ABSTRACT

Alkali-silica reaction (ASR) is a frequent cause of concrete deterioration. ASR occurs when certain silica-containing aggregates react with hydroxyl and alkali ions to form an expansive silica gel, leading to cracking of the aggregate and concrete. Because ASR-induced concrete deterioration is a gradual time-dependent process, concrete structures undergoing ASR can often still serve their intended purpose provided that the effects of the ASR are understood, monitored, and managed.

After identifying 40 structures with the potential for alkali-silica reaction (ASR) due to the use of suspect aggregates, the Massachusetts Department of Transportation (MassDOT) undertook a research program to develop a means of managing the potential effects of any ASR. Building upon work completed by the Federal Highway Administration and the Institution of Structural Engineers, the program established a protocol for field inspection and diagnosis of ASR, evaluation of the extent of any ASR-related damage and its potential effect on the structure, monitoring of its progression, and long-term management of each affected structure.

This paper presents the protocol, including the preliminary field assessment (visual observation, cracking index measurements, and core sampling), supplemental laboratory evaluation (petrographic examination and Damage Rating Index tests), and resulting evaluation of the structural and performance implications. Using examples, particular emphasis will be applied to the resulting evaluation and management plans presented in the protocol that incorporates and guides the future management of the ASR in the structures.

Keywords: Alkali-silica reaction (ASR), transportation structures.
INTRODUCTION

In early 2009, the Massachusetts Department of Transportation (MassDOT) identified 40 structures that have the potential for alkali-silica reaction (ASR) due to the use of suspect reactive aggregates (Figure 1). These structures include structural elements of major and minor bridges, highway sign foundations, strain pole foundations, highway sound barrier foundations, sidewalks, etc. Thus, MassDOT undertook a research program and retained Simpson Gumpertz & Heger Inc. (SGH) to develop a means of managing the potential effects of any ASR.

The objective of the project is to establish a protocol for field inspection and diagnosis of ASR, evaluation of the extent of any ASR-related damage and its potential effect on the structure, monitoring of its progression, and long-term management of each affected structure.

FIGURE 1 ASR testing and evaluation program – structure locations

BACKGROUND OF ASR

What is Alkali-Silica Reaction (ASR)?

Alkali-silica reaction (ASR) is one of the most-common causes of concrete deterioration and occurs when certain types of silica-containing reactive aggregates (typically strained quartz, chert, and greywacke) react with the hydroxyl and alkali ions in the concrete to form a silica gel. The gel absorbs significant quantities of water, causing it to swell and crack the aggregates and surrounding cement paste. The gel can then migrate into the cracks where it can absorb additional water and continue swelling and causing additional cracking and interconnection of the cracks. ASR will continue as long as the concrete contains a sufficient supply of alkalis and has a relative humidity above approximately 85%. Moisture fluctuation can exacerbate the signs of distress.
ASR was first recognized in 1940 publications by Thomas Stanton. Since its discovery, ASR has been reported to affect various structures around the world. Although New England concrete aggregates were thought to have been of generally high quality and ASR-free, reports of ASR in New England are becoming more frequent as concretes with slowly reactive New England aggregates age and newer concretes use less reliable aggregate sources.

**Effect of ASR Distress on the Physical Properties of Concrete**

ASR-affected concrete deterioration is primarily characterized by internal expansion leading to an interconnected network of cracks. This deterioration affects physical properties of concrete including compressive and tensile strength and the modulus of elasticity. The Institution of Structural Engineers (ISE 1992) published physical properties measured on unrestrained concrete specimens for various amount of free expansion as summarized in Figure 2 below.

![Residual mechanical properties vs. free expansion](image)

**FIGURE 2** Residual mechanical properties vs. free expansion, from ISE 1992 (1), Table 4.

**Guidelines on Assessment and Management of ASR-affected Structures**

Unlike other concrete deterioration processes such as cyclic freeze-thaw deterioration or corrosion of reinforcing bars, ASR cannot be easily treated or mitigated because the three conditions, alkali (from cement), reactive silica (from aggregates), and moisture (from rain or groundwater), are typically present in the concrete and difficult to eliminate after construction. However, typical ASR-induced concrete deterioration is a gradual process that changes the properties of concrete over time. A concrete structure undergoing ASR can often still serve its intended purpose and design functions until a limiting state (structural, aesthetic, or loss of function) is reached; therefore, many owners initiate programs to assess and manage ASR-affected structures.

Protocols for managing the ASR are not well developed, but available options range from long-term structural-health monitoring and evaluation to structural retrofits or structure...
replacement. Two primary guidelines, providing for diagnosis and prognosis for ASR distress in transportation structures and typical building and parking structures, are as follows:

- **FHWA-HIF-09-004 (2)** – This report provides a basis for the correlation of visible distress and deterioration in concrete structures to ASR, prescribes Cracking Index (CI) and cracking criteria to identify the extent of the ASR distress, describes the reductions of mechanical properties of concrete affected by ASR, and discuss the strategies for its management. ASR distress is quantified based on damage levels seen in many transportation structures.

- **ISE 1992 (1)** – This document provides standardized classifications and tables to assist the user in rating the effects of ASR distress and in developing a management plan. It recommends a customized response based on multiple characteristics and key parameters, including expansion index, site environment, reinforcement details, and consequence of failure. This document provides some of the basis for FHWA-HIF-09-004 (2).

According to both documents, after ASR is diagnosed, the CI can be used to estimate the expansion to date in the ASR-affected concrete. As described in these References, the CI is obtained by measuring and summing the crack widths along a set of lines drawn on the surfaces of a concrete member. Both documents also describe an expansion monitoring method that works in concert with the CI to allow for periodic in situ monitoring of expansion, providing a comparative and quantitative rating of any future ASR-induced expansion or deterioration.

In addition, AASHTO PP 65-11 (3) can be useful in the evaluation of the ASR-affected structures. This standard provides a process for determining aggregate reactivity and selecting measures for preventing deleterious expansion in new concrete construction. This process consists of classifying the aggregate reactivity, the exposure, and the severity of the consequences of the structures due to ASR deterioration, and using two provided tables to determine the appropriate mitigation measures. Although the standard is intended to address new construction, its classifications and guidelines are useful in evaluating the obtained information from ASR-affected concrete.

**ASR INSPECTION AND EVALUATION PROTOCOL**

The general approach of the MassDOT ASR inspection and evaluation protocol, based upon the work conducted by the FHWA and ISE, is illustrated as a flowchart in Figure 3 and described in the following sections.
FIGURE 3 ASR inspection and evaluation protocol flow chart

Cracking Criteria:
Cracking Index > 0.0018 in./yd
OR
Crack Widths > 0.006 in.
Preliminary Field Assessment

SGH visited each of the 40 structures to conduct a field investigation, focusing on the ASR-related concrete deterioration. At each structure, SGH performed the following tasks:

- **Visual Observations** - The main objective of the visual survey was to review the exposed concrete surface and to investigate if the concrete structure exhibits common visual symptoms of ASR, such as apparent pattern-cracking, broad brownish zone and damp appearance at cracks, pop-outs of reactive aggregate, ASR gel exudation, as well as structural deformation and relative movement and displacement. Figure 4 illustrates typical visual symptoms of ASR on some MassDOT structures. If the concrete structure is suspected to have been affected by ASR, it is important to document the degree and extent of the ASR deterioration, typical crack width, and exposure condition of the concrete structure or various structural elements.

- **Cracking Index (CI) Measurements** - If the concrete structure is suspected to have been affected by ASR and the cracking condition appears to have exceeded the CI criteria (CI value greater than 0.018 in./yd or any individual crack widths greater than 0.006 in.), CI measurement at each structure or structural element is warranted. The objectives of the CI measurements were to establish a baseline of the extent of cracking in a structure member (expansion-to-date), to evaluate the strength and durability of the existing concrete, and to quantitatively monitor the propagation of crack widths and expansion of the concrete. At each CI location, the task involves documenting the concrete condition, conducting CI measurements using an optical magnifying comparator at each reference line of four interconnected 10 in. by 10 in. square reference grids on the concrete surface (Figure 5), and installing gage points at the corners of the reference grids to allow baseline expansion monitoring measurements to be made.
Core Sampling - If the concrete structure is suspected to have been affected by ASR, core samples from representative ASR-distressed areas were extracted for use in petrographic examination and to determine the Damage Rating Index (DRI).

Supplemental Laboratory Evaluation

If the concrete structure exceeded the established cracking criteria CI and ASR would not have a “negligible” effect on the structure (as defined later in Table 1), a sampling and supplemental laboratory investigation was undertaken using the following techniques.

Petrographic Examination - The main objective of the petrographic examination is to diagnose the potential cause(s) of the concrete deterioration (ASR, freeze-thaw, shrinkage, etc.), to examine the pattern of internal cracking (depth, presence in the aggregates) and the presence and distribution of the reaction product (ASR gel, reaction rim), and to evaluate the quality of the concrete (water to cement ratio, cement shortage, air content, and the presence of other cementitious materials such as fly ash or slag, etc.). In each case, the detailed petrographic and microscopic examinations were conducted in accordance with applicable procedures outlined in ASTM C856 – Petrographic Examination of Hardened Concrete. Typical petrographic features of ASR, as observed from ASR-affected MassDOT structures, include reactive rims around the aggregate, internally fractured aggregate, fractures extending from aggregate into the surrounding paste structure, or the presence of ASR gel. Figure 6 illustrates the microstructure of ASR-affected concrete from an ultrathin section under a magnification of 50X.
Determination of Damage Rating Index (DRI) - In addition to petrographic examination, DRI tests were used on the polished sections from the core samples to quantify the degree of ASR-related damage and to evaluate the overall condition of the concrete below the exposed surface. The DRI method was developed by Dr. Grattan-Bellew in the 1990s. It evaluates the condition of concrete by counting the number of typical petrographic features of ASR on polished concrete sections at a magnification of 16X. The DRI is a quantitative representation of a normalized (to an area of 16 sq in.) count of these features each of which is weighted to represent its relative importance in the overall deterioration process. A review of two DRI research publication (4, 5) for laboratory and field specimens indicate that typical ASR-damaged concretes exhibit DRI values of 250 to 370, with an extreme reported value of 670. The typical DRI values on the polished sections from ASR-affected MassDOT structures fall within this boundary range, suggesting that a minor to appreciable degree of ASR has been occurring on these structures. Figure 7 illustrates typical DRI test results from two concrete samples from pole foundations for overhead signs that were affected by minor-to-moderate ASR.
FIGURE 7 Damage Rating Index (DRI) of polished sections from two concrete samples from pole foundations for overhead signs.

ASR Risk Assessment and Management Planning
In addition to providing the methodology for the field and laboratory testing, the protocol provides a framework for consistent interpretation of the test results. This was a critical component of the protocol because it provided clear “next steps” for the field personnel responsible for the structures, but who may not be familiar with ASR and its effects. As described in the following sections, the protocol provides a consistent response that is commensurate with the severity of the ASR, the potential effect of any ASR on the structure, the degree of existing ASR, and the severity of the exposure of the structure.

Basis documents for assessment
The AASHTO PP 65-11 (3) and ISE 1992 (1) provided base concepts for the risk assessment and planning portion of the protocol. In particular:

- The AASHTO PP 65-11 (3) document provided the concept of establishing an ASR risk level by using the potential concrete expansion, exposure condition, and structural classification to provide a recommended level of ASR prevention and mitigation to achieve a typical service life.
- The ISE 1992 (1) document provided the concept of evaluating key in-service parameters, including expansion index (I through V), site environment (dry, intermediate), reinforcing detailing class (1 through 3), and consequence of failure (slight and significant), to establish an ASR severity rating on which a management plan can be based for each specific ASR-affected structure.

SGH Assessment and management of ASR – affected structures
While the AASHTO PP 65-11 (3) standard and ISE 1992 (1) provide very useful information on ASR assessment and associated management strategies, these approaches and management
strategies are not directly suitable to manage ASR-affected MassDOT structures due to the following reasons:

- The AASHTO PP 65-11 (3) only provides preventive measures for new construction, and does not provide direct information about ASR assessment of existing ASR-affected structures.
- The “consequence of failure” classifications in the ISE 1992(1), “slight” and “Significant,” are too limited to efficiently apply to the variable types of the MassDOT structures. Defining “failure” due to ASR-distress is difficult, and may mean different things (such as reduced serviceability or appearance, loss of bond, large-scale concrete spalling that may cause personal injury, or increased structural risk of unknown degree) to different users.
- The ISE management strategies are very demanding and impractical and do not align with other MassDOT risk management practices. For example, the 2 and 4 month inspection frequency given by the ISE 1992 (1) for ASR ratings of “severe” and “moderate”, respectively, would require a diversion of resources from other projects not commensurate with the actual risk. Similarly, the ISE requirement to perform monthly detailed inspections and monitoring of cracks and to perform a full investigation of the structural detailing for “severe” ASR would similarly require that resources be diverted from structures that present a greater overall risk.

To account for the role of key parameters, including the consequence of failure, expansion characteristics, environmental exposure, and reinforcement detailing, on the expected performance of ASR-affected structures and to direct the associated management strategies, the evaluation protocol developed for the project incorporated them into the custom evaluation matrices shown in Table 1-“Severity Ratings of ASR-Affected MassDOT Structure or Element” and Table 2 - “Assessment Rating and Management Plan for ASR-Affected MassDOT Structure or Element” to guide the management of MassDOT’s ASR-affected structures. These two tables were based on the ISE 1992 (1); but modified to incorporate additional factors that are relevant to typical MassDOT structures. Table 1 describes a proposed procedure to rate the severity and importance of ASR on the element or structure based on all the affecting parameters described above, and Table 2 provides a management plan based on the ASR rating.
## TABLE 1 Severity Ratings of ASR-Affected MassDOT Structure or Element

<table>
<thead>
<tr>
<th>Rating</th>
<th>Negligible</th>
<th>Minor</th>
<th>Significant Property Value/ Personal Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ample Warning</td>
<td>Sudden Failure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>Fair</td>
<td>Poor</td>
</tr>
</tbody>
</table>

### Reinforcing Detailing Class

- **Good**: Stirrups, hooked ends, or welded laps
- **Fair**: Conventional (corner lapped stirrups)
- **Poor**: no through ties, no or side-lapped stirrups

### Expansion Index

**I**: < 0.5 mm/m (0.018 in./yd)
- Good – Stirrups, hooked ends, or welded laps

**II**: 0.5 mm/m – 1.0 mm/m (0.018 in./yd – 0.036 in./yd)
- Fair – Conventional (corner lapped stirrups)

**III**: 1.0 mm/m – 1.5 mm/m (0.036 in./yd – 0.054 in./yd)
- Poor – no through ties, no or side-lapped stirrups

**IV**: 1.5 mm/m – 2.5 mm/m (0.054 in./yd – 0.090 in./yd)
- *For classification, assume typical reinforcement details were used if drawings are unavailable.*

**V**: > 2.5 mm/m (0.090 in./yd)

### Exposure

**Mild** (Dry environment, internal RH < 75%)

- I
- II
- III
- IV
- V

**Intermediate** (Internal RH between 75% ~ 85%; vertical surfaces w/o exposure to deicing salts; Ex. pier caps, sound walls, above-grade columns and piers)

- I
- II
- III
- IV
- V

**Severe** (Wet environment, deicing salt exposure, horizontal surfaces; ex. retaining walls, foundations, abutments, decks, barrier walls)

- I
- II
- III
- IV
- V

### Effect of ASR on Function

- **Negligible**: No structural implications or safety concerns beyond those of non-ASR-affected concrete (sidewalks, aprons, etc).
- **Minor**: Only a limited portion of the element is affected by ASR.
- **Significant**: ASR damage will cause no significant loss of performance.
- **Property Value/Personal Injury**: ASR damage does not pose a risk of personal injury due to sudden failure.
- **Redundant**: Significant redundancy exists within a large structural element or element is redundant within the overall structure.
- **Gradual**: No or only gradual change in effect of ASR damage expected within the next 4 years.
- **Ample Warning**: “Ample warning” – Effect of ASR will occur with noticeable advance warning such as significant cracking, deflection or displacement. This will typically be the case for bridge decks, bridge piers, foundation walls, abutment walls, barrier rails etc);
- **Sudden Failure**: “Sudden failure” – Effect of ASR will occur with no advance warning. This will typically be the case for pre-stressed elements and shear- and development-based modes, including anchorage, localized bearings, and shear-controlled bearings.

Note: *This also includes the cases that “minor” does not apply for entire structure or an element.*
# TABLE 2 Assessment Rating and Management Plan for ASR-Affected MassDOT Structure or Element

<table>
<thead>
<tr>
<th>Color code</th>
<th>Rating</th>
<th>Effect of ASR on Performance of Element or Structure</th>
<th>Management Plan</th>
</tr>
</thead>
</table>
|            | 0      | Negligible                                           | • No ASR-specific response required.  
|            |        |                                                      | • Reassess only if new information or changes are noted in course of other routine work. |
|            | 1      | Minor                                                | • Visually inspect *every two years* for signs of large changes in condition (new spalling, staining, “alligator cracking” with cracks wider than 1/32 in.)  
|            |        |                                                      | • For bridge structures, add note to NBIS report to alert inspectors of potential ASR during future inspections.  
|            |        |                                                      | • If possible, minimize moisture intrusion to increase service life.  
|            |        |                                                      | • Repeat detailed ASR inspection and risk assessment during second MassDOT NBIS inspection cycle for bridges or after 4 years for structures not covered by routine inspections. |
|            | 2      | Moderate                                              | • Visually inspect annually for signs of large changes in condition (new spalling, staining, “alligator cracking” with cracks wider than 1/32 in.)  
|            |        |                                                      | • If possible, minimize moisture intrusion to increase service life.  
|            |        |                                                      | • Perform detailed crack survey and CI measurements as part of NBIS inspections for bridges or with local staff for other structures *every two years* and repeat ASR risk assessment. If a new ASR rating is assigned, modify current management plan and act accordingly. |
|            | 3      | Appreciable                                           | • Visually inspect and perform detailed crack survey and CI measurement *every six months* until implementation of a management and maintenance plan.  
|            |        |                                                      | • Prepare and implement a structure-specific management and maintenance plan. This may include one or more of the following options depending on factors such as the expected time to scheduled replacement, replacement value of the structure(s), relative cost analysis, and local monitoring capabilities.  
|            |        |                                                      |   • Structural analysis and evaluation and/or prediction of remaining service life using reduced concrete properties due to ASR distress. This option may require additional field investigation, non-destructive testing, and extensive laboratory testing to determine reduction of concrete properties and potential future ASR expansion.  
|            |        |                                                      |   • Formal monitoring with a scheduled frequency, if indicated by structural analysis and evaluation. This option may require using additional monitoring techniques, such as “tell-tale” markers or crack displacement gages.  
|            |        |                                                      |   • Permanent repair and/or strengthening.  
|            |        |                                                      |   • Replacement of the structure. |
|            | 4      | Significant                                           | • Visually inspect and perform detailed crack survey and CI measurement *every three months* until implementation of a management and maintenance plan.  
|            |        |                                                      | • Prepare and implement a structure-specific management and maintenance plan, as described for “Rating 3” above. |
CASE STUDIES

The implementation of the protocol on three MassDOT structures is presented below.

Case Study 1

The subject concrete components are sidewalks, handicap ramps, median islands, and traffic signal foundations. They are located at the intersection of Plymouth Street and the Exit 7 ramp of Route I-195 Eastbound. The structure was constructed about 12 years ago and it has been exposed to weathering, moisture, and splash/spray roadway deicing salts since.

Visual observations on the exposed concrete surfaces indicated that the concrete was in good condition with none-to-minor indications of common visual symptoms of ASR. There were no visual indications of expansion-related distress and the structural significance is low in this case. Since the cracking condition was below the threshold required to justify further field sampling or testing, based on ASR Inspection and Evaluation Protocol Flow Chart (Figure 3), CI measurements or core sampling or laboratory testing was not performed at this structure.

The key parameters were determined as follows:
- Exposure Condition = “Severe”
- Expansion Index = “I”
- Effect of ASR on Function = “Negligible”
- Reinforcement Detailing Class = “Poor”

Using the ASR assessment rating system and management plan (Tables 1 and 2), this potentially ASR-affected structure was determined to have an ASR severity rating of “0 – Negligible” with no ASR-specific response required.

Case Study 2

The subject concrete components are pole foundations for cantilevered sign posts located along Rte 24 between Bridgewater and Freetown. The structures were constructed about 12 years ago, and have been exposed to weathering, moisture, and splash/spray roadway deicing salts since.

Visual observations on the exposed portions of three concrete foundations indicated that the concrete exhibited common visual symptoms of ASR. The crack widths of the suspect pattern cracking varied from 0.003 in. (very fine cracking) to 0.040 in. (prominent cracking). There were no visual indications of expansion-related distress, such as anchor-bolt movement/slippage or large-scale concrete spalling that would indicate impairment of the current structural integrity. Since the cracking condition has exceeded the threshold required to justify further field sampling or testing, CI measurements were performed at representative cracking area of two pole foundations and core samples were extracted at three pole foundations. The CI results on two sign foundations ranged from 0.053 in./yd to 0.093 in./yd, significantly greater than the CI threshold (0.018 in./yd). Petrographic examination on three core samples indicated that the concrete exhibited extensive pattern-cracking due to ASR and DRI tests on polished sections from two core samples showed that the DRI value ranged from 447 to 559. Overall, the field investigation and laboratory testing concluded that the concrete in these pole foundations exhibited moderate-to-severe ASR.

The key parameters were determined as follows:
- Exposure Condition = “Severe”
- Expansion Index = “V”
Effect of ASR on Function = “Significant Property Value/Personal Injury – Sudden Failure”

Reinforcement Detailing Class = “Good”

Using the ASR assessment rating system and management plan (Tables 1 and 2), these ASR-affected sign foundations were determined to have an ASR severity rating of “4 – Significant.” This requires visually inspect and perform detailed crack survey and CI measurement every three months until implementation of a structure-specific management and maintenance plan, such as structural analysis and evaluation and/or prediction of remaining service life using reduced concrete properties due to ASR distress, formal monitoring with a scheduled frequency if indicated by structural analysis and evaluation, permanent repair and/or strengthening, or replacement of the structure.

Case Study 3

The subject concrete components are concrete elements, including concrete deck, center pier and pier cap, and parapet walls, on the Miller Street Bridge over Interstate 495 in Middleborough, MA. The structures were constructed about 15 years ago, and have been exposed to weathering, moisture, and splash/spray deicing salts since construction.

Visual observations on the exposed concrete surfaces of these structural elements indicated that the suspect pattern-cracking was primarily located at the edges of the concrete deck with minor instances on the center piers and parapet walls. There were no visual indications of expansion-related distress (such as displacement between the concrete deck and parapet walls, or large-scale concrete spalling) impairing the structural integrity. Since the cracking condition has exceeded the threshold required to justify further field sampling or testing, CI measurements were performed and core samples were extracted at representative cracking area of each structural element. The CI results ranged from 0.143 in./yd to 0.166 in./yd on the south nose of the center pier cap, ranged from 0.042 in./yd to 0.049 in./yd on the north edge of the concrete deck, and ranged from 0.059 in./yd to 0.125 in./yd on the south parapet wall. Petrographic examination reveals that the concrete extracted from the parapet wall, does not have any indications of ASR distress; however, the concrete has the potential for developing ASR due to the use of the reactive aggregate. All of the evidence from the core sample extracted from the edge of the bridge deck consistently indicated a minor-to-moderate degree of ASR damage and possible cyclic freezing-thawing damage. DRI tests on polished sections from two core samples extracted from the concrete deck showed that the DRI value ranged from 153 to 264. Overall, the field investigation and laboratory testing concluded that the concrete in the bridge deck, center pier and pier cap exhibited moderate-to-severe ASR, while the concrete in the parapet walls did not exhibit ASR distress but has the potential for developing ASR.

The key parameters were determined as follows:

**Center Pier and Pier Cap**

- Exposure Condition = “Severe”
- Expansion Index = “V”
- Effect of ASR on Function = “Significant Property Value/Personal Injury – Ample Warming”
- Reinforcement Detailing Class = “Good”

**Concrete Deck**

- Exposure Condition = “Severe”
• Expansion Index = “III”
• Effect of ASR on Function = “Significant Property Value/Personal Injury – Ample Warming”
• Reinforcement Detailing Class = “Fair”

Parapet Walls
• Exposure Condition = “Severe”
• Expansion Index = “I”
• Effect of ASR on Function = “Significant Property Value/Personal Injury – Ample Warming”
• Reinforcement Detailing Class = “Fair”

Using the ASR assessment rating system (Table 1), the center pier and pier cap were determined to have an ASR severity rating of “3 – Appreciable,” the concrete deck was determined to have an ASR severity of “2 – Moderate,” and the parapet walls were determined to have an ASR rating of “1 – Minor.” Specific management plan, in accordance with Table 2, should be applied to the various structural elements of this bridge structure accordingly.

CONCLUSION
Although ASR cannot be easily treated or mitigated, concrete structures undergoing ASR can still serve their intended purpose provided that the effects of the ASR are understood, monitored, and managed.

Through this study, MassDOT developed an ASR inspection and evaluation protocol, including preliminary field assessment (visual observations, cracking index measurements, core sampling), supplemental laboratory testing (petrographic examination and damage rating index), and ASR risk assessment and customized management strategies for various ASR-affected MassDOT structures (Tables 1 and 2). In addition to providing the methodology for the field and laboratory testing, the protocol provides a framework for consistent interpretation of the test results that is commensurate with the severity of the ASR, the potential effect of any ASR on the structure, the degree of existing ASR, and the severity of the exposure of the structure.

Using this protocol, MassDOT was then able to evaluate 40 structures suspected of containing ASR-affected aggregates.
REFERENCES


