SAFETY AND SERVICEABILITY

# Alkali-Silica Reaction: Testing Demonstrates Unexpected Capacity

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Although there are a number of causes for the early deterioration of transportation structures, this article focuses specifically on one concrete durability problem, alkali-silica reaction (ASR), and my experience with it at the University of Texas.

ASR takes place when reactive aggregates are subjected to a high-alkali pore solution in concrete. The third, and necessary, ingredient for this chemical reaction is water or high internal relative humidity (~80% or higher) in concrete. When these three ingredients are all present, ASR takes place. The reaction product, a hygroscopic gel, absorbs water and expands. Expansion results in cracking of concrete, raising concerns about structural integrity as well as the durability of the structural component.

Since joining the faculty at the University of Texas nearly two decades ago, I have conducted research on damage caused by ASR and delayed ettringite formation (DEF), among other concrete durability problems. This work has focused on the structural implications of ASR damage, considering also the deleterious effects of ASR on concrete material properties, for several projects sponsored by the Texas Department of Transportation (TxDOT) and, more recently, the nuclear power industry. In some cases, my research group fabricated specimens with ASR-prone concrete mixtures for laboratory testing to understand structural performance under varying levels of ASR damage.[1] In other cases, where field testing was possible and practical, we evaluated the structural performance of damaged concrete structures or their components through destructive testing.[2–4]

I would like to share some of what we learned while performing field tests on high-mast illumination pole (HMIP) drilled-shaft foundations in Houston, Tex. HMIPs are commonly used in urban areas to illuminate intersections, direct connectors, and highways. **Figure 1** shows that under strong winds, HMIPs experience substantial loads. Potential failure of foundations—more specifically, the anchor rods in the concrete supporting the HMIPs—during hurricane-level winds prompted TxDOT to contract with the University of Texas to study the structural performance of deep anchor rods embedded in ASR-affected drilled-shaft foundations with significant cracking. **Figure 2** is a close-up view of typical ASR cracks that were present in one of the drilled shafts tested. One of the additional concerns in the investigation was the presence of below-grade cracking, with ASR cracks serving as conduits to the reinforcing cage in the foundations that could allow water and other corrosive agents to penetrate the foundations. In addition to the structural implications of ASR, the owner was concerned about potential corrosion of the steel reinforcement within the drilled shafts.

Field tests were performed on six drilled shafts with substantial ASR damage to provide a basis for evaluating the structural adequacy of hundreds of other foundations with similar, or lesser, levels of damage and the same structural details as those tested. **Figure 3** shows the test setup.

The overall strength and stiffness implications for shafts damaged by ASR have been previously discussed in great depth.[2–4] A complete review of these issues is beyond the scope of this article. In our tests, foundations with ASR cracks performed adequately and the capacities of the anchor rods were not compromised by severe cracking resulting from ASR-induced expansions with the reinforced detail used by TxDOT. Furthermore, reinforcing bars located slightly above, at, or below grade in concrete with extensive ASR cracking showed no signs of corrosion despite frequent exposure to rainstorms. Reinforcing bar corrosion was not observed because the highly alkaline (high pH) levels in the pore solution in ASR-affected concrete cause passivation on the surface of reinforcing bars and therefore create an environment that may not promote corrosion of typical ASTM A615 carbon steel reinforcing bars. In general, the corrosion rate of reinforcing

*Figure 1. Florida Department of Transportation photo showing high-mast illumination pole during a high wind. All Photos adapted from Reference 2.*

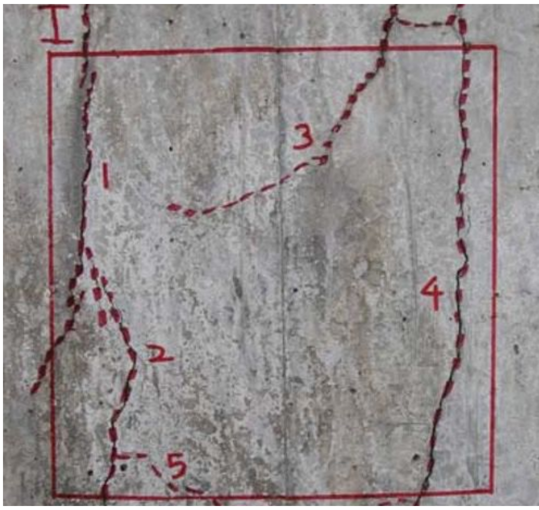


*Figure 2. Cracks caused by alkali-silica reaction in the drilled-shaft foundation of a high-mast illumination pole.*

*Figure 3. Setup for field testing the deep anchors in the ASR-damaged drilled-shaft foundation of a high-mast illumination pole.*

bars made with carbon steel decreases as pH values increase.

Advanced levels of ASR can significantly reduce the compressive and tensile strength as well as the modulus of elasticity of plain (unreinforced) concrete.[5] However, in the study of the performance of deep anchors in drilled shafts, the confinement provided by the reinforcing bar cage (longitudinal steel confined with spiral reinforcement as shown in **Fig. 4**) compensated for the adverse effects of ASR on the mechanical properties of plain concrete.[2] A recognition of the beneficial effects of confinement reinforcement was necessary to explain why the substantial reduction in observed mechanical properties of the ASR-damaged concrete had no discernable effect on the structural performance of the deep anchors. More specifically, the tensile and compressive loads on the deep anchor rods were transferred to the neighboring longitudinal reinforcing bars with the help of the spiral (confinement) reinforcement. Simple strut-and-tie models were used to explain the structural response.[4] The viability of the load transfer relied on the integrity of the struts forming in the structural core and the presence of the confining reinforcement providing restraint against radial blowout forces.

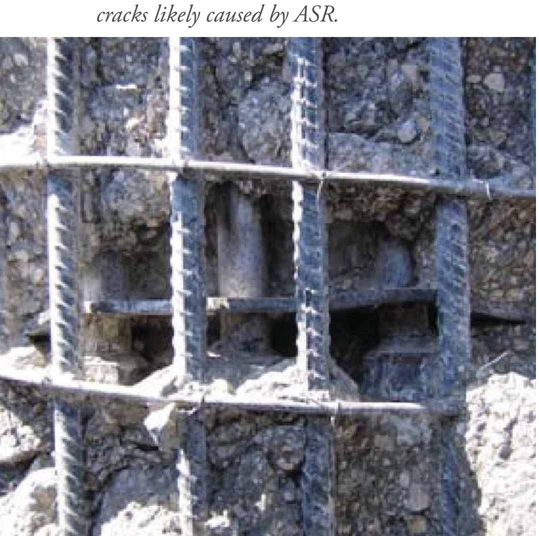

*Figure 4. No corrosion of the reinforcement was evident in the drilled shafts having significant cracks likely caused by ASR.*

As a result of the favorable structural test results and observed behavior that could be explained on the basis of first principles, many ASR-affected drilled-shaft foundations of HMIPs were kept in service. The lack of observed corrosion in reinforcing bars and anchor rods contributed to this decision.

As our nation's transportation infrastructure continues to age, most bridge engineers will be involved with the assessment of the existing structure inventory. The good news is that we will find most of the concrete bridge inventory is in excellent shape, ready to serve our communities for many decades to come. In some cases, as in the case of the ASR problem discussed in this article, the body of knowledge developed in the United States and around the world will help us evaluate our bridges, and may allow us to keep them in service, possibly with repairs if necessary, and thus use our resources judiciously. Above all, we must all aspire to use available resources in a responsible manner. (For more information on ASR and DEF, see articles in the Summer 2018 and Spring 2019 issues of *ASPIRE*®.)

## References


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