Dealing with ASR in Concrete Structures

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Alkali-silica reactivity (ASR) is a durability problem that has resulted in premature deterioration of various types of concrete structures in the United States and throughout the world. Supplementary cementitious materials have been used for more than 50 years for preventing damage to concrete structures by controlling the expansion due to ASR. In recent years, lithium compounds have been used as an additive in concrete mixtures.

ASR-induced damage is caused by the expansion resulting from the chemical reaction between the alkali and silica in the mixture in the presence of moisture. ASR damage in concrete structures is evidenced by the map-like cracking on the surfaces, surface discoloration and gel exudations, and the displacement of components.

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) established funding for further development and deployment of techniques to prevent and mitigate ASR. In response to this act, the Federal Highway Administration (FHWA) initiated an ASR Development and Deployment Program to focus on preventing and mitigating ASR in concrete bridges, pavements, and other highway structures, such as median barriers and retaining walls.

Elements Essential for ASR

Three elements are essential for ASR to occur: reactive silica (from aggregates); alkalis (mainly from portland cement); and moisture (from drainage, leakage and/or high humidity). To effectively combat ASR, one or more of these elements must be controlled or eliminated.

Reactive Silica

The presence of reactive aggregates or another reactive silica source in concrete is necessary for ASR to occur. The term *reactive* refers to aggregates that tend to breakdown under exposure to the highly alkaline pore solution in concrete and subsequently react with the alkalis (sodium and potassium) to form an expansive ASR gel.

Alkali

The presence of sufficient alkalis is another required ingredient for ASR. Portland cement is considered the main contributor of alkalis. Other ingredients that may contribute to additional alkalis are fly ash, slag, silica fume, aggregates, chemical admixtures, seawater, and deicing chemicals.

Moisture

The presence of moisture is necessary to cause the damaging effects of ASR in concrete structures. Concrete mixtures comprised of highly reactive aggregates and high-alkali cements have shown little or no expansion in certain very dry environments. Similarly, portions of the structure exposed to a constant or steady source of moisture have exhibited significant ASR-induced damage, while other portions of the structure that remain essentially dry have shown little or no damage.

Preventing or Mitigating ASR

Several viable methods exist to prevent ASR in new concrete structures, such as

- use of only low- or non-reactive aggregates,
- use of low-alkali cement, or the addition of supplementary cementitious materials such as fly ash, slag, or silica fume, and
- addition of lithium.

Very few methods are available for mitigating further damage in structures already affected by ASR-induced expansion and cracking.

Mitigating ASR in Existing Concrete

Lithium has been shown in limited laboratory studies to have the potential of suppressing the expansion caused by ASR. Field studies have been conducted to introduce lithium into existing concrete:

- Topical treatment—applying lithium to the surface and allowing the lithium to penetrate the concrete
- Electrochemical migration with lithium as electrolyte—using the electrochemical chloride extraction method with lithium as an electrolyte
- Vacuum impregnation—similar to topical treatment, except a vacuum is used to enhance deeper penetration of the lithium into the concrete

However, to-date the field application of lithium has proved to be challenging and in most cases has not proved to be effective in suppressing ASR.

Signs of ASR-induced damage. Photo: Courtesy of Texas Department of Transportation. Copyright © 2002. All rights reserved.

Other methods to mitigate the effects of ASR are being studied in the field, such as the application of sealers or coatings to limit ingress of moisture and reduce the internal humidity of the structure and restraining or confining expansion of the structure elements. Other methods that should be considered for mitigating the effects of ASR are:

- treating existing cracks to minimize future expansion and avoid ingress of moisture, deicing salts, and the like,
- avoiding the use of deicing salts high in alkali content,
- providing proper drainage, and
- sealing leaks.

The FHWA ASR Development and Deployment Program

The FHWA ASR Development and Deployment Program was initiated through SAFETEA-LU funding and addresses the needs of stakeholders. More information was needed on test methods and specifications to control reactive aggregates and ASR in new concrete structures and the methods and techniques to mitigate the effects

Application of Carbon Fiber Reinforcement Polymer (CFRP) wrap to a bridge column. Photo: Federal Highway Administration.

of ASR in existing concrete structures. As a result the program includes a number of initiatives:

- Providing a central location for information pertinent to ASR
- Developing documents to guide practitioners in designing concrete mixtures resistant to ASR and identifying ASR in field structures
- Conducting field trials to further explore methods and techniques to mitigate the effects of ASR in existing structures

More information on the program can be found at: http://www.fhwa.dot.gov/pavement/concrete/asr.cfm.

ASR Reference Center

The ASR Reference Center is a central location that houses numerous documents specifically on ASR. Topics include the basic mechanism of ASR and methods for detection, research reports, ASR specifications from the United States and throughout the world, guidance documents, and a special section on case studies. The case studies highlight various ASR field trials and studies. The ASR Reference Center can be found at: http://www.fhwa.dot.gov/pavement/concrete/asr/reference.cfm.

Application of elastomeric paint to a median barrier. Photo: Federal Highway Administration.

Reports for Additional Support

FHWA put out several publications this summer from the ASR Development and Deployment Program. *The ASR Field Identification Handbook* will assist in the identification of ASR in field structures. The *Alkali Silica Reactivity Surveying and Tracking Guidelines* outlines a process to survey and track structures with ASR. In addition, a report discussing the field trials conducted under the program and suggested methods and techniques to mitigate the effects of ASR is scheduled to be published in the spring of 2013. Reports will be posted on FWHA's web site: http://www.fhwa.dot.gov/pavement/concrete/asr.cfm.

FHWA Publications

Report No. FHWA-HIF-09-001

The title of this report is: *Report on Determining the Reactivity of Concrete Aggregates and Selecting Appropriate Measures for Preventing Deleterious Expansion in New Concrete Construction*. This report provides both a performance and a prescriptive-based approach for preventing ASR in new concrete structures. This report is the basis for the AASHTO Provisional Standard PP 65-11 *Determining the Reactivity of Concrete Aggregates and Selecting Appropriate Measures for Preventing Deleterious Expansion in New Concrete Construction*.

Report No. FHWA-HIF-09-004

The title of this report is: *Report on the Diagnosis, Prognosis, and Mitigation of Alkali-Silica Reaction (ASR) in Transportation Structures*. This report provides information on detecting ASR in the field, confirming the presence of ASR through laboratory tests, and an approach for the quantification of expansion to-date, current expansion rate, and the potential for future expansion. This report also briefly discusses mitigation measures for structures with ASR.

Recommended Actions

New Structures

- Use only low- or non-reactive aggregates
- Use low-alkali cement
- Add supplementary cementitious materials such as, fly ash, slag, or silica fume; or lithium admixtures
- All or combination of the above

Existing Structures

- Test for potential reactivity of aggregates and alkali reactivity of cement-aggregate combinations
- Perform petrographic examination on cores
- Test mitigation strategies in the field to find the most effective remediation methods
- Develop specifications for performing the repair
- Estimate the remaining service life after repair and the cost effectiveness of the proposed repair
- Repair or replace ASR affected components of structures as appropriate

Closing Remarks

ASR is a problem, but several methods are available for preventing and mitigating ASR-induced expansion, including the use of nonreactive aggregates, low-alkali concrete, supplementary cementitious materials, and lithium compounds. In response to the SAFETEA-LU legislation, FHWA, in cooperation and collaboration with AASHTO, NCHRP, and the transportation industry, has been actively developing and implementing research, deployment, and education programs to prevent and mitigate the problems associated with ASR.

EDITOR'S NOTE

More information on the FHWA's guide to identifying ASR can be found in the August 2012 issue of Focus located at www.fhwa.dot.gov/publications/focus/index.cfm and click on Past Issues.