Avoiding Failure from Alkali Aggregate Reactions

How Epoxy Mitigation Manufacturers Know Their Product is Trouble

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History

AAR has been around as long as concrete has existed

Alkali-Aggregate Reaction (AAR) is a reaction in concrete between alkali (Na, K, Ca) hydroxides and certain types of crystalline silicaceous aggregate. two types of AAR are recognized; alkali-silica-reactions (ASR) and alkali-carbonate-reactions (ACR). Obviously, the differences between the two are related to the reactions of silica versus carbonate phases in aggregate rock. ASR will be discussed as it is the more common problem found related to flooring but some concepts here are common to both.

Concrete is a porous material (10% of concrete volume) and in saturated concrete near the 40% depth of the slab, the pores contain a solution of alkali hydroxides. Although these alkali's represent a small fraction of Portland cement, they dominate the concrete pore solution, elevating the internal pH of concrete to an average of 13.5 (see; Concrete Pore Water, ASTM D7705).

As Figure 1 illustrates the sequence of ASR development in concrete is very straight forward. Some forms of aggregate (typically volcanic in nature) are unstable at high pH and are attacked by the hydroxide ions. This will release soluble silicate from the aggregate. This silicate will react with the available hydroxide and water to form a hydrophilic gel. the reaction follows:

$$\mathbf{X}_2SiO_3 + 4H_2O + 3Ca(OH)_2 \rightarrow \mathbf{3CaO{\cdot}SiO_3{\cdot}4H_2O} + 2\mathbf{X}OH \qquad \mathbf{X} = K \text{ or } Na \qquad \textbf{C-S-H (I)}$$

$3CaO{\cdot}SiO_3{\cdot}4H_2O$ is often abbreviated as C-S-H (I) and is often referred to a C-S-H gel. This form of C-S-H tends to be more soluble in water (hydrophilic) and prone to expansion or swelling as additional silicate is released from the aggregate and reacts with the available alkali hydroxides.

Not all forms of silicaceous aggregate are reactive to concrete pore water (CPW). The reactivity depends upon the crystal structure of the silica rock rather than its composition. As an example, both quartz and opal are silica minerals composed of SiO_2. Although similar in composition, the quartz stone has a more ordered structure. Opal, on the other hand, has an internal structure that is more like a densely packed aggregation of spheres of silica crystal and is highly reactive to CPW.

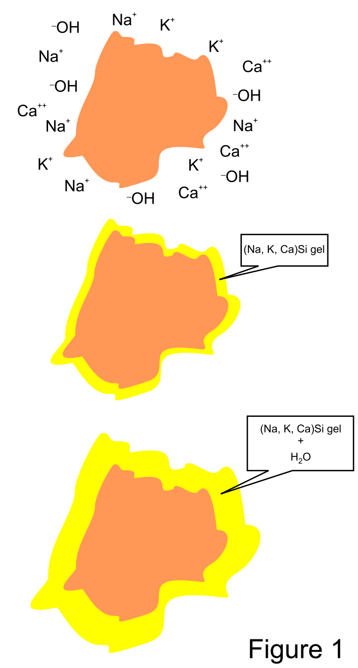

Figure 1

Effective Treatments

Reduce the moisture, reduce the risk

Effective treatments for existing concrete structures are reported with silane-type sealers.[1] Silanes are not silicates. They are however, inorganic compounds with the chemical formula $R_1SiR_2R_3H$ (where the R groups can be aliphatic or contain and alkyl carbon bonded to oxygen). These materials are reactive and can form a loose, breathable yet hydrophobic film on mineral surfaces like concrete. Since these films reduce the penetration of liquid water but allow the moisture as a vapor to transpire from the concrete and result in an overall reduction of surface relative humidity. By reducing surface moisture the exterior development of concrete surface cracking and spalls resulting from the development of ASR was arrested.[2]

In a similar way to silane-type sealers, Aquaflex adhesive is equally hydrophobic and breathable. Aquaflex will also reduce the relative humidity at the near-surface region. This effect may not resolve the entire slab issue related to ASR but it has been effective in eliminating the expansive aggregate event at the near-surface region. Arresting this event sufficiently to eliminate the formation of concrete spalls.

Conversely, epoxy mitigation may be the worst type of strategy for ASR concrete. By creating a completely occlusive film with a near-zero permeance , the relative humidity at the near-surface region quickly approaches 100% saturation. The movement of alkali hydroxides to the bond line of the epoxy film creates a super-saturated solution (supernatant) that pulls water of less concentration to it, building pressure (osmosis). Eventually this erupts into a blister caused by osmotic pressures.

Understanding that ASR is simply an expansive event associated with the combination of the "wrong" form of aggregates, water and alkali hydroxides is the key to preventing the negative consequence. Starve the near-surface region for moisture and the problem resolves itself. Try to contain or block moisture from a concrete slab and suffer the ASR wrath.

[1] Kojima, T, et al., "Effect of Coating to Inhibit AAR in Concrete Structures", The Concrete Society, 2002

[2] Berube M, et al., "Effectiveness of Sealers in Counteracting ASR in Highway Median Barriers" Can. J of CE, 2002