to [redacted]%. For normalized elastic modulus values less than [redacted], the expansion values increase sharply. Uncertainty with the methodology is more impactful for normalized elastic modulus values less than [redacted].

NextEra previously tested cores from ASR-affected areas for elastic modulus as part of the original diagnosis of ASR at Seabrook Station. Using these test results and Approach 1 for establishing the original elastic modulus, MPR performed a scoping calculation that concluded that the minimum normalized elastic modulus currently at Seabrook Station is higher than [redacted]. Uncertainty associated with determining the normalized elastic modulus may result in a potential value for elastic modulus that is less than [redacted] and therefore in the range of high sensitivity for determining expansion.

MPR will conduct a more specific treatment of uncertainty and the associated consequences for determining structural performance when all test data are available.

5 References

1. Institution of Structural Engineers, *Structural Effects of Alkali-Silica Reaction: Technical Guidance on the Appraisal of Existing Structures*, London, UK, 1992.

2. Bayrak, O., "Structural Implications of ASR: State of the Art," July 2014. (Seabrook FP # 100697)

3. Fournier, B. et al, FHWA-HIF-09-004, *Report on the Diagnosis, Prognosis, and Mitigation of Alkali-Silica Reaction in Transportation Structures*, January 2010.

4. MPR-3727, *Seabrook Station: Impact of Alkali-Silica Reaction on Concrete Structures and Attachments*, Rev. 1, May 2012. (Seabrook FP # 100716.)

5. MPR-3848, *Seabrook Station - Approach for Shear and Reinforcement Anchorage Testing of Concrete Affected by Alkali-Silica Reaction*, Rev. 0, April 2013. (Seabrook FP # 100818)

6. United States Nuclear Regulatory Commission, NRC Information Notice 2011-20, "Concrete Degradation by Alkali-Silica Reaction," November 18, 2011. (ADAMS Accession No. ML112241029)

7. Test Program Drawings

   7.1. FSEL Drawing DWG_0326-0063_[redacted]S-G, [redacted]*-Inch Shear Specimen Geometry*, Revision 1.

   7.2. FSEL Drawing DWG_0326-0063_[redacted]A-G, [redacted]*-Inch Anchorage Specimen Geometry*, Revision 3.

   7.3. FSEL Drawing DWG_0326-0063_[redacted]S-R1, [redacted]*-Inch Shear Specimen Reinforcement*, Revision 1.

   7.4. FSEL Drawing DWG_0326-0063_[redacted]A-R1, [redacted]*-Inch Anchorage Specimen Reinforcement*, Revision 3.

   7.5. FSEL Drawing DWG_0326-0063_[redacted]I-R2, [redacted]*-Inch Instrumentation Specimen Reinforcement - Assembly*, Revision 0.

   7.6 FSEL Drawing DWG_0326-0063_[redacted]S-I, [redacted]*-Inch Shear Specimen Instrumentation*, Revision 1.

8. FSEL Procedure 4-3, *Periodic Monitoring of Concrete Expansions*, Revision 6.

9. Deschenes, D., Bayrak, O., and Folliard, K., *ASR/DEF-Damaged Bent Caps: Shear Tests and Field Implications*, Technical Report IAC-12-8XXIA006, Center for Transportation Research, Bureau of Engineering Research, University of Texas at Austin, August 2009.

10. Miyagawa, T. et al, *Fracture of Reinforcing Steels in Concrete Structures Damaged by Alkali-Silica Reaction - Field Survey, Mechanism, and Maintenance*, Journal of Advanced Concrete Technology, Vol. 4 No. 3, October 2006.

11. FSEL Procedure 1-5, *Placement and Curing of Materials Testing Samples*, Revision 3.

12. MPR Test Specification 0326-0062-05, Revision 9, "Specification for Shear and Reinforcement Anchorage Testing of ASR-Affected Reinforced Concrete." (Seabrook FP # 100759)

13. MPR Calculation 0326-0062-CLC-03, *Correlation Between Through-Thickness Expansion and Elastic Modulus in Concrete Test Specimens Affected by Alkali-Silica Reaction (ASR)*, Revision 1.

14. Clark, L., Critical Review of the Structural Implications of the Alkali Silica Reaction in Concrete, Transport and Road Research Laboratory Contractor Report 169, July 1989.

15. Smaoui, N. et al, Mechanical Properties of ASR-Affected Concrete Containing Fine or Coarse Reactive Aggregates, Journal of ASTM International, Vol. 3, No. 3, March 2006.

16. Ahmed, T. et al, *The Effect of Alkali Reactivity on the Mechanical Properties of Concrete*, Construction and Building Materials, 17 (2003) 123-144, January 9, 2002.

17. ACI 318-71, *Building Code Requirements for Reinforced Concrete*, 1971 Edition, Fourth Printing.

18. MPR Calculation 0326-0062-CLC-01, *Evaluation of ACI Equation for Elastic Modulus*, Revision 0.

19. MPR Calculation 0326-0062-CLC-02, *Compressive Strength Values for Concrete at Seabrook Station*, Revision 0.

20. Pittsburgh Testing Laboratory letter dated January 25, 1986, "Seabrook Nuclear Station Spec. 9763.006-5-1 Statistical Analysis -- Concrete Compression Test Data January 1986." (Seabrook FP # 100348)

21. Letter from FSEL (Bayrak) to MPR (Simons) dated June 23, 2015, "Measurement of Z-Direction Expansion of A- and S-Series Specimens."

22. MPR Commercial Grade Acceptance Record CGAR-0326-0062-43-1, Revision 1.

23. MPR Commercial Grade Acceptance Record CGAR-0326-0062-43-2, Revision 0.

24. MPR Commercial Grade Acceptance Record CGAR-0326-0062-43-3, Revision 0.

A
Correlation Between Expansion and Elastic Modulus

This appendix includes MPR Calculation 0326-0062-CLC-03, *Correlation Between Through-Thickness Expansion and Elastic Modulus in Concrete Test Specimens Affected by Alkali-Silica Reaction (ASR)*, Revision 1.

MPR	MPR Associates, Inc. 320 King Street Alexandria, VA 22314

CALCULATION TITLE PAGE

Client: NextEra Energy Seabrook	Page 1 of 12 + Appendices A-C (28 pages total)
Project: Approach for Estimating Through-Wall Expansion from Alkali-Silica Reaction at Seabrook Station	Task No. 0326-1405-0074
Title: Correlation Between Through-Thickness Expansion and Elastic Modulus in Concrete Test Specimens Affected by Alkali-Silica Reaction (ASR)	Calculation No. 0326-0062-CLC-03

Preparer / Date	Checker / Date	Reviewer & Approver / Date	Rev. No.
Michael Saitta February 2, 2015	Vaibhav Bhide February 2, 2015	John W. Simons February 2, 2015	0
Michael Saitta June 23, 2015	Kathleen Mulvaney June 23, 2015	John W. Simons June 23, 2015	1

QUALITY ASSURANCE DOCUMENT

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

MPR

MPR Associates, Inc.
320 King Street
Alexandria, VA 22314

RECORD OF REVISIONS

Calculation No.	Prepared By	Checked By	Page: 2
0326-0062-CLC-03		Kathryn Hemmings	

Revision	Affected Pages	Description
0	All	Initial Issue
1	All	Added correction factor for through-thickness expansion values to account for influence of mid-plane cracks on the expansion measured using embedded rods. (See new Section 5.2)

Note: *The revision number found on each individual page of the calculation carries the revision level of the calculation in effect at the time that page was last revised.*

Table of Contents

1.0 PURPOSE

This calculation determines a correlation between through-thickness expansion and elastic modulus of concrete test specimens affected by Alkali-Silica Reaction (ASR). The correlation is based on data from test programs that MPR is sponsoring at Ferguson Structural Engineering Laboratory (FSEL). The correlation is compared to published data.

2.0 SUMMARY OF RESULTS

There is a strong correlation between elastic modulus and through-thickness expansion of concrete test specimens that are affected by ASR. The data were fit with a least squares regression using a [redacted] form. Figure 2-1 below shows the FSEL test data and the least squares fit. The least squares fit compares favorably with the trend observed in the data. The R^2 value of the correlation is [redacted].

Figure 2-1 also shows data found in the literature for free expansion of ASR-affected concrete specimens. These data are consistent with the FSEL data.

[redacted]

Figure 2-1. Strong Correlations Between Elastic Modulus and Expansion

3.0 Background

Published data show that the material properties of ASR-affected concrete change with increasing levels of ASR expansion. MPR intends to use the relationship between material properties and ASR expansion to develop a methodology to determine the through-thickness expansion of concrete structures at Seabrook Station. This relationship will be defined using data from test programs that MPR is sponsoring at FSEL to investigate ASR in reinforced concrete elements. The test specimens are consistent with structures at Seabrook Station in terms of reinforcement details, depth of cover and overall depth. In addition, the concrete used in the specimens is representative of the concrete used at Seabrook Station, with some deviations to produce significant ASR expansion in a short timeframe.

4.0 Assumptions

4.1 Assumptions with a Basis

There are no assumptions with a basis.

4.2 Unverified Assumptions

There are no unverified assumptions.

5.0 Discussion

5.1 Test Data

The test data used herein are for specimens from the Shear Test Program and the Reinforcement Anchorage Test Program, as well as the Instrument Beam. Combining data from these programs is appropriate as the same concrete mix was used in all specimens and specimen configurations and reinforcement details are similar.

Test data on [redacted] concrete specimens are used in this calculation. The baseline material properties are the 28-day tests performed on cylinders molded at the time of concrete placement. The material properties at various levels of ASR expansion are based on tests of cores removed from the specimen. The available data include the following:

- 28 days after concrete placement
  - Three compressive strength values
  - Three elastic modulus values
  - Three splitting tensile strength values (note that this test was only performed for [redacted] of the [redacted] specimens, a total of [redacted] tests)
- After ASR had occurred
  - Three compressive strength values

- Three elastic modulus values
- Three splitting tensile strength values
- Through-thickness expansion at the time the cores were removed

These values are taken from Reference 1 and are summarized in Appendix A.

5.2 Expansion Measurement Correction Factor

The test specimens have developed large cracks on the concrete surface in the through-thickness direction between the reinforcement mats. The large cracks concentrate though-thickness expansion between the embedded rods. Therefore, the expansion measurement taken at the rods was significantly higher than the average expansion of the specimen along its width. FSEL developed a correlation to correct the expansion measured using the embedded rods, yielding an estimate of the average through-thickness expansion (Reference 6, See Appendix C; Reference 7 and Reference 8). This correlation is:

[redacted]

Where:

ϵ_{pin} is the expansion measured using the rods, measured in percent, and
ϵ is the corrected expansion, measured in percent.

This correction is applied to all of the expansion data, and the corrected data are used throughout the remainder of the calculation. The results of the correction are presented in Appendix A.

5.3 Selection of Elastic Modulus as the Property for the Correlation

To allow for more valid comparisons, the material properties of each specimen from the post-ASR testing were normalized against its average value from the 28-day test. Therefore, a sample that had seen very little change in a material property would have a normalized value of approximately 1, whereas one that had experienced a 25% reduction in a material property would have a normalized value of 0.75.

Figure 5-1 plots the normalized compressive strength and the normalized elastic modulus versus expansion. From the plot, it appears that there is a strong correlation between modulus and expansion. There also appears to be a weak correlation between compressive strength and expansion.

There were insufficient data to normalize the splitting tensile strength. Therefore, the splitting tensile strength was plotted against expansion in Figure 5-2. There does not appear to be a correlation between splitting tensile strength and expansion. Therefore, it is determined that elastic modulus is the best choice to correlate against expansion.

[redacted]

Figure 5-1. Normalized Strengths/Stiffness vs Expansion

[redacted]

Figure 5-2. Splitting Tensile Strength vs Expansion

5.4 Elastic Modulus Correlation

Non-linear least squares regression was used to fit a curve for the relationship between normalized modulus and expansion. Based on scoping analysis of several types of equations, it was determined that the best-fit curve would take the form of:

[redacted]

Least squares fitting was used to determine the constants A and B. The process of least squares is described in detail in Appendix B. This resulted in a final correlation of:

[redacted]

Where:

> *expansion* is the relative through-thickness expansion of the concrete specimen (0.02 implies a 2% expansion)
> *modulus* is the normalized modulus of the concrete specimen after ASR

This correlation is shown in Figure 5-3. The least squares fit compares favorably with the observed data. The R^2 value for the correlation is [redacted].

[redacted]

Figure 5-3. Correlation between Expansion and Normalized Modulus

5.5 Comparison to Published Values

Data on the elastic modulus as a function of ASR expansion are available in the literature. These data are for free expansion of small concrete specimens. Table 5-1 lists data from the sources considered in Reference 2.

Table 5-1. Existing Data Showing Expansion (%) and Corresponding Elastic Modulus

Expansion (%)	Normalized Elastic Modulus	Reference
0.05	100	3, Table 2.1
0.10	70	3, Table 2.1
0.25	50	3, Table 2.1
0.50	35	3, Table 2.1
1.00	30	3, Table 2.1
1.50	20	3, Table 2.1

Table 5-1. Existing Data Showing Expansion (%) and Corresponding Elastic Modulus

Expansion (%)	Normalized Elastic Modulus	Reference
0.002	100	4
0.039	66.0	4
0.114	65.2	4
0.210	54.7	4
0.328	50.2	4
0.392	46.7	4
0.007	100	4
0.020	97.7	4
0.038	91.2	4
0.095	78.3	4
0.128	75.8	4
0.29[1]	86.5[2]	5
1.253[1]	13.9[2]	5
0.43[1]	70.2[2]	5
1.573[1]	13.7[2]	5
0.43[1]	39.7[2]	5
1.656[1]	10.3[2]	5
0.43[1]	32.8[2]	5
1.686[1]	8.1[2]	5

Note 1: Longitudinal prism expansion was selected as the most representative

Note 2: Taken as elastic modulus at testing divided by elastic modulus at 28 days

Figure 5-4 plots these data and compares them to the FSEL data and to the correlation based on the FSEL data.

[redacted]

Figure 5-4. Modulus vs Expansion From Published Literature

As shown in Figure 5-4, the data from published literature follow a trend that is consistent with the FSEL test data and the correlation determined using these data.

6.0 REFERENCES

1. FSEL Special Test and Inspection Reports (STIRs) as accepted by CGAR-0326-0062-43-1 Revision 1 and CGAR-0326-0062-43-2 Revision 0
   a) STIR-24-21, Revision 0
   b) STIR-24-23, Revision 0
   c) STIR-24-24, Revision 0
   d) STIR-24-26, Revision 0
   e) STIR-24-34, Revision 0
   f) STIR-24-35, Revision 0
   g) STIR-24-56, Revision 1
   h) STIR-24-58, Revision 0
   i) STIR-24-59, Revision 0
   j) STIR-24-60, Revision 0
   k) STIR-24-61, Revision 0
   l) STIR-24-62, Revision 0
   m) STIR-24-63, Revision 0
   n) STIR-24-64, Revision 0
   o) STIR-24-67, Revision 0
   p) STIR-24-68, Revision 0
   q) STIR-24-69, Revision 0
   r) STIR-24-70, Revision 0
   s) STIR-24-71, Revision 0
   t) STIR-24-72, Revision 0
   u) STIR-24-79, Revision 1
   v) STIR-24-81, Revision 1
   w) STIR-24-86, Revision 0
   x) STIR-24-88, Revision 0
   y) STIR-24-89, Revision 0
   z) STIR-24-103, Revision 0

aa) STIR-24-104, Revision 0
bb) STIR-24-105, Revision 0
cc) STIR-24-106, Revision 0
dd) STIR-24-107, Revision 0
ee) STIR-24-108, Revision 0
ff) STIR-24-110, Revision 0
gg) STIR-24-114, Revision 0
hh) STIR-24-115, Revision 0
ii) STIR-24-116, Revision 0
jj) STIR-24-120, Revision 0
kk) STIR-24-132, Revision 0
ll) STIR-24-133, Revision 0
mm) STIR-24-134, Revision 0
nn) STIR-24-140, Revision 0
oo) STIR-24-147, Revision 0

2. Bayrak, Oguzhan, *Structural Implications of ASR: State of the Art*, July 28, 2014, transmitted to Seabrook Station in MPR Letter 0326-0058-200, dated July 29, 2014.

3. Clark, L.A., *Critical Review of the Structural Implications of the Alkali Silica Reaction in Concrete*, Transport and Road Research Laboratory Contractor Report 169, July 1989.

4. Smaoui, N. et al., *Mechanical Properties of ASR-Affected Concrete Containing Fine or Coarse Reactive Aggregates*, Journal of ASTM International, Vol. 3, No. 3, March 2006.

5. Ahmed, T. et al., *The effect of Alkali Reactivity on the Mechanical Properties of Concrete*, Construction and Building Materials, 17 (2003) 123-144, January 9, 2002.

6. Letter from Oguzhan Bayrak (FSEL) to John Simons (MPR), "Measurement of Z-Direction Expansion of A- and S-Series Specimens", dated June 23, 2015. (Included as Appendix C)

7. STIR-0326-0062-24-171, Revision 0.

8. CGAR-0326-0062-43-3, Revision 0.

A Test Data

This Appendix includes tables of summarized test data originally from FSEL. Table A-1 contains data from tests conducted 28 days after casting. The data are used to normalize the post-ASR data. Table A-2 contains data from tests that were conducted after ASR had occurred. Table A-3 contains expansion values measured using the specimen rods and the corrected expansion determined using the correlation discussed in Section 5.2. Test data are taken from Reference 1 of the main body of this calculation.

Calculation No.	Prepared By	Checked By	Page: A-2
0326-0062-CLC-03	[signature]	Kathryn Hultman	Revision: 1

Table A-1. FSEL 28-Day Compressive Strength, Elastic Modulus, and Splitting Tensile Strength Test Data

[redacted]

Calculation No.	Prepared By	Checked By	Page: A-3
0326-0062-CLC-03		Kathleen Hulemmy	Revision: 1

Table A-2. FSEL Average Expansion, Compressive Strength, and Elastic Modulus Test Data After ASR

[redacted]

Table A-3. FSEL Expansion Test Data With Correction Factor

[redacted]

B
Least Squares Regression

Purpose

This appendix explains the methodology used to perform the Least Squares Regression Analysis. A brief description of the fit statistic R^2 is also given. After the method of Least Squares is explained, the method is applied to the correlation between the FSEL test data for compressive strength and corrected through thickness expansion.

Discussion

Least Squares Regression is a commonly accepted method of fitting a curve to a set of scattered data. This is done by minimizing the sum of squares error term. This is a common statistical method that is documented in textbooks such as "Applied Data Analysis and Modeling for Energy Engineers and Scientists" by T.A. Reddy. The sum of squares is given by:

$$S = \sum_{i=1}^{m} r_m^2$$

Where:

S is the error term,
m is the number of known values, and
r_m is the residual of the mth value, as given by:

$$r_m = y_i - f(x_i, C)$$

Where:

y_i and x_i are a known value pair,
f is the regressed or fit function, and
C is the set of constants used to fit the model.

By combining the above equations with a known set of values, S is minimized by varying C. In some cases, this can be accomplished analytically, but is often accomplished numerically. The values of C that minimize S are said to be the fitting parameters, and the function $f(x_i, C)$ is the curve of best fit in the least squares sense.

It is often desirable to determine how well a given curve fits a set of data. A commonly used statistic to determine this is the coefficient of determination, R^2. R^2 is defined as:

$$R^2 = 1 - \frac{SS_{res}}{SS_{tot}}$$

$$SS_{res} = \sum_{i=1}^{m} (y - f(x_i, C))^2 = S$$

$$SS_{tot} = \sum_{i=1}^{m} (y - \bar{y})^2$$

Example

The least squares regression performed in the main body of this calculation is described in detail below. The set of points is listed in Table B-1 and plotted in Figure B-1.

Table B-1. Known Values

[redacted]

Table B-1. Known Values

[redacted]

[redacted]

Figure B-1. Plot of Known Values

It appears that a power fit is reasonable. Therefore, it can be fit to an equation of form:

[redacted]

Where:

x is the set of values of X as shown in Table B-1.
A and B are a set of constants (C) used to fit the model.

To begin, we will guess at the values of A and B. In this example, our first guess will be that $A = 1$ and $B = -0.01$. Using the model given above, we compute a value for y at each given x. For each computed value, the residual is also computed. These values are shown in Table B-2.

Table B-2. Example Values With Computed Residuals

[redacted]

Taking the sum of squares of the residuals, we find a value of [redacted]. However, this can be improved on. To do so, we iteratively adjust the values A and B to minimize S.

Values of $A =$ [redacted] and $B =$ [redacted] result in S being minimal and provide a good estimate of the solution. The fitted curve is plotted against the data in Figure B-2. The newly computed values are shown in Table B-3. The regressed equation is:

[redacted]

Table B-3. Example Values With Computed Residuals- Updated

[redacted]

[redacted]

Figure B-2. Regressed Curve

R^2 can now be computed using the regressed curve. The sum of squared residuals is [redacted] (SS_{res}). The mean of y is [redacted]. Therefore, the sum of squared totals is [redacted] (SS_{tot}). R^2 can now be computed.

$$R^2 = 1 - SS_{res}/SS_{tot}$$

$$R^2 = \text{[redacted]}$$

C
Reference 6

This appendix includes a copy of Reference 6: Letter from Oguzhan Bayrak (FSEL) to John Simons (MPR), “Measurement of Z-Direction Expansion of A- and S-Series Specimens”, dated June 23, 2015.

Note that Reference 6 is accepted by References 7 and 8

(5 pages follow)

PHIL M. FERGUSON STRUCTURAL ENGINEERING LABORATORY
THE UNIVERSITY OF TEXAS AT AUSTIN
10100 Burnet Road, Building 177, Austin, Texas 78758-4497 · (512) 471-3062 · Fax (512) 471-1944

June 15, 2015; Revised June 23, 2015

Mr. John W. Simons
MPR Associates Inc.
320 King Street
Alexandria, VA 22314-3230

Subject: Measurement of Z-Direction Expansion of A- and S-Series Specimens

Dear Mr. Simons,

Over the past few years, Ferguson Structural Engineering Laboratory (FSEL) has been using embedded pins to measure expansion in the through-thickness, or Z-direction, of beam specimens in the MPR-sponsored test programs. A general view of a test specimen and directional definitions are provided in Figure 1. Measurement pins are located within the structural core of the test specimens, [redacted] in. from the face with [redacted] in. of concrete cover and [redacted] in. from the face with [redacted] in. of concrete cover (Figure 2). This arrangement places the pins [redacted] in. apart, and this distance forms the gage length for any pin-based expansion measurements.

Over time, most specimens have developed large mid-plane cracks. Investigation of past specimens with such cracks indicates that these mid-plane cracks are localized near the exposed surfaces of the specimens, and do not traverse the entire perpendicular dimension of [redacted] in. These large cracks occur between the pins mentioned above and cause significant displacement between measurement points. Thus, expansions measured using these pins are heavily influenced by the width of this crack and may not be representative of Z-direction expansion of the entire specimen including areas outside the embedded pins. In an effort to address this edge effect and to examine expansion of the entire specimen, a new measurement frame has been designed and fabricated by FSEL.

Annotated views of the frame and specimen cross section are shown in Figure 2. The frame contacts the specimen at three points on formed concrete surfaces and aligns to both ends of both embedded pins. Once aligned, a total of [redacted] measurements can be taken at the locations shown in the figure using a calibrated depth micrometer. These measurements allow thickness of expanded specimens to be calculated in a repeatable manner and precisely at [redacted] locations. However, the initial through-thickness dimensions of the specimens are not known precisely at this time. To enable expansion calculations, initial through-thickness dimensions of the specimens have been taken equal to the width of the bottom portion of the steel forms used to cast the specimens. The forms were measured at five locations (Figure 3) using calibrated calipers and averaged to determine an initial width of [redacted] in. for the specimens. All expansion calculations compare the average width measurement of the bottom form with subsequent through-thickness measurements taken on the specimens.

[redacted]

Figure 1 – Direction Definitions for A- and S-Series Specimens

[redacted]

Figure 2 – Schematic View of the Measurement Frame to Measure Expansions in Z-direction

[redacted]

Figure 3 – Plan View of Steel Form Bottom Panel with Width Measurements

Through-thickness expansions can be determined by using the measurement frame, and these expansion values can be compared with those determined using the embedded pins. A summary of those data are plotted in Figure 4. It is important to note that in addition to the average expansions calculated using [redacted] measurements per specimen per cycle of measurement, the minimum and the maximum values are also shown to provide context. The plot also includes a [redacted] best-fit line through the data. Further, this figure includes both the official data and the data collected on an information-only basis. However, conclusions and recommendations presented in this letter are based only on the official data.

[redacted]

Figure 4 – Relationship between Expansion Measurements Based on Embedded Pins and External Frame

Based on the plotted comparison, an equation for through-thickness expansion based on pin measurements can be established as:

[redacted] Equation 1

Where: $\varepsilon_{z,pin}$ = Z-direction expansion based on embedded pins in percent, and
$\varepsilon_{z,frame}$ = Z-direction expansion based on the measurement frame in percent.

Equation 1 is based on a combination of physical parameters related to the specimens and measurements alongside additional parameters developed based on a statistical best-fit linear regression. A detailed explanation for the derivation of Equation 1 is provided below.

[redacted]

4

[redacted]

Equation 1 represents a combination of terms based on both engineering mechanics and statistical regression analysis. Over upcoming months, additional data will be taken for expansion measurements using both the embedded pins and the external frame. Since specimens continue to expand with time, additional data will be plotted, primarily populating the right-hand side of Figure 4. Within the existing test programs, no new data will be available to place points within the lower left portion of the figure. When additional data are available, the coefficients within Equation 1 may evolve, though significant changes are not expected due to the basis of the equation in structural mechanics. If changes should be warranted, the form of the equation and the methodology used for its development should remain unchanged.

Please contact me if you have any questions or comments.

Regards,

Oguzhan Bayrak

Oguzhan Bayrak, Ph.D., P.E.
Director, Phil M. Ferguson Structural Engineering Laboratory
Professor, Civil, Architectural and Environmental Engineering
Charles Elmer Rowe Fellow, Cockrell School of Engineering
The University of Texas at Austin

B

Evaluation of ACI Equation for Elastic Modulus

This appendix includes MPR Calculation 0326-0062-CLC-01, *Evaluation of ACI Equation for Elastic Modulus*, Revision 0.

<table>
<tr><td colspan="4">MPR
MPR Associates, Inc.
320 King Street
Alexandria, VA 22314</td></tr>
<tr><td colspan="4">CALCULATION TITLE PAGE</td></tr>
<tr><td colspan="3">Client:
NextEra Energy Seabrook, LLC</td><td>Page 1 of 12+
Appendix A and B</td></tr>
<tr><td colspan="3">Project:
Approach for Estimating Through-Wall Expansion from Alkali-Silica Reaction at Seabrook Station</td><td>Task No.
0326-1405-0074</td></tr>
<tr><td colspan="3">Title:
Evaluation of ACI Equation for Elastic Modulus</td><td>Calculation No.
0326-0062-CLC-01</td></tr>
<tr><td>Preparer / Date</td><td>Checker / Date</td><td>Reviewer & Approver / Date</td><td>Rev. No.</td></tr>
<tr><td>Amanda Card
Amanda Card
01/29/2015</td><td>David H. Bergquist
DHB
01/29/2015</td><td>John W. Simons
John W. Simons
01/29/2015</td><td>0</td></tr>
<tr><td colspan="4">QUALITY ASSURANCE DOCUMENT
This document has been prepared, checked, and reviewed/approved in accordance with the QA requirements of 10CFR50 Appendix B and/or ASME NQA-1, as specified in the MPR Nuclear Quality Assurance Program.</td></tr>
</table>

MPR

MPR Associates, Inc.
320 King Street
Alexandria, VA 22314

RECORD OF REVISIONS

Calculation No.	Prepared By	Checked By	Page: 2
0326-0062-CLC-01	Amanda Card	[signature]	

Revision	Affected Pages	Description
0	All	Initial Issue

Note: *The revision number found on each individual page of the calculation carries the revision level of the calculation in effect at the time that page was last revised.*

Table of Contents

1.0 INTRODUCTION

1.1 Purpose

This calculation evaluates the applicability of the elastic modulus equation provided in Section 8.5.1 of ACI 318-71 (Reference 2) to the concrete mix used in the Beam Test Programs that MPR is sponsoring at Ferguson Structural Engineering Laboratory (FSEL).

1.2 Background

MPR is developing a methodology to determine the through-thickness expansion of concrete structures at Seabrook Station due to Alkali-Silica Reaction (ASR). The through-thickness expansion results in a reduction in the elastic modulus. One approach for estimating the original elastic modulus (i.e., the elastic modulus before ASR expansion occurs) is to calculate it using the 28-day compressive strength of the concrete and the equation provided in ACI 318-71.

2.0 SUMMARY OF RESULTS AND CONCLUSIONS

Based on the results of this calculation, the relationship between the measured 28-day compressive strength and the elastic modulus for the test specimens within the Beam Test Programs at FSEL is consistent with the ACI equation. The measured data and calculated results show a similar trend. Measured and calculated elastic modulus values for all but three data sets were within the variability range stated in Reference 2, 20%.

3.0 APPROACH

Section 8.5.1 of ACI 318-71 (Reference 2) states that the 28-day elastic modulus (E_c) of concrete can be calculated based on the density of concrete in lb/ft^3 (w_c) and the 28-day compressive strength of concrete (f_c'). This relationship is expressed using Equation 1.

$$E_c = 33 w_c^{1.5} \sqrt{f_c'} \qquad (1)$$

Section R8.5.1 of ACI 318 (Reference 2) also states that measured values for elastic modulus range from 80% to 120% of the calculated value.

Reference 3 provides the basis for Equation 1 and supports Reference 2. Equation 1 is based on light weight and normal weight concrete test data from various published articles and unpublished reports from the Expanded Shale, Clay, and Slate Institute.

The elastic modulus for normal weight concrete (approximate density of $144 \frac{\text{lb}}{\text{ft}^3}$) can be calculated using Equation 2, a simplified version of Equation 1. (Reference 2)

$$E_c = 57{,}000\sqrt{f_c'} \qquad (2)$$

As part of the Shear and Reinforcement Anchorage Test Programs and Instrumentation Specimen Testing, FSEL has determined the 28-day concrete elastic modulus and compressive strength for each beam specimen fabricated to date. These tests use cylinders molded at the time of concrete placement. In addition to the 28-day data, data are also available from cores removed from the test specimens used for control tests (i.e., tests performed shortly after 28 days, before the onset of deleterious ASR expansion). The results of the FSEL elastic modulus and compressive strength tests are compared to Equation 2 (and therefore Equation 1) in this calculation to confirm that the ACI equation is applicable to the concrete mix used in the Beam Test Programs.

4.0 INPUTS

As stated in Section 3.0, the 28-day elastic modulus and the 28-day compressive strength of twenty beams, collected by FSEL, were used to confirm the applicability of Equations 1 and 2. A total of [redacted] data sets were evaluated.

The data were taken from the Special Test and Inspection Records (STIRs) listed in Table 1. (Reference 5 through Reference 40)

Table 1. References for Test Data

[redacted]

Table 1. References for Test Data

[redacted]

5.0 CALCULATION

5.1 Concrete Density Verification

It is important to note that the density of concrete varies slightly among the beams that were tested. However, all test beams are composed of normal weight concrete ($144\frac{\text{lb}}{\text{ft}^3}$).

The simplified equation for normal weight concrete, Equation 2, is therefore applicable and was used to calculate the elastic moduli reported in this calculation.

The relevance of Equation 2 was verified by calculating the density of a beam and comparing it to the density of normal weight concrete. The two values agreed.

A sample density calculation is provided in Appendix A.

5.2 Elastic Modulus Determination

The average 28-day compressive strengths and Equation 2 were used to calculate the 28-day elastic modulus for each of the [redacted] data sets listed in Table 1. The percent error is calculated between the measured and calculated elastic modulus values.

The calculation is provided in Appendix B.

6.0 RESULTS AND CONCLUSIONS

The measured elastic modulus values for the [redacted] data sets collected at FSEL align well with the calculated elastic modulus values (from Equation 2). All but [redacted] of the measured elastic modulus values are within 80% to 120% of the calculated value.

Figure 1 compares the FSEL data to the trendline for Equation 2.

Figure 2 and Figure 3 illustrate that nearly all of the FSEL data falls within 80% and 120% of the calculated elastic modulus value, which is consistent with the statement in Section R8.5.1 of ACI 318 (Reference 2) regarding the accuracy of the equation.

It is important to note that the measured elastic modulus is plotted and compared to the trendline associated with Equation 2 in Figure 1 and Figure 2. The percent difference between measured elastic modulus and calculated elastic modulus (per Equation 2) is plotted in Figure 3. All three figures support the conclusion that Equation 2 (and therefore Equation 1) applies to the FSEL data.

The calculations required to generate Figure 1, Figure 2, and Figure 3 are also provided in Appendix B. Cylinders are depicted in blue. Cores are depicted in green.

Based on the results of this calculation, the elastic modulus equation, provided in Section 8.5.1 of ACI 318-71, is validated.

[redacted]

Figure 1. Comparison of FSEL Elastic Modulus Test Data with Equation 2

[redacted]

Figure 2. Range of FSEL Elastic Modulus Test Data

[redacted]

Figure 3. Percent Error: FSEL Elastic Modulus Test Data vs. Equation 2 Elastic Modulus

7.0 REFERENCES

1. Seabrook Foreign Print No. 100629, "Concrete Test Report," Revision 5.
2. ACI 318-71, "Building Code Requirements for Structural Concrete and Commentary," American Concrete Institute, 1971.
3. Pauw, A., "Static Modulus of Elasticity of Concrete as Affected by Density," *Journal of the American Concrete Institute*, Vol. 32, No. 6, December 1960, pg. 679-687.
4. United Engineers Calculation No. CD-20, "Design of Mats at El. 20' 0" and 0' 0" and Walls Below Grade for Electrical Tunnels and Control Building," Revision 2.
5. MPR Special Test and Inspection Record No. STIR-0326-0062-24-9, Revision 0.
6. MPR Special Test and Inspection Record No. STIR-0326-0062-24-17, Revision 0.
7. MPR Special Test and Inspection Record No. STIR-0326-0062-24-21, Revision 0.
8. MPR Special Test and Inspection Record No. STIR-0326-0062-24-24, Revision 0.
9. MPR Special Test and Inspection Record No. STIR-0326-0062-24-30, Revision 0.
10. MPR Special Test and Inspection Record No. STIR-0326-0062-24-34, Revision 0.
11. MPR Special Test and Inspection Record No. STIR-0326-0062-24-50, Revision 0.
12. MPR Special Test and Inspection Record No. STIR-0326-0062-24-45, Revision 0.
13. MPR Special Test and Inspection Record No. STIR-0326-0062-24-93, Revision 0.
14. MPR Special Test and Inspection Record No. STIR-0326-0062-24-110, Revision 0.
15. MPR Special Test and Inspection Record No. STIR-0326-0062-24-86, Revision 0.
16. MPR Special Test and Inspection Record No. STIR-0326-0062-24-96, Revision 0.
17. MPR Special Test and Inspection Record No. STIR-0326-0062-24-13, Revision 0.
18. MPR Special Test and Inspection Record No. STIR-0326-0062-24-19, Revision 0.
19. MPR Special Test and Inspection Record No. STIR-0326-0062-24-23, Revision 0.
20. MPR Special Test and Inspection Record No. STIR-0326-0062-24-26, Revision 0.

21. MPR Special Test and Inspection Record No. STIR-0326-0062-24-31, Revision 0.

22. MPR Special Test and Inspection Record No. STIR-0326-0062-24-35, Revision 0.

23. MPR Special Test and Inspection Record No. STIR-0326-0062-24-84, Revision 0.

24. MPR Special Test and Inspection Record No. STIR-0326-0062-24-106, Revision 0.

25. MPR Special Test and Inspection Record No. STIR-0326-0062-24-117, Revision 0.

26. MPR Special Test and Inspection Record No. STIR-0326-0062-24-11, Revision 0.

27. MPR Special Test and Inspection Record No. STIR-0326-0062-24-47, Revision 0.

28. MPR Special Test and Inspection Record No. STIR-0326-0062-24-95, Revision 0.

29. MPR Special Test and Inspection Record No. STIR-0326-0062-24-111, Revision 0.

30. MPR Special Test and Inspection Record No. STIR-0326-0062-24-89, Revision 0.

31. MPR Special Test and Inspection Record No. STIR-0326-0062-24-98, Revision 0.

32. MPR Special Test and Inspection Record No. STIR-0326-0062-24-87, Revision 0.

33. MPR Special Test and Inspection Record No. STIR-0326-0062-24-107, Revision 0.

34. MPR Special Test and Inspection Record No. STIR-0326-0062-24-90, Revision 0.

35. MPR Special Test and Inspection Record No. STIR-0326-0062-24-123, Revision 0.

36. MPR Special Test and Inspection Record No. STIR-0326-0062-24-124, Revision 0.

37. MPR Special Test and Inspection Record No. STIR-0326-0062-24-127, Revision 0.

38. MPR Special Test and Inspection Record No. STIR-0326-0062-24-128, Revision 0.

39. MPR Special Test and Inspection Record No. STIR-0326-0062-24-135, Revision 0.

40. MPR Special Test and Inspection Record No. STIR-0326-0062-24-136, Revision 0.

A

Sample Concrete Density Calculation

The density of S8 was calculated using data provided in STIR-24-90. (Reference 34)

The relevant data and density calculation are provided in Table A-1.

Table A-1. Concrete Density Calculation

[redacted]

B
Test Data and Calculations

The information used to perform this calculation and to generate the graphs included herein is provided in Table B-1and Table B-2.

Table B-1. Compressive Strength and Calculated Elastic Modulus

[redacted]

Table B-1. Compressive Strength and Calculated Elastic Modulus

[redacted]

Table B-1. Compressive Strength and Calculated Elastic Modulus

[redacted]

Table B-1. Compressive Strength and Calculated Elastic Modulus

[redacted]

Table B-2. Elastic Modulus

[redacted]

Table B-2. Elastic Modulus

[redacted]

Table B-2. Elastic Modulus

[redacted]

C

Compressive Strength of Concrete at Seabrook Station

This appendix includes MPR Calculation 0326-0062-CLC-02, *Compressive Strength Values for Concrete at Seabrook Station*, Revision 0.

MPR	MPR Associates, Inc. 320 King Street Alexandria, VA 22314

CALCULATION TITLE PAGE

Client: NextEra Energy Seabrook, LLC	Page 1 of 8 plus Appendix A
Project: Approach for Estimating Through-Wall Expansion from Alkali-Silica Reaction at Seabrook Station	Task No. 0326-1405-0074
Title: Compressive Strength Values for Concrete at Seabrook Station	Calculation No. 0326-0074-CLC-02

Preparer / Date	Checker / Date	Reviewer & Approver / Date	Rev. No.
David H. Bergquist January 28, 2015	Christina Hamm January 28, 2015	John W. Simons January 28, 2015	0

QUALITY ASSURANCE DOCUMENT

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

MPR-QA Form QA-3.1-1, Rev. 2

MPR

MPR Associates, Inc.
320 King Street
Alexandria, VA 22314

RECORD OF REVISIONS

Calculation No.	Prepared By	Checked By	Page: 2
0326-0074-CLC-02			

Revision	Affected Pages	Description
0	All	Initial Issue

Note: *The revision number found on each individual page of the calculation carries the revision level of the calculation in effect at the time that page was last revised.*

MPR QA Form QA-3.1-2, Rev. 0

Calculation No.	Prepared By	Checked By	Page: 3
0326-0074-CLC-02			Revision: 0

Table of Contents

1.0 PURPOSE

This calculation evaluates available 28-day compressive strength values determined from concrete cylinders during the original construction of Seabrook Station. These values are then displayed on a histogram to show the data distribution, mean, and standard deviation. Additionally, the data are separated by location and by the strength class of the concrete (i.e. specified compressive strength).

2.0 SUMMARY OF RESULTS

All available 28-day compressive strength data points were compiled to form the histogram given in Figure 1. The average 28-day compressive strength is 5456 psi and the standard deviation is 568 psi. Seventy-five percent of the data fall within one standard deviation of the mean and ninety-four percent of the data fall within two standard deviations of the mean.

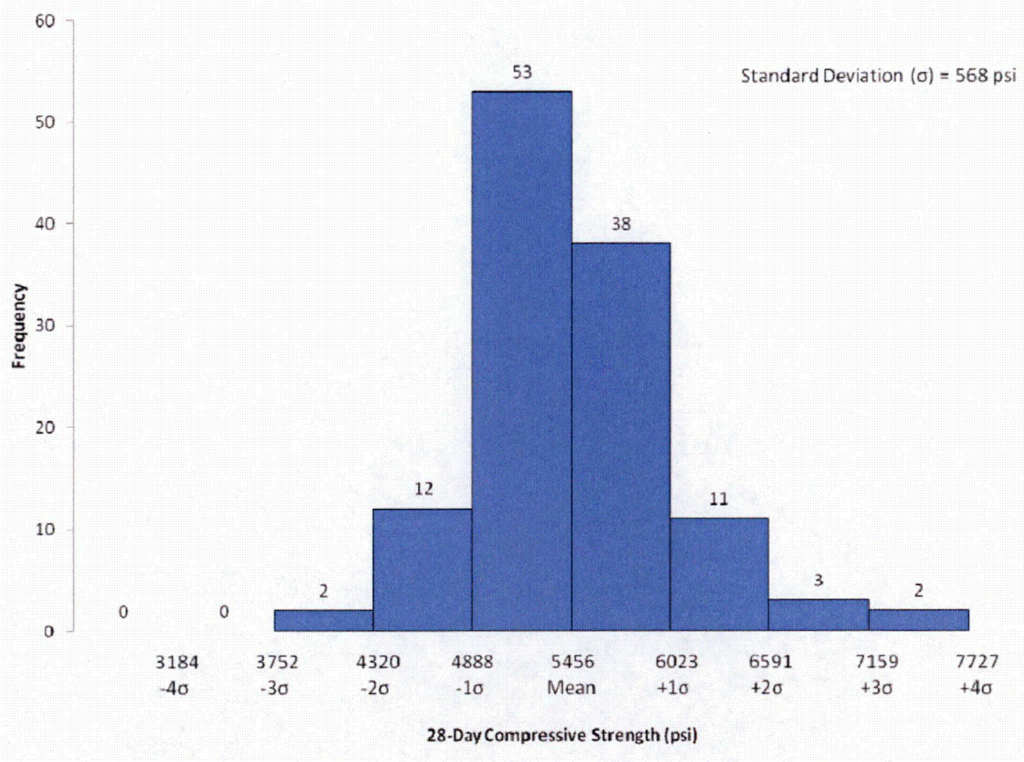

Figure 1. 28-Day Compressive Strength Values for Concrete Cylinders at Seabrook Station

Table 1 shows the data presented in Figure 1 along with the data categorized by room at Seabrook and by concrete strength class.

Table 1. 28-Day Compressive Strength Data for Seabrook Station

	Mean	Standard Deviation (σ)	No. Of Data Points	Min	Max	% of data within 1 σ	% of data within 2 σ
All Data	5456	568	121	4240	7360	75%	94%
3000 PSI Strength Class	5621	691	50	4270	7360	74%	96%
4000 PSI Strength Class (Note 1)	5339	430	71	4240	6150	70%	99%
Containment Enclosure Building	5426	380	24	4880	6080	67%	100%
RHR Equipment Vault	5503	491	35	4240	6150	63%	97%
EFW Pump House Stairway A	5390	269	12	4950	5870	67%	100%
RCA Walkway	4891	404	12	4270	5450	50%	100%
B EDG Building	5197	371	21	4600	5840	62%	100%
B Electrical Tunnel	6163	705	17	5220	7360	65%	100%

Note 1: The strength class of 9 samples from the RHR Equipment Room cannot be identified with certainty due to poor resolution of the reference document. These samples are most likely 4000 psi strength class samples based on their proximity to other 4000 psi strength class samples. See Appendix A for more details.

3.0 BACKGROUND

MPR is developing a methodology to determine the through-thickness expansion of concrete structures at Seabrook Station due to the Alkali-Silica Reaction (ASR). The through-thickness expansion is related to the reduction in elastic modulus of the concrete over time. One approach for estimating the original elastic modulus is to calculate it from the 28-day compressive strength of the concrete using an equation from ACI 318 (Reference 1).

4.0 METHODOLOGY

Seabrook Foreign Print No. 100629 and United Engineers Calculation No. CD-20 (References 2 and 3) include 28-day compressive strength results for concrete used in original construction for the following buildings at Seabrook Station:

- Containment Enclosure Building
- RHR Equipment Vault
- EFW Pump House Stairway A
- RCA Walkway
- B Diesel Generator Building
- B Electrical Tunnel

These references provide the 121 data points used in this calculation. These 28-day compressive strength data points are included in Appendix A.

5.0 RESULTS

The average 28-day compressive strength of all data points is 5456 psi and the standard deviation is 568 psi. Seventy-five percent of the data fall within one standard deviation of the mean and ninety-four percent of the data fall within two standard deviations of the mean. Therefore, the mean is a representative value for the 28-day compressive strength of all concrete used at Seabrook. See Section 2.0 for a histogram of all data points as well as a table of the compressive strength data by room and concrete strength class. Figures 2 and 3 display the data for the 3000 psi and 4000 psi strength class concrete cores, respectively.

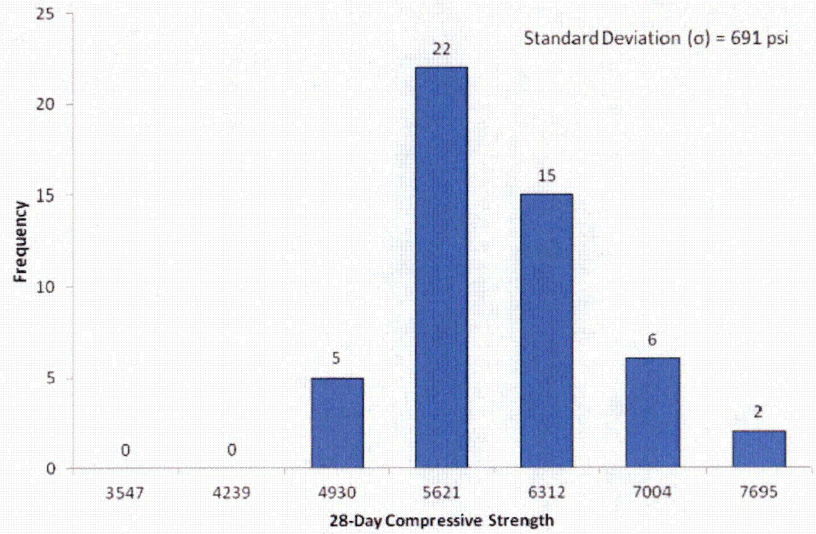

Figure 2. 28-Day Compressive Strength Values for 3000 psi Strength Class Concrete Cores

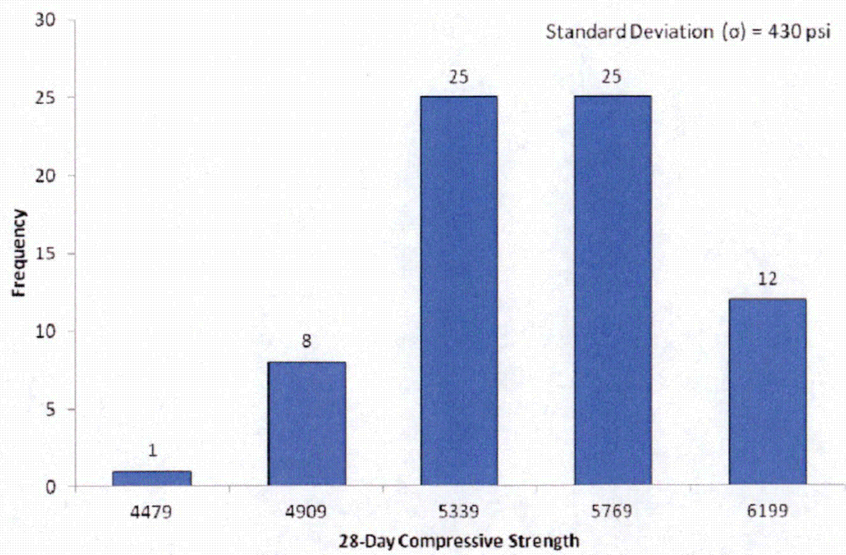

Figure 3. 28-Day Compressive Strength Values for 4000 psi Strength Class Concrete Cores

Calculation No.	Prepared By	Checked By	Page: 8
0326-0074-CLC-02			Revision: 0

6.0 REFERENCES

1. ACI 318-71, "Building Code Requirements for Structural Concrete," American Concrete Institute, 1971.

2. Seabrook Foreign Print No. 100629, "Concrete Test Report," Revision 0.

3. United Engineers Calculation No. CD-20, "Design of Mats at El. 20' 0" and 0' 0" and Walls Below Grade for Electrical Tunnels and Control Building," Revision 4.

A

Compressive Strength Data

Table A-1 contains the 28-day compressive strength data for concrete cores at Seabrook Station.

Table A-1: 28-Day Compressive Strengths for Concrete Cores at Seabrook Station

Room	Sample No.	Compressive Strength (psi)	Strength Class (psi)
Containment Enclosure Building (Reference 2)	4405	5130	4000
	4406	5200	4000
	4407	5620	4000
	4405A	6080	4000
	4406A	5700	4000
	4407A	5410	4000
	4641	5200	4000
	4642	5060	4000
	4643	5410	4000
	4641A	5980	4000
	4642A	6050	4000
	4643A	6010	4000
	4648	5020	4000
	4649	5090	4000
	4650	4950	4000
	4655	5380	4000
	4656	5240	4000
	4657	4880	4000
	4648A	5020	4000
	4649A	5160	4000
	4650A	5360	4000
	4655A	5780	4000
	4656A	5730	4000
	4657A	5770	4000

Calculation No.	Prepared By	Checked By	Page: A-2
0326-0074-CLC-02			Revision: 0

Table A-1: 28-Day Compressive Strengths for Concrete Cores at Seabrook Station

Room	Sample No.	Compressive Strength (psi)	Strength Class (psi)
RHR Equipment Vault (Reference 2)	94	6070	3000
	95	5780	3000
	96	5710	3000
	101	5800	3000
	102	5730	3000
	103	5700	3000
	108	6140	3000
	109	5960	3000
	110	6030	3000
	430	5020	4000[1]
	431	4990	4000[1]
	432	5060	4000[1]
	430A	5450	4000
	431A	5480	4000
	432A	5380	4000
	437	6010	4000
	438	5620	4000
	439	5980	4000
	437A	6010	4000
	438A	6150	4000
	439A	6120	4000
	unknown	4670	4000
	unknown	4740	4000
	unknown	5660	4000
	unknown	5450	4000
	unknown	5480	4000
	unknown	5620	4000
	unknown	5700	4000
	unknown	5700	4000
	unknown	4600	4000[1]
	unknown	5130	4000[1]
	unknown	4240	4000[1]
	unknown	5270	4000[1]
	unknown	5240	4000[1]

[1] Concrete strength class cannot be determined with certainty due to poor resolution of reference document.

Calculation No.	Prepared By	Checked By	Page: A-3
0326-0074-CLC-02			Revision: 0

Table A-1: 28-Day Compressive Strengths for Concrete Cores at Seabrook Station

Room	Sample No.	Compressive Strength (psi)	Strength Class (psi)
RHR Equipment Vault	unknown	4920	4000[1]
EFW Pump House Stairway A (Reference 2)	590	5700	3000
	591	5700	3000
	592	5590	3000
	590A	4950	3000
	591A	5200	3000
	592A	5240	3000
	597A	5290	3000
	598A	5870	3000
	599A	5380	3000
	604A	5180	3000
	605A	5340	3000
	606A	5240	3000
RCA Walkway (Reference 2)	489	5310	3000
	490	4440	3000
	491	4950	3000
	489A	5200	3000
	490A	5450	3000
	491A	4880	3000
	484	4470	3000
	485	4270	3000
	486	4370	3000
	484A	5040	3000
	485A	5090	3000
	486A	5220	3000
B EDG Building (Reference 2)	unknown	4620	4000
	unknown	4700	4000
	unknown	4600	4000
	unknown	5150	4000
	unknown	5660	4000
	unknown	5200	4000
	315	5520	4000
	316	5590	4000
	317	5470	4000
	315A	5840	4000

Table A-1: 28-Day Compressive Strengths for Concrete Cores at Seabrook Station

Room	Sample No.	Compressive Strength (psi)	Strength Class (psi)
B EDG Building (Reference 2)	316A	5110	4000
	317A	5640	4000
	unknown	4600	4000
	unknown	4950	4000
	unknown	4950	4000
	unknown	5380	4000
	unknown	5310	4000
	unknown	5040	4000
	unknown	5340	4000
	unknown	5040	4000
	unknown	5430	4000
B Electrical Tunnel (Reference 3)	427	5410	3000
	428	5220	3000
	426A	6560	3000
	427A	6490	3000
	428A	6100	3000
	433	5470	3000
	434	5550	3000
	435	5890	3000
	433A	7000	3000
	434A	7220	3000
	435A	7360	3000
	440	5730	3000
	441	5480	3000
	442	5390	3000
	440A	6330	3000
	441A	6810	3000
	442A	6760	3000

MPR

June 25, 2015
DRN 0326-0062-69

Mr. Rick Noble
NextEra Energy Seabrook LLC
P.O. Box 300
Lafayette Road
Seabrook, NH 03874

Subject: Withholding MPR-4153 from Public Disclosure under 10 CFR 2.390

Dear Mr. Noble:

We understand that NextEra Energy Seabrook intends to submit MPR-4153, *Seabrook Station – Approach for Determining Through-Thickness Expansion from Alkali-Silica Reaction*, Revision 1 on the docket to support the NRC's review of the alkali-silica reaction (ASR) issue at Seabrook Station. Further, we understand that NextEra is requesting that the documents be withheld from public disclosure under 10 CFR 2.390(a)(4). The report is marked proprietary to NextEra Energy Seabrook and MPR Associates as it contains information which has a commercial value to both parties. Specifically, the report includes details on the test programs that MPR is sponsoring on behalf of NextEra, as well as results from the test programs. Public release of the information would concede intellectual property and a commercial advantage to others pursuing similar test programs or assessing the structural implications of ASR.

We hereby grant our consent to docket MPR-4153, Revision 1 in support of the NRC's review of the Seabrook ASR issue provided it is withheld from public disclosure. In support of NextEra requesting that the information be withheld from public disclosure under 10 CFR 2.390(a)(4), we are providing the following:

- A notarized affidavit for withholding the report from public disclosure under 10 CFR 2.390.
- Three versions of MPR-4153, Revision 1:
  - A version that includes a heading that states "proprietary information – withhold from public disclosure under 10 CFR 2.390."
  - A markup that shows the proposed redactions using red boxes. It includes a statement on the cover regarding the basis for redacting information.
  - A non-proprietary version in which the proprietary information is redacted. (Headings and statements about it being proprietary have been removed to be consistent with a non-proprietary designation.)

Please contact me (703-519-0258) if you have any questions.

Sincerely,

John W. Simons

John W. Simons
Director, Plant Systems & Components

NextEra Energy Seabrook, LLC

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

County of Rockingham)
)
State of New Hampshire)

I, Dean Curtland, being duly sworn according to law, depose and state the following:

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

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

(3) The information sought to be withheld is contained in Enclosures 4 of NextEra Energy Seabrook's letter SBK-L-15107, Dean Curtland (NextEra Energy Seabrook) to U.S. Nuclear Regulatory Commission, entitled "Seabrook Station Response to Requests for Additional Information for the Review of the Seabrook Station, License Renewal Application- SET 23 (TAC NO. ME4028) Relating to the Alkali-Silica Reaction (ASR) Monitoring Program," dated June 30, 2015. The NextEra Energy Seabrook proprietary information in Enclosure 4 of SBK-L-15107, is identified by enclosing boxes ([__]).

(4) The information sought to be withheld is considered to be proprietary and confidential commercial information because alkali-silica reaction (ASR) is a newly-identified phenomenon at domestic nuclear plants. The information requested to be withheld is the result of several years of intensive NextEra Energy Seabrook effort and the expenditure of a considerable sum of money. This information may be marketable in the event nuclear facilities or other regulated facilities identify the

presence of ASR. In order for potential customers to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended. The extent to which this information is available to potential customers diminishes NextEra Energy Seabrook's ability to sell products and services involving the use of the information. Thus, public disclosure of the information sought to be withheld is likely to cause substantial harm to NextEra Energy Seabrook's competitive position and NextEra Energy Seabrook has a rational basis for considering this information to be confidential commercial information.

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

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

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

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

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

Dean Curtland
Site Vice President
NextEra Energy Seabrook, LLC
626 Lafayette Road
Seabrook, New Hampshire 03874

Subscribed and sworn to before me
this 30 day of June, 2015.

Shirley Sweeney
Notary Public

My commission expires January 14, 2020

SHIRLEY SWEENEY
MY COMMISSION EXPIRES JAN. 14, 2020
NOTARY PUBLIC
NEW HAMPSHIRE