TECH**BRIEF**

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# Protocol for Selecting ASR-Affected Structures for Lithium Treatment

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## Objective

This TechBrief describes a protocol for evaluating damaged concrete structures to determine whether they are suitable candidates for lithium treatment to address alkali-silica reactivity (ASR). A major part of the TechBrief's source document, *Protocol for Selecting Alkali-Silica Reaction (ASR)-Affected Structures for Lithium Treatment* (FHWA-HRT-04-113), deals with the approach/tools that can be used to determine whether ASR is the principal cause, or only a contributing factor to, the observed deterioration (diagnosis); determine the extent of deterioration due to ASR in the structure; and evaluate the potential for future expansion due to ASR (prognosis). A full version of the report is available through the Federal Highway Administration (FHWA).(1)

## Introduction

Three conditions are necessary to initiate and sustain ASR in concrete (as shown in figure 1):

- A sufficient amount of reactive siliceous phase(s) must be present in the aggregate.
- The concentration of alkali hydroxides (sodium ($Na^+$), potassium ($K^+$), hydroxide ($OH^-$)) in the concrete pore solution must be high enough.
- Sufficient moisture must be present.

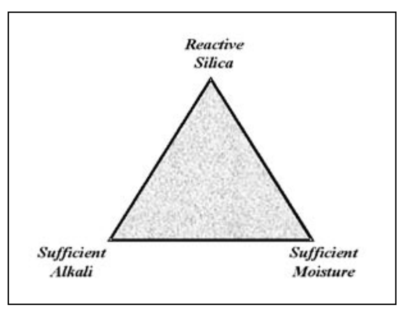


*Figure 1. The three necessary components for ASR-induced damage in concrete.*

To reliably evaluate the efficacy of lithium in treating ASR-damaged concrete structures, the structures selected for field trials must meet the following general criteria:

- ASR must be firmly established as a primary cause of deterioration.
- Even where ASR is confirmed as a primary cause of deterioration, the action of other deterioration processes may render treatment ineffective.
- Deterioration due to ASR should have reached a certain level/severity.
- There must be potential for further ASR-caused expansion and damage to occur if the structure is left untreated.

## Documentary Evidence

The first phase in the evaluation procedure is to review all documents relating to the structure, including:

- The type and location of the structure.
- The age of the structure and the details and dates of any modifications or repairs.
- Plans, drawings, and specifications.
- Details of the approved concrete mixtures used, and details of any analyses or tests conducted on concrete materials.
- Previous inspection/testing reports (including petrographic reports if available), especially the dates when deterioration was first observed.
- Information from other structures in the area that may have been constructed with similar materials.

## Diagnosis

### Site Investigation

Field inspection is a critical part of the diagnosis of ASR in concrete structures. When examining the structure, leading experts recommend that attention be paid to the following features:

- *Environmental conditions.* ASR can only develop and be sustained in concrete elements with high internal relative humidity, and damage is generally most severe in areas subjected to an external supply of moisture.
- *Nature and extent of cracking.* The pattern of cracking due to ASR is influenced by the geometry of the concrete element, the environmental conditions, the presence and the arrangement of reinforcement, and the load or stress fields applied to the concrete. (See figures 2 through 4.) Map cracking often is associated with, but not exclusive to, ASR.
- *Popouts.* Locating gel at the popout is a strong indication of ASR; however, popouts also can be caused by freezing and thawing or by low-density porous aggregates.
- *Movements, displacements, and deformations.* The concrete swelling because of ASR may cause distresses

*Figure 2. Map cracking in a section of pavement on Interstate 84 near Mountain Home, ID.*

*Figure 3. Concrete barriers along State Highway 2 near Leominster, MA.*

*Figure 4. Concrete girder treated for ASR in Corpus Christi, TX.*

*Figure 5. Misalignment of adjacent sections of a parapet wall on a highway bridge due to ASR-induced expansion.*[2]

*Figure 6. Surface discoloration in a bridge structure caused by ASR.*


*Figure 7. Concrete structure showing discoloration, or "gel staining," around cracks.*

such as relative movements, misalignment, or separation of adjacent concrete members or structural units. (See figure 5.)

- *Surface discoloration.* Cracks caused by ASR often are bordered by a broad brown zone that appears to be permanently damp. (See figures 6 and 7.)
- *Surface deposits* (gel exudation versus efflorescence). Although surface gel exudation is a common and characteristic feature of ASR, the presence of surface deposits is not necessarily as indicative of ASR as of other mechanisms (such as frost action); however, a chemical analysis can help determine whether ASR gel is present in the deposit. Canadian Standards Association (CSA) A864 provides a classification system based on the occurrence of the above features obtained from the field survey of concrete structures.[3] Additional information can be found in the FHWA document FHWA-HRT-04-113.[1]

### Sampling

Samples, typically 100 millimeters in diameter, are to be taken from the major components of the structure and/or those areas showing the most typical signs of deterioration. Samples also are needed from areas subjected to different exposure conditions and exhibiting different degrees of damage. (See figure 8.)

## Laboratory Investigations

The main objectives of laboratory investigation are:

- Diagnosis—to confirm the presence of ASR and to determine whether the apparent damage to the structure can reasonably be attributed to ASR.
- Prognosis—to predict the potential for further deterioration because of ASR.

### Petrographic Examination

The following macroscopic features may assist in the diagnostic process, and their presence should be noted:

- Cracking location (e.g., at surface, around, or through aggregate particles), associated gel exudation, width, depth, etc.
- Presence of gel (or other reactive products) in voids/pores, cracks, around aggregate particles, or exuding from the core.
- Damp patches on the concrete surface.
- Reaction rims around aggregate particles. (See figure 9.)

Polished surfaces and thin sections should be prepared from samples taken at various depths within the structure.

*Figure 8. Core extraction from a concrete barrier along State Highway 2 near Leominster, MA.*

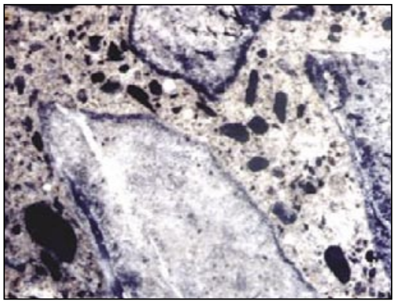

*Figure 9. Polished concrete section showing dark reaction rims at the periphery of the reactive aggregate particles.*

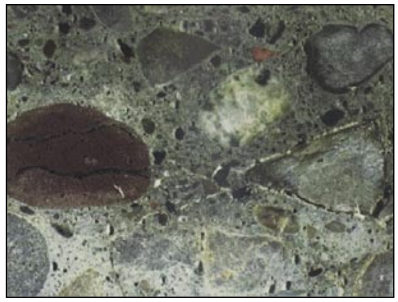

*Figure 10. Example of a polished concrete surface.*

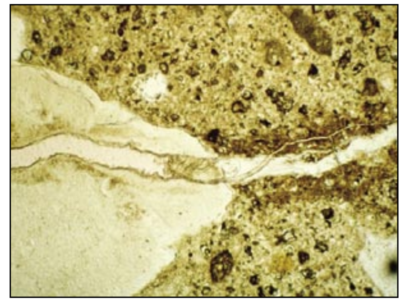

*Figure 11. Example of a thin section sample.*

Examining polished surfaces is an efficient method for studying large areas of concrete and determining the intensity of certain macroscopic features. (See figure 10.) However, examining thin sections is often necessary to positively identify features of ASR; this examination generally is used to confirm the existence of features identified on polished surfaces. (See figure 11.)

The uranyl-acetate treatment is a method that helps detect alkali-silica gel on polished and broken surfaces of concrete specimens.[2,4] Although ASR gel fluoresces much brighter than cement paste, not all fluorescence indicates ASR gel; the test is ancillary to more petrographic examinations and tests to determine expansion and must not be used alone to diagnose ASR. (See figure 12.)

Petrographic examination of polished and thin sections is the most powerful tool in establishing whether ASR has occurred and whether the extent of the reaction is sufficient to cause the level of concrete deterioration observed onsite. CSA A864 classifies the occurrence of features obtained from petrographic examination to give an overall assessment of the probability of ASR.[3] Additional information about petrographic examination is available in the full version of this document (FHWA-HRT-04-113).[1]

### Mechanical Testing

In addition to petrographic examination, some mechanical testing of cores can be performed; however, selecting the appropriate test methods is critical because ASR does not alter the engineering properties of concrete equally.

### Interpretation of Findings (Diagnosis)

The interpretation of the data collected from the investigation outlined here should be conducted by a professional concrete specialist with experience in evaluating concrete structures affected by ASR. CSA A864 analyzes the findings from both the site and laboratory investigations to determine the likely contribution of ASR to the overall observed deterioration.[3] Additional information about diagnosing ASR findings from the laboratory and from the field is available in the full version of this document (FHWA-HRT-04-113).[1]

## Prognosis

Ideal candidate structures for lithium treatment are those for which laboratory testing or in situ monitoring indicate that potential for further expansion

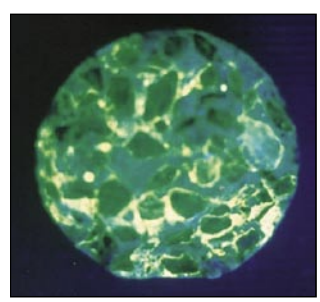

*Figure 12. Uranyl-acetate treatment on concrete sample showing ASR-affected concrete.*

*Figure 13. Expansion measurements being conducted after pavement was treated with lithium nitrate.*

and damage because of ASR is significant if the structure is left untreated.

### In Situ Evaluation

The most reliable method for determining the likelihood of further reaction and expansion is to instrument the structure and monitor its behavior for a period of time. Several ways to monitor the rate of expansion include:

- *Expansion measurements.* The long-term change of length between reference points mounted on or embedded in the concrete surface can be measured. (See figure 13.)
- *Crack mapping.* Crack mapping is a useful visual tool for evaluating the progress of the expansion or deterioration. (See figure 14.)
- *Temperature and humidity measurements.* Humidity and temperature measurements at different depths within the concrete elements can be helpful when interpreting seasonal fluctuations in the in situ expansion measurements.

Gathering sufficient data to correct for the effects of variations in ambient temperature and humidity is important. It usually is necessary to take at least several years of measurements before definite conclusions can be reached about the rate of ASR-induced expansion in the structure.

### Laboratory Evaluation

Expansion tests (usually carried out at 38 °C) on cores often are used to indicate the potential for further expansion of the concrete and the amount of reactive aggregate remaining in the system. The initial volume and mass changes observed when the specimen is placed at high humidity (and temperature) may indicate the extent of ASR already in the concrete (e.g., water uptake by the existing alkali-silica gel). Therefore, these measurements should be interpreted with great caution. Expansion tests on cores immersed in alkali solution (1 mole sodium hydroxide (NaOH) at 38 °C or 80 °C has been used) can indicate the amount of reactive aggregate remaining in the system. The water-soluble alkali content, on the other hand, can provide a measure of the alkalis that are still available for reaction. If cores do not expand when stored under laboratory conditions, this should not be interpreted as an indication that ASR expansion has ceased in the field. A procedure for predicting the future risk of expansion of structures based on such measurements has been developed by Bérubé, et al.[5]

## Selection of Structures for Lithium Treatment

Ideal structures for lithium treatment will be those for which, in general:

- It has been confirmed that the structure is suffering from ASR and that the reaction is the principal cause of deterioration.
- ASR deterioration has reached a certain severity displayed by noticeable surface cracking.
- In situ or laboratory investigations show a significant potential for further expansion and damage due to ASR if the structure is left untreated.

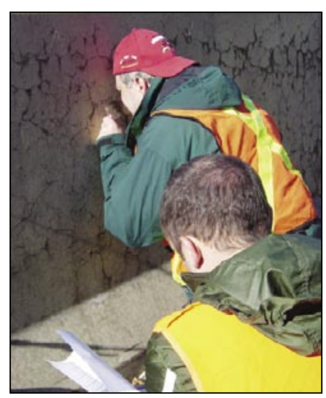

*Figure 14. Crack mapping measurements performed on a concrete barrier near Leominster, MA.*

- The nature or geometry of, or access to, the affected concrete member makes lithium treatment possible.
- The owner is committed to keeping the treated structure in service for a period of time to ensure and allow access to monitor the effectiveness of the treatment adequately.
- There is an opportunity to evaluate the effectiveness of lithium treatment versus—or in combination with—other types of treatments.

Proponents are asked to prepare submission files reporting findings from site inspection and laboratory investigations of the proposed concrete structures in accordance with the recommendations described in this protocol. State departments of transportation can receive assistance in developing this proposal, especially for analyzing field evidence of ASR, in evaluating the petrographic features of the ASR, and in performing mechanical testing of samples taken from candidate structures.

FHWA currently is conducting a series of research activities under the lithium technology program; its research activities are overseen by Fred Faridazar. Contact him for additional information about this program at 202–493–3076 or fred.faridazar@fhwa.dot.gov.

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