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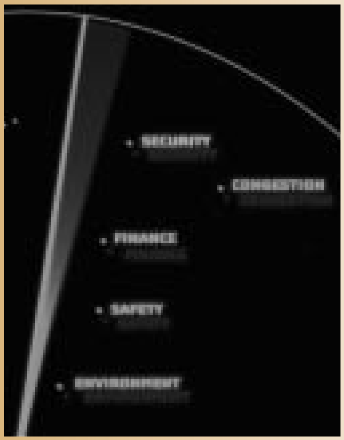


**Cover:** Transportation's radar screen detects 14 looming challenges for leaders, policy makers, and researchers to guide safely toward down-to-earth solutions in the immediate future.

# ALKALI-SILICA REACTION

## *Preventing Damage in Hydraulic Cement Concrete*

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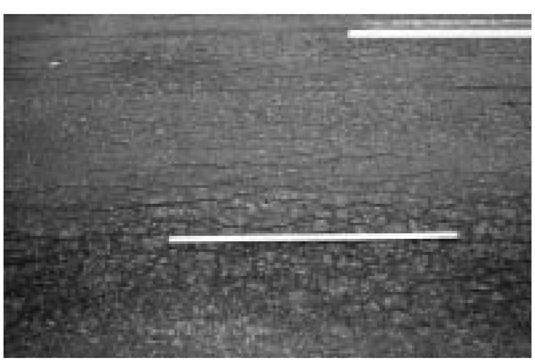
Alkali-silica reaction (ASR)—a chemical reaction affecting certain aggregates in concrete—can reduce the service life of concrete significantly. By-product materials—such as fly ash—used in concrete can prevent ASR and extend the service life of pavements and structures at no additional cost.

The premature deterioration of concrete in structures and pavements adds significantly to the life-cycle cost of transportation systems. One widespread cause of deterioration in concrete is alkali-silica reaction (ASR). Water collected in the concrete's pores dissolves compounds such as calcium and alkali hydroxides, producing the alkaline fluid that initiates ASR, a reaction causing the silica minerals (e.g., quartz) to corrode. ASR can produce expansive forces that crack the concrete, reducing structural integrity and increasing vulnerability to deterioration from other causes.

In the 1940s and 1950s, public agencies—notably the California Department of Highways, the U.S. Bureau of Reclamation, the U.S. Army Corps of Engineers, and the U.S. Bureau of Public Roads—focused on developing tests to identify aggregates susceptible to ASR. The principal strategy was to identify and avoid potentially reactive aggregates; however, if potentially reactive aggregates had to be used, the alkali content of the cement had to be limited.

By the 1980s, researchers recognized that the problem of ASR was more widespread than originally believed. Neither the criteria for identifying potentially reactive aggregates nor the limitation on cement alkali content was universally effective. As a result, ASR became a topic of study under the Strategic Highway Research Program.

FIGURE 1 Interstate 64's continuously reinforced concrete pavement, constructed in 1972, near Charlottesville, Virginia, after 15 years of service. Section was replaced in 1987.



## Problem

In the mid- to late 1980s, the Virginia Department of Transportation (DOT) noted a network of closely spaced cracks in a section of concrete pavement that had been in service for only 10 years (see Figure 1). The deterioration continued, and after 15 years of service, major reconstruction or rehabilitation was necessary. Investigation revealed that the primary distress mechanism in the pavement was ASR.

## Solution

The Virginia Transportation Research Council initiated a study to

- Identify the extent of ASR problems and potentially reactive aggregates in Virginia,
- Evaluate available test methods for identifying reactive aggregates,
- Investigate ways to use reactive aggregates without detrimental effects, and
- Develop a specification for concrete materials to prevent damage from ASR in new construction.

ASR-damaged structures and pavements were found throughout the state, except in the most western region. A variety of aggregates were involved, all containing quartz as the reactive constituent.

An evaluation indicated that the accelerated mortar bar test (AASHTO T 303, ASTM C 1260) was best suited for rapid screening. A concrete prism test (ASTM C 1293) subsequently was found more reliable as an indicator of potential reactivity; however, results could take up to one year.

Because it is difficult to discriminate potentially reactive from innocuous aggregates, and since the majority of sources would be classified as potentially reactive, attention focused on negating the detrimental effects of high-alkali portland cement on aggregates in concrete. Adding particular pozzolans (fly ash) or ground slag was found to prevent ASR damage by incorporating alkalis into the hydration products.

The alkali content of portland cement varies with the source, and sources in Virginia are representative

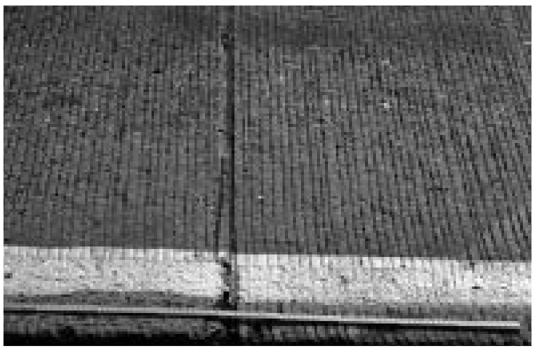


FIGURE 2 Interstate 64's continuously reinforced concrete pavement, reconstructed in 1987, near Charlottesville, Virginia, after 14 years of service. Pavement is in excellent condition, as shown in lower photo.

of those available in North America. Pozzolans and ground slag are readily available and have been used for economic reasons since the early 1980s. Initial evaluations with standard reactive material (Pyrex) confirmed the effectiveness of the locally available pozzolans and slag in preventing ASR damage and permitted the establishment of minimum replacement levels based on the alkali content of the portland cement.

Subsequent research used the concrete prism test to evaluate the effectiveness of pozzolans and slag with one of Virginia's most reactive aggregates. Results illustrated the conservative approach of using Pyrex to determine the amounts of pozzolan necessary to control the reactivity of aggregates similar to those in Virginia.

Tests also demonstrated a correspondence between the amounts of pozzolan or slag needed to control reactivity in the longer-term concrete prism test and the amounts needed to control reactivity in modifications of the rapid mortar bar test. Findings indicated that low lime content fly ash in the range of 15 to 25 percent by mass of cementitious material or ground slag in the range of 35 to 40 percent by mass is sufficient to avoid ASR damage with aggregates similar to those found in Virginia.

## Application

Virginia DOT began to allow the use of pozzolans or slag in 1985, and a detailed survey of the early structures will begin soon. In 1992 Virginia DOT adopted a specification to avoid potential ASR in hydraulic cement concrete. As a result, the majority of concrete produced for Virginia DOT construction contains either a pozzolan or slag.

Preliminary indications are that these concretes are performing well. For instance, the section of pavement shown in Figure 1 was replaced in 1987 using cement and aggregates from the original sources with characteristics similar to those of the original materials. To prevent ASR, ground slag was used at 20 percent by mass of the cementitious material. At 14 years, the pavement shows no significant signs of ASR-related distress and continues to perform well (see Figure 2).

## Benefits

During a nine-year period, Virginia DOT spent approximately $400,000 on ASR research and related activities. The most significant benefit will be the greatly increased durability of the concrete pavements with regard to ASR, as observed on the Interstate 64 project.

Virginia DOT maintains 2,000 lane-miles of concrete pavements. A conservative assumption is that ASR would affect 10 percent of these lane-miles within the first 15 years of service-life if practices remain unchanged. Implementation of the new specification based on the ASR may extend the service life of the concrete pavement from 15 to 30 years.

Projections from the rehabilitation costs for the Interstate 64 section show that Virginia DOT would spend $80 million to $100 million over a 30-year period with the old specification. Implementation of the new specification based on this research may reduce rehabilitation costs by 50 percent.

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Suggestions for "Research Pays Off" topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, 2101 Constitution Avenue, NW, Washington, DC 20418 (telephone 202-334-2952, e-mail gjayapra@nas.edu).