Countering alkali-silica reaction in concrete

Experience in the United Kingdom

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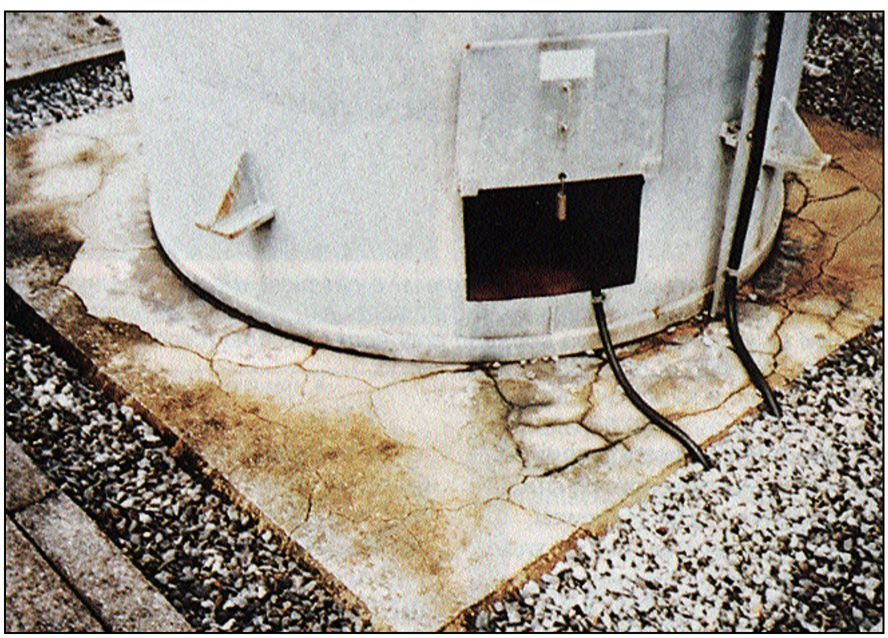
Before 1976, no concrete aggregates in the United Kingdom were thought to react harmfully with alkalies. But that year researchers found that some structures had indeed cracked because of an alkali-silica reaction (ASR). It's now believed that parts of 100 to 300 structures, most built between 1969 and 1971, have expanded and cracked as a result of ASR.

Expansion and cracking has occurred in unreinforced and reinforced foundation bases, columns, beams, walls, and cladding panels. Most of the affected members are exposed to groundwater, rain, or heavy condensation and the concrete generally contained more than 760 pounds of cement per cubic yard. Cement alkali content was high, ranging from 1% to 1.4% by mass. Chert particles present in natural aggregates, mostly from three sources, contained the reactive silica. Except for two instances where an artificial glass aggregate was used, the alkalies for the reaction came primarily from the portland cement.

In many members the cracking is minor, but in others it is visibly se-

Cracking caused by alkali-silica reaction (ASR) occurs in beams, foundations, and other structures exposed to moisture. Although the width of ASR cracks may exceed 4 mm (0.16 inches), crack widths are generally less than 1 mm (0.04 inches).



vere. Crack widths range up to 4 mm (0.16 inches) or more but are generally less than 1 mm (0.04 inches). Depth is normally from 25 to 50 mm (1 to 2 inches). Visual observations on several ASR-affected structures and measurements on one indicate that expansion is largely complete 8 to 15 years after construction.

Because water is needed for the expansive reaction, coatings or cladding may affect the reaction by altering the concrete moisture content. The effects of ASR in a race course grandstand were retarded by the use of ventilated cladding. At a factory in Plymouth in which three external columns had cracked, all the external columns were surface coated. On two other affected structures, surface coatings were applied over small exposed areas 6 years ago when the structures were about 10 years old. The coatings have performed reasonably well, possibly because the expansive effects of the reaction were largely complete when they were applied.

Evaluating safety and serviceability of ASR-damaged structures

ASR doesn't necessarily threaten the structural integrity of concrete members. Load tests were carried out on parts of an ASR-affected parking structure in 1981, 1982, 1985, and 1986. These tests confirmed that the beams were able to carry their design and actual service loads with a considerable margin for extra load bearing.

The presence of ASR cracking does not indicate that low-quality concrete was used. About 100 of the 500 lightly prestressed columns supporting a concrete reservoir roof were found to have cracks along their entire length. These cracks occurred in the lower face of the columns as cast and were up to 4 mm (0.16 inches) wide. The damaged columns were replaced, but subsequent core testing showed that the affected concrete was of high quality, with strengths ranging from 10,000 to 14,500 psi.

The compressive strength of cores from the affected concrete ranges from about 5800 to 14,550 psi and the modulus of elasticity from 1.5 to 4.5 million psi. But cores may expand after extraction because of the removal of structural restraint. Thus the properties measured by core tests may not be representative of the concrete member from which the cores were taken.

Reducing the risk of cracking

In controlled laboratory tests on concrete, no British cement-aggregate combination has been observed to crack because of ASR at original alkali contents below 8.4 pounds per cubic yard. Thus, one preventive approach is limiting the alkali content of concrete made with potentially reactive aggregates. One of the following two procedures is used:

Limiting the concrete active alkali content from all sources to 5 pounds per cubic yard or less. Here, the cement alkali level is the certified average supplied by the cement manufacturer or the specified average that the manufacturer has declared will not be exceeded without prior notice. The certified average is that of the last 25 determinations carried out on daily samples by the manufacturer. Because some variation in cement alkali is inevitable in cement production, the actual alkali content of the concrete when this limit is being met can in extreme cases be as high as 6.4 pounds per cubic yard.

The 5-pound-per-cubic-yard limit may also be met by using a factory-made cement containing fly ash or slag, or by combining ordinary portland cement with fly ash or slag at the concrete plant. The British Cement Association, the three United Kingdom cement manufacturers, and governmental agencies recommend that the active alkali of a fly ash or slag be taken as ⅙ and ½, respectively, of their total alkali content. These ratios were based on expansion tests which showed that fly ash and slag contributed alkali to the reaction. The Concrete Society recommends assuming that the active alkali content of fly ash and slag is equal to their water-soluble alkali contents. The total alkali content of fly ashes used in the United Kingdom ranges from 0.7% to 4.6% by mass, and of slag, from 0.5% to 1.2% by mass.

Limiting the active alkali content of the cement or binder to 0.6% or less when the alkalies from other sources don't exceed 0.3 pound per cubic yard. This limit can be met by selecting a portland cement with a guaranteed maximum alkali content of 0.6% by mass or by using a composite cement or binder containing at least 25% by mass of fly ash or slag. The ⅙- and ½-alkali rules are applied to the fly ash and slag respectively.

Research in progress

Reports on several aspects of ASR have been prepared by concrete industry organizations:

- Minimizing the risk of ASR cracking, from The Concrete Society
- The diagnosis of cracking caused by ASR, from the British Cement Association
- The structural effects of ASR, from the Institution of Structural Engineers

Research is also in progress at a number of institutions and universities, with some interesting results. For instance, work done by the British Cement Association has shown that ASR doesn't have a big effect on bond for plain or deformed bars. Other studies concern how ASR influences concrete member performance, developing a method for structural assessment of affected highway structures, and how fly ash and slag affect expansion.

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