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Reactive Solutions

An FHWA Alkali-Silica Reactivity News Publication

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Got ASR?

Mitigation Options for Concrete Structures Affected by ASR

Kevin J. Folliard, Ph.D.
Associate Professor
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Ever since alkali-silica reaction (ASR) was discovered by Thomas Stanton in the 1940's, it has become a problem that has plagued concrete structures throughout the world, and highway pavements and structures in the United States have not escaped this plight. Although great progress has been made in developing and implementing preventive measures for new concrete construction (i.e., use of supplementary cementing materials (SCMs), low-alkali concrete, etc.), there are many existing structures already suffering from ASR. Unfortunately, options for extending the service life of ASR-affected structures have not been studied, implemented, or monitored to the extent that preventive measures for new concrete construction have, and as such, there is no clear consensus on how best to deal with these afflicted structures. Research funded by FHWA is aiming to fill in these missing gaps through several ongoing and planned field trials. This article briefly summarizes some of the candidate methods that may be considered for ASR-affected concrete structures.

When attempting to extend the service life of ASR-affected concrete, one can attempt to address the causes of this reaction or the symptoms of the reaction. To address or counteract the underlying causes of ASR, it is important to note that the three necessary components of ASR include (1) availability of moisture, (2) presence of reactive aggregates, and (3) availability of sufficient alkalies to drive and sustain the reaction. Removing or eliminating any of these three components will effectively halt the progression of ASR.

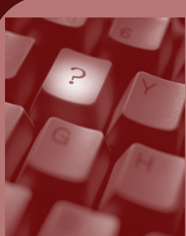
The most feasible and commonly employed approach for field structures is to attempt to remove water from within the concrete through improved drainage or the application of claddings, coatings, or sealers. The application of silane (or siloxane) compounds has been found to be particularly effective in field applications – these products work by preventing water from entering the concrete while still allowing internal water vapor to escape, thereby reducing the internal relative humidity within the concrete. If the relative humidity within concrete can be reduced below about 80 percent, ASR-induced expansion can be halted. Although it is not possible to remove reactive aggregates or alkalies from the concrete (components 2 and 3 from above), it has been shown that lithium compounds can be used to treat existing concrete by altering the nature of the ASR gel and hence rendering it non-expansive. Laboratory research has shown that it is possible to reduce expansion by treating small laboratory specimens by immersing them in lithium nitrate solution; however, there is little, if any data, from field trials showing similar beneficial effects. The largest impediment to translating this technology to real-world applications has been the general lack of penetration of lithium when applied topically to pavements and other transportation structures; however, significant lithium penetration has been measured when electrochemically driving lithium into concrete. Because lithium has shown promise in laboratory studies, work is underway, funded by FHWA, that is focusing on methods of driving lithium into concrete through electrochemical means. (*cont. on pg.4*)

Editor's Corner

Dear Readers,

This issue focuses on the treatment of concrete structures suffering from alkali-silica reaction (ASR). As the article from Dr Folliard points out – it is much easier to prevent ASR in the first place through appropriate testing and selection of materials than it is to halt the reaction once it has begun. However, there are strategies for slowing down the reaction, reducing the rate of expansion and mitigating the symptoms, although the efficacy of the different techniques varies widely and, in some cases, there is little information to confirm some strategies actually make a significant difference to the performance of the structure. Hopefully some of the field and laboratory studies presented in this newsletter will help identify the most promising technologies for extending the life of ASR-affected structures.

Dr. Michael Thomas, University of New Brunswick



A.sk
S.end
R.eceive

This Issue's Question

Do you know of any new specifications dealing with ASR?

Submit your answers to: asrnewsletter@transtec.us

An Update on Federal Highway's ASR Development and Deployment Program

ASR Research Progress

A detailed research project to develop Alkali Silica Reaction (ASR) products and technologies was advertised at the federal government website www.fbo.gov in January 2008 composed of four major objectives. A technical panel meeting was held in late April 2008, and based on the recommendations received, Professional Service Industries (PSI) and The Transtec Group were selected as the contractors to perform the research. This contract will be in place for four years.

PSI has two subcontractors - Purdue University and Clemson University - and will perform research on the following two objectives:

Objective 1: Advancing the fundamental understanding of ASR mechanism and develop a concrete mixture design process resistant to ASR phenomenon

Objective 2: Developing reliable improved rapid laboratory test method to evaluate concrete mixture design to predict field performance.

For more information, contact Paul Virmani at: Paul.Virmani@fhwa.dot.gov

Transtec has number of subcontractors - Universities of Texas, New Brunswick, Laval, and Sherbrooke, Vector Corrosion, Olson Engineering and Structural Preservation Systems - and will perform research on the remaining objectives 3 and 4:

Objective 3: Non-destructive field test methods for evaluation of concrete structures for: presence of ASR; concrete deterioration rate and predict future expansion

Objective 4: Develop cost effective methods to control ASR and extend service life of existing highway structures.

9th International Conference on Concrete Pavements

The 9th International Conference on Concrete Pavements (ICCP) was held August 17-21, 2008. The conference featured 18 technical sections with presentations from authors of accepted technical papers and invited speakers. Ten "Hot Topic" workshops were held to provide a more relaxed atmosphere and obtain a global perspective on various issues facing the engineering community.

One of the workshops featured was titled "Alkali-Silica Reactivity-Latest Research". Presenters included representatives from the FHWA, Navy Facilities Engineering Service Center, Delaware Department of Transportation, South Dakota Department of Roads, Texas A & M University, and FMC Corporation. Presentations included information being developed by FHWA on the prevention of ASR and various test methods and various analysis techniques to determine aggregates reactivity and potential for ASR reactivity of concrete mixtures. The workshop concluded with a panel discussion on test methods and methods to prevent ASR in new concrete structures. It is clear that more work is needed to address all of the ASR concerns that engineers and practitioners face. Keeping an open dialogue through workshops such as this will help advance our efforts to protect our structures from ASR.

For more information on the conference visit: http://www.concretepavements.org/Membership/Newsletter/ISCP_enewsletter_Vol5_No4.htm

Response to Last Issue's A.S.R.

"Is there one specific test that your state uses that lets you know you have ASR?"

Minnesota DOT uses ASTM C1260 to determine ASR potential, only on the sand. Previous testing by the state using C1293 determined the reactivity of known coarse aggregates. They also list their data testing numerous sands across the state with various cements, ash and GGBF slag. They have a flow chart to follow in making the decision on what mitigation method to use based on the percent expansion.

Submitted by: Ken Prom

Senior Engineering Technician, American Engineering Testing Inc.

Mitigation Case Studies Around the Nation

Electrochemical Lithium Treatment

David Whitmore, P.Eng.
Vector Corrosion Technologies

Houston, Texas - TexasDOT and FHWA funded a project to evaluate different methods of treating concrete bridge structures suffering from Alkali Silica Reactivity (ASR). The principal work was completed on the substructure of the I-10 Katy Expressway in Houston, TX. Various methods were evaluated including surface treatments, vacuum impregnation and electrochemical lithium impregnation.

Electrochemical lithium treatment is completed using the Norcure process and utilizes a low voltage direct current electric field to draw lithium ions into reinforced concrete structures. When treatment is complete, the system is removed allowing the structure to remain in service without any permanent installation or maintenance requirements. The I-10 Katy Expressway Project studied the application and monitored the performance of the various treatments. This project demonstrated the ability of Electrochemical Lithium Impregnation to drive sufficient lithium into the concrete to mitigate ASR. The Electrochemical method shows promise to treat and extend the service life of reinforced concrete bridge structures which are suffering from ASR.

Topical Lithium Treatment

Michael D.A. Thomas, Ph.D.
University of New Brunswick

Mountain Home, Idaho - In September 2004, a 3-mile-long section of I-84 was treated topically with lithium nitrate (30% solution) at an application rate of 0.24 L/m² (6 gal./1000 ft²); see Figure 1. Approximately two thirds of this section was treated a second time in the Spring of 2005 and one third of the 3-mile section was treated a third time in the Fall of the same year. The application rate was in the range from 0.12 to 0.24 L/m² (3 to 6 gal./1000 ft²) for the second and third treatments.

The pavement surface was very slippery immediately after application of the lithium and some salt was observed to have precipitated out of solution. A decision was made to apply water about 1 hour after the lithium treatment to re-dissolve the salt to enable it to penetrate into the concrete. One further water application was required before the pavement was opened for traffic. The performance of the treated and control sections is being monitored by measuring length change and mapping cracks in the field and taking core samples to establish depth of lithium penetration and determine the extent of damage using petrographic and stiffness damage rating techniques. Figure 2 shows lithium concentration profiles for cores taken after the third application. The depth of penetration is very limited and only the surface 3 mm (1/8-in) received sufficient lithium to suppress ASR expansion.

Consequently, Idaho Department of Transportation decided not to pursue this technology for the remainder of the ASR-affected concrete on I-84.

Figure 1. Topical application on I-84

Topical Lithium Treatment

Jim Pappas
Delaware Department of Transportation

Bear, Delaware - The Delaware Department of Transportation (DelDOT) first used lithium as a mitigation tool for alkali silica reactivity (ASR) on a section of State Route (SR) 1 between US 13 and SR 273 in Bear, Delaware. This section of Portland cement concrete pavement had been constructed in the early 1990's and was showing signs of ASR by the mid-1990's.

DelDOT looked at various rehabilitations for this section of concrete including reconstruction and overlay with hot-mix asphalt. At the time, these two techniques were not considered viable options so we looked at a third option, a topical application of lithium. This option was discussed based upon testing conducted through the Strategic Highway Research Program (SHRP) that had shown that lithium was effective in slowing down the ASR reaction if it could penetrate the concrete.

So, in 1998, DelDOT started applications of lithium nitrate applied through a rolling lane closure on the ASR affected concrete. We were not anticipating the ASR would be stopped completely; we were looking for the reaction to be slowed down sufficiently enough so that funds could be established to perform a more in-depth rehabilitation. The topical applications were completed in 2001.

The lithium applications accomplished the goal the Department had intended it to – it bought us time until a larger project could be funded and constructed which took place in 2006 when we overlaid the ASR affected concrete with an ultra-thin layer of hot-mix asphalt followed by a lift of a dense graded polymer modified asphalt wearing course. To date, the pavement is still performing well.

Like more information about the case studies mentioned here? Email us at **asrnewsletter@transtec.us**

Schedule of Events

November

30-December 2
8th International Conference on Creep, Shrinkage, and Durability of Concrete and Concrete Structures
Ise-Shima, Japan

December

3-5
Fourth International Conference on Forensic Engineering, London, UK

3-5
ACPA 45th Annual Meeting
San Antonio, TX

January '09

11-15
TRB 88th Annual Meeting
Washington, D.C.

February '09

3-6
World of Concrete
Las Vegas, NV
Washington, D.C.

23-26
PCA's Design and Control of Concrete Mixtures
Skokie, IL

Got ASR? (cont. from page 1)

As mentioned previously, rather than treating the underlying cause of ASR, one can instead treat the symptoms of ASR, specifically expansion and cracking. Numerous studies and field trials have shown that physical restraint or confinement (e.g., encapsulation of the affected member by a surrounding non-reactive concrete, applied stress or reinforcement) can significantly reduce deleterious expansion due to ASR in the direction of restraint (Fournier et al. 2004). Because of the unique nature of this mitigation approach and the fact that the structural response is impacted, it is imperative that a structural engineer play the leading role in specifically designing the methodology for a given ASR-affected structure. Cracking due to ASR may not only have an impact on the performance of a given structure, but the cracks serve as access points by which water, external alkalies, chlorides, and sulfates can enter the concrete, exacerbating ASR and potentially leading to other forms of distress, such as frost attack, salt scaling, and corrosion of reinforcing steel. To address this cracking, one can seal the cracks to minimize the ingress of external water and dissolved ions – the use of caulking or flexible grouts is preferred over rigid polymer- and cement-based grouts because the rigid nature of the latter materials and strong bonding with the substrate concrete often forces cracks to appear adjacent to the grouted area.

In summary, this article has attempted to shed some light on options available for treating and managing ASR-affected structures. There are still many questions to answer and research to be done to advance such techniques, and it is hoped that the various field trials being performed under FHWA funding will help to serve this purpose. Regardless, it is safe to say that it is much easier to prevent ASR in the first place than it is to slow it down or stop it in existing concrete structures.

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