

# Floor Coating Failure

Gel found beneath a blistered coating may not always be NSAR.

Near-surface alkali reaction (NSAR) gel has been reported as the cause of debonding and blistering of epoxy coatings. In this article, we describe blistering in a low-permeance floor coating system where lithium silicate was applied to a shot-blasted concrete surface. The initial analysis, based solely on optical studies, suggested that alkali-silica reaction (ASR) was the cause. Without additional, specialized analysis, such as scanning electron microscopy and electron dispersive spectroscopy (SEM/EDS), lithium silicate residue or its gel can mistakenly be identified as ASR gel. Although lithium cannot be detected by EDS, other alkalis found in ASR gel, such as sodium and potassium, can be identified. It is possible to inadvertently assume the residue or reaction product of lithium silicate applied on shot-blasted concrete surface is an ASR byproduct.

## Alkali-silica reaction

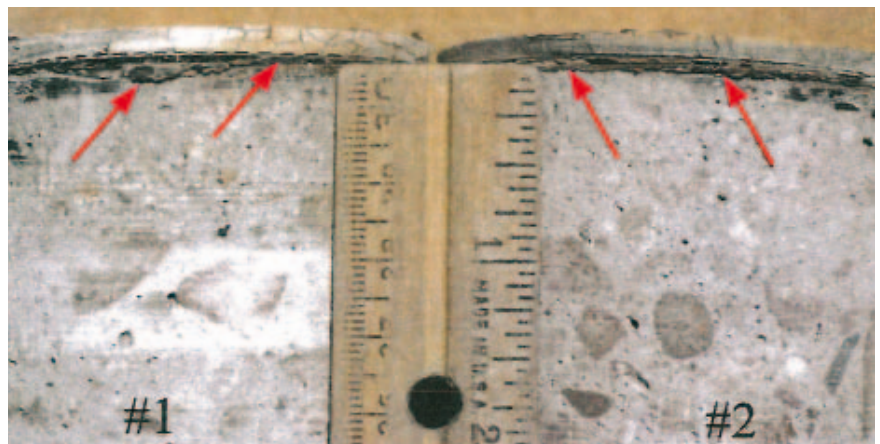
ASR is a well-known type of concrete degradation. Three conditions are necessary for ASR to occur: 1) a reactive form of silica or silicates; 2) available alkali,

normally sodium or potassium; and 3) moisture. When these conditions are present, ASR gel formation is possible. However, the presence of ASR gel does not necessarily mean concrete damage will occur or that the gel is responsible for any degradation. Damage can be caused as the ASR gel absorbs moisture and swells, causing extreme pressure from expansion. ASR typically takes many years to develop and results in “map cracking,” cracked aggregates

within the slab, and ASR gel within or on the reactive aggregates.

Recently, a new degradation mechanism called NSAR has been proposed (see sidebar, pg 36). NSAR occurs closer to the surface, involves smaller aggregates, takes less time to develop, and is associated with a low-permeance floor coating. Like ASR, it requires the presence of reactive silica or silicates, available alkali, and moisture to form the gel. The failure appears as blistering in the

Figure 1.



Both core samples (side view) from the failed floor had near-surface parallel cracks. PHOTOS: RJ LEE GROUP

**Figure 2.**



The layers of the floor system with arrows pointing to the white areas (silica gels) on the surface of the concrete.

low permeability surface coating applied to the concrete. The fluid build-up under the coating is said to be caused by osmosis. The presence of excess alkali from NSAR at the concrete surface creates an imbalance of solute that generates an osmotic cell leading to attraction of more water. The water is pulled through the concrete, which acts as a semi-permeable membrane, and collects on the concrete surface. The presence of the relatively impermeable coating covering the concrete surface traps the excess moisture and the result is blistering of the coating.

#### Mitigation

Lithium compounds have been used in concrete to prevent ASR from causing degradation and to protect the surface by aiding in the concrete densification. When applying in the field, the concrete is shot-blasted to remove any previous coating, contamination, and laitance. This also provides a better mechanical profile for improved bonding.

There must be sufficient calcium hydroxide in the concrete with which the lithium can react, forming calcium silicate hydrate (C-S-H). Two things are accomplished by this reaction: the C-S-H acts to densify the concrete and fill the pores; and the lithium finds available reactive silica to form lithium silicate gel. This lithium gel prevents the formation of ASR gels but it does not absorb water and expand. It is important that the lithium compound not be applied excessively since it could produce an unstable film that will adversely affect the adhesion of coatings and epoxies.

IF A GEL IS OBSERVED AND LITHIUM SILICATE HAS BEEN APPLIED, ADDITIONAL ANALYSIS IS WARRANTED PRIOR TO DRAWING ANY CONCLUSIONS.

#### Failed floor

The floor investigated was a 5.5-inch thick slab with no vapor barrier between the slab and subgrade. Three to 4 years after construction, a floor covering was installed and blisters developed. A year later, it was removed and the surface was shot-blasted, a concrete hardener and ASR mitigating coating of lithium silicate was applied, followed by an epoxy adhesive, underlayment, and tile. Within 1 year, blistering was again reported throughout the new floor.

Core samples were taken and found to have fine cracks parallel to the surface (Fig. 1, pg 33). The surface was irregular with concave upward micro-cracks near the surface of the cores, which is characteristic of a shot-blasted surface.

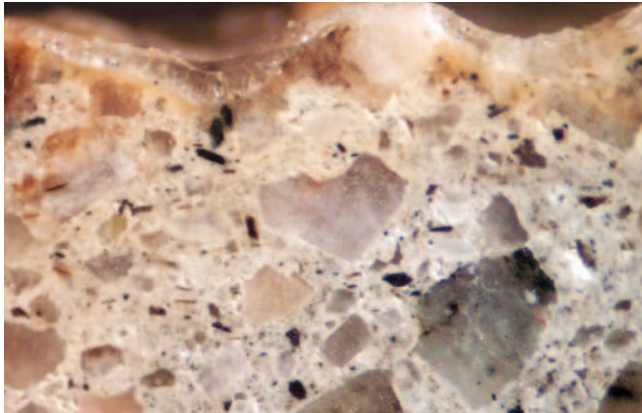
A micrograph of a core sample cross-section (Fig. 2) shows the layered components of the floor system: tile, underlayment, epoxy, silicate gel, and shot-blasted concrete surface. Our initial conclusion was that the near surface cracks were a result of distress from NSAR gel, instead of from shot-blasting and poor surface preparation. Lithium silicate, applied to the shot-blasted surface, was assumed to have been applied to arrest ASR in the near-surface concrete. This lithium reaction is similar to those of other alkalis. Unlike in ASR, however, lithium silicate gel does not absorb excess moisture, thereby preventing harmful gel expansion, stress,

**Figure 3.**



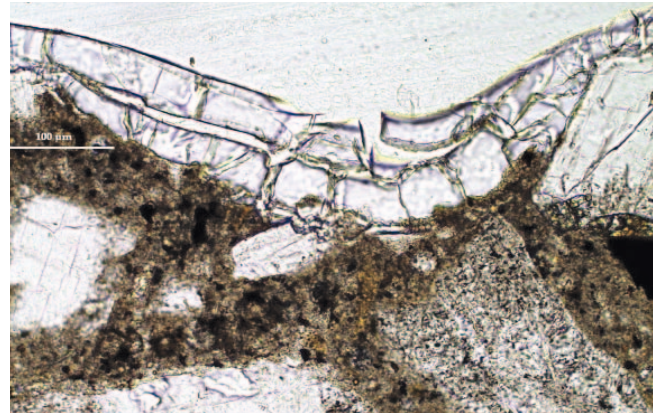
The surface of the lab sample shows lithium silicate applied to the sand-blasted concrete surface.

**Figure 4.**



This cross section, left, of the lab sample shows lithium silicate along the sand-blasted concrete surface. Note the gel in the depressions created by sand blasting. This thin-section photomicrograph shows lithium silicate gel on the undulating, sand-blasted concrete surface.

**Figure 5.**



and degradation. The gel in this instance, initially misidentified as coming from NSAR, may have been a residue of lithium silicate or the non-expansive lithium silicate gel that simply occupied surface defects and fine cracks created by shot-blasting.

#### Laboratory replication

The gel in the failed floor appeared identical to ASR but could be lithium gel instead. To address this, we did some work in the lab. We used a 3-inch diameter concrete core with a finished surface and sand-blasted it to create a concrete surface without any pre-existing laitance or contaminants. We then applied a commercial lithium silicate solution uniformly on the sand-blasted concrete surface and allowed it to dry overnight. Figure 3 (pg 34) shows the irregular surface from shot-blasting and the lithium silicate coating.

Next, we cut a cross-section to study the penetration of the solution into the concrete and to determine if it occupied pre-existing defects and micro-cracks in the concrete. A thin cross-section was prepared from the top portion of the core and was analyzed using optical and scanning electron microscopy. Figures 4 and 5 show photographs from the optical microscopy examination.

The presence of the applied lithium silicate is evident along the undulating surface. Note the similarity in gel location and appearance in the laboratory sample and field sample (Fig. 2, pg 34).

To complete the study we used the scanning electron microscope on a

cross-section of the laboratory sample to show that the hardened gel has a similar appearance and the same optical properties as ASR gels. We then ran EDS to determine which elements were present in the gel. Note that there is no lithium peak since lithium is not detectable using EDS. Sodium and potassium, however, which can be detected using EDS, are present at only extremely low levels. Sodium and potassium are elements that are associated with ASR and NSAR. So knowing that lithium is not detectable using EDS, and that lithium silicate was applied to the surface, we conclude that the gel is lithium silicate and not NSAR gel.

#### Conclusions

When performing investigations of blistering and other failures of concrete flooring systems, it is important to observe and take into account a number of factors, such as:

1. Lithium silicate was applied to the concrete surface. Its primary uses are to arrest ASR or to promote concrete densification, and it has not been shown to contribute to NSAR.
2. The cracks present in the field core samples were parallel or sub-parallel to the surface. ASR cracks typically form in a “map cracking” pattern, as popouts, or as cracks radiating from the aggregate to the surface. None of these ASR-related features were observed in the field failure.
3. The alkali concentration was found to be several times higher at the surface of the concrete than in the

#### NSAR

There is growing evidence that suggests an alkali-related reaction called ASR can occur in the near-surface region of a concrete slab. When it occurs, the reaction can contribute to the blistering and disbondment of low-permeance coating systems. To differentiate this near-surface reaction from conventional ASR, we have named this condition near-surface alkali reaction (NSAR).

Excerpt from NSAR in Concrete Slabs by Peter Craig, Dennis Pinelle, Mauro Scali, and Matt Sherman, CONCRETE SURFACES, Spring 2008

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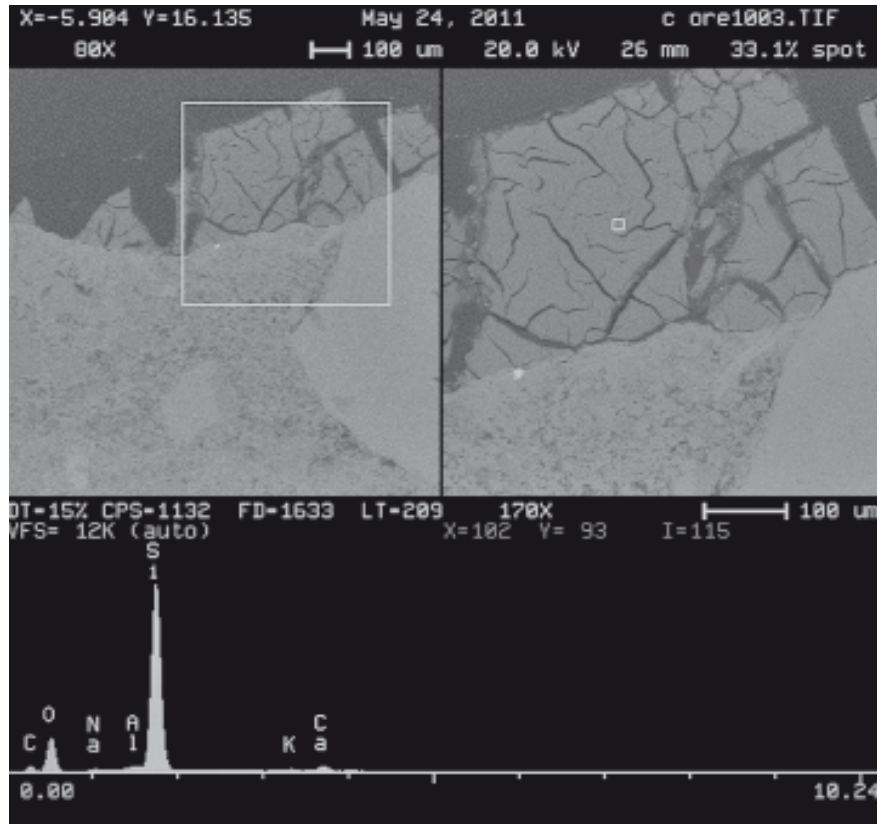
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Figure 6.



At the top are scanning electron microscope images of a cross-section of the laboratory sample. At the bottom is the electron dispersive spectroscopy spectrum showing the elemental composition of the lithium silicate gel along the surface.

interior, consistent with a semi-permeable concrete slab without a vapor barrier between it and the soil. This high alkali concentration, together with high moisture content in the concrete, would provide the chemical imbalance needed to create osmotic pressure, a well-known cause of failure in epoxy flooring systems.

4. Field blisters were reportedly filled with fluid, and we recognize that hydrostatic pressure would have been a contributing cause to their formation.
5. Elevated surface alkali concentrations would be expected to attack residual lithium silicate weakening the epoxy bond.
6. The aggregates were uniformly distributed, and small aggregates were not preferentially present near the surface as noted in NSAR.

In this case, the mistakenly reported NSAR gel along surface defects is, in fact, lithium silicate residue or the reac-

tion product of non-expansive lithium silicate gel from the commercial product applied to the concrete surface. A careful integration of analytical methods, such as SEM/EDS, is necessary to tell the difference between NSAR/ASR gel and lithium silicate gel. Be sure to keep in mind that if a gel is observed along near-surface micro-cracks and surface defects, and a surface treatment, such as lithium silicate, has been applied, then additional analysis is warranted to confirm the elemental identity prior to drawing any conclusions. **CC**

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