ASR-Related Distress in Floor Coatings

Reported failures, findings, and testing

by Xiaoqiang (Hugh) Hou, Richard A. Cechner, Terrence M. McGovern, Kevin A. Michols, and Todd Nelson

Alkali-silica reaction (ASR) is a common distress mechanism associated with certain aggregates in portland cement concrete.[1] ASR occurs when glassy, cryptocrystalline, microcrystalline, or physically strained silica (all chemically SiO_2) reacts with the alkaline pore solution in the concrete and forms a gel that expands as it absorbs water.[2,3] Small amounts of potentially ASR-reactive particles are common in many aggregates. These particles may or may not be destructive, depending on their reactivity, quantity and size, alkali contents in the mixture, and moisture exposure.

Flooring Failures

We recently investigated blistering of flooring in three buildings. The flooring materials were installed on concrete slabs in an industrial building, a medical facility, and an airport hangar. In each case, the flooring exhibited localized raising (shown in Fig. 1 and 2(a)). In two of the cases, the floor slabs were constructed with vapor retarders directly

Fig. 1: Blisters in an airport hangar floor coating (larger ones shown with red arrows)

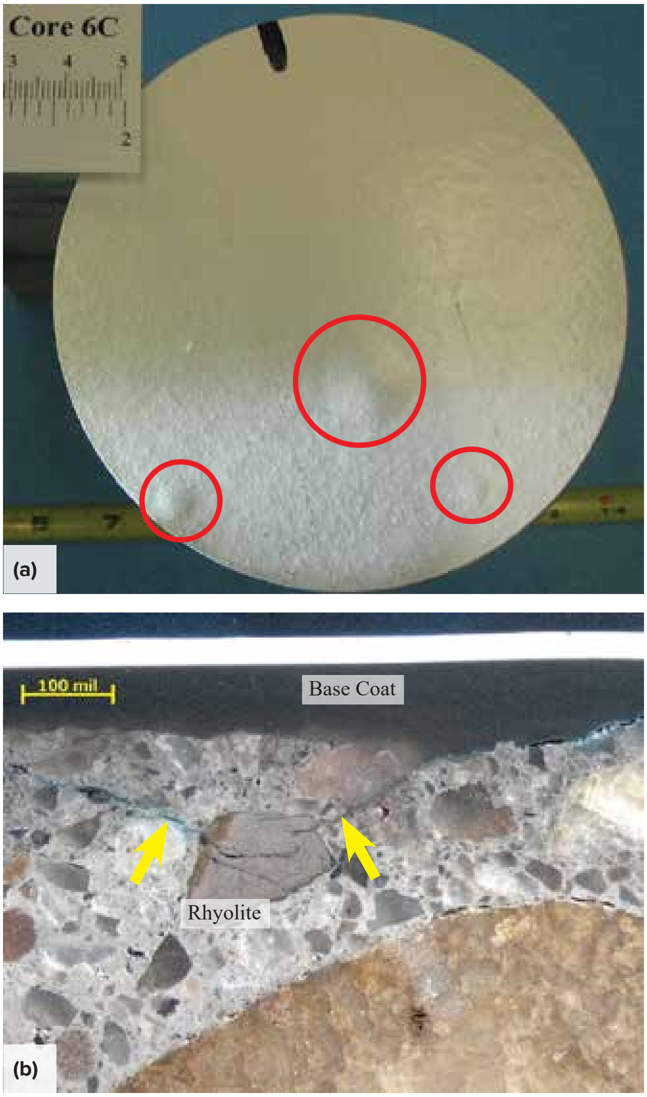

Fig. 2: Blisters in floor coating: (a) larger blisters are marked with red circles; and (b) close-up of a blister cross section showing a rhyolite particle below the blister and cracks emanating from the rhyolite particle (yellow arrows) (Note: 100 mil = 2.5 mm)

below the concrete. In the third case, the floor slabs were elevated. In each case, blistering was observed in the flooring from a few months to about 2 years after installation.

Two cases occurred in Colorado, 120 miles (193 km) apart. In one of these cases, the flooring comprised vinyl composition tile (VCT) bonded directly to the concrete slab. In the second case, a continuous flooring material was bonded to a moisture-reduction system on the concrete surface. Another case occurred in San Antonio, TX. In this and in one of the Colorado cases, the blistering problem had reportedly recurred repeatedly after repair or replacement of the flooring. In the other Colorado case, blistering occurred only in areas of floor slabs where concrete had been removed and replaced.

Our investigations revealed that the blistering of the flooring in each building was caused by ASR in the near-surface concrete. The ASR is located near the surface because an impermeable flooring acts as a vapor retarder, allowing condensation to form at the interface with the concrete. Combined with the presence of high alkalinity near the surface of a slab, the liquid water supplied by the condensation will affect potentially ASR-reactive particles in the aggregates.

Findings

We identified ASR of rhyolite, a volcanic rock with high amorphous and microcrystalline silica, to be the culprit of blistering in both cases in Colorado. Rhyolite is an extrusive rock, equivalent to plutonic granite, that is frequently present in the gravel used by producers as coarse aggregate. In the Colorado building that exhibited blistering only in repaired floor areas, we determined that the coarse aggregate in the repair concrete contained rhyolite. We identified ASR of chert in fine aggregate as the cause of blistering of the flooring in the Texas building.

Generally, our investigations revealed a reactive particle (rhyolite or chert) below a blister (Fig. 2(b), 3, and 4), and the size of a surface blister generally correlated with the size and depth of the reactive aggregate particle. Microcracks filled with ASR gel emanated from the affected particles and extended to the concrete surface (shown in Fig. 2(b) and 4). ASR gel was frequently observed at the blister area between the base coat or adhesive of the flooring system and the concrete surface. The near-surface reactive particle occasionally exhibited material loss along the internal cracks due to consumption caused by reactions. Microcracks in the concrete were usually more abundant below and near the blistered area than away from the blister.

In the two cases involving rhyolite, ASR gel and associated microcracking were also observed in the body of the concrete. Exposed rhyolite particles and nearby paste frequently

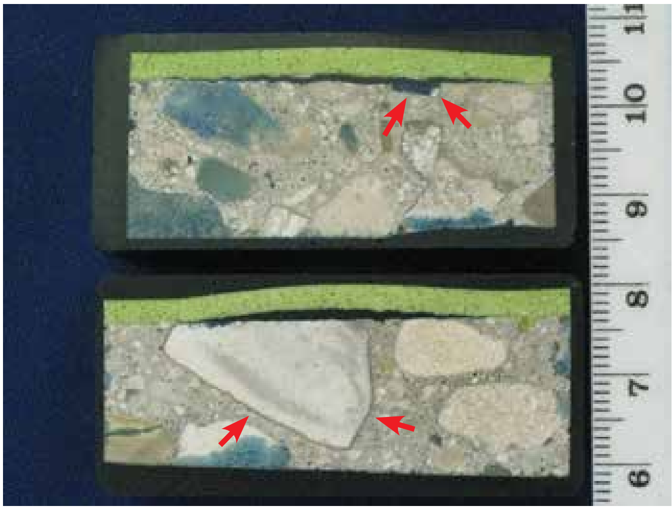

Fig. 3: Cross sections of floor coating showing blisters and underlying ASR-reactive chert particles (red arrows). Two flooring layers are observed. The base layer is a polymer layer (up to 10 mil [0.3 mm] thick) with white portland cement and small amounts of finely ground limestone. The top layer is a 120 mil (3 mm) thick layer consisting of an organic matrix, portland cement, and sand aggregate

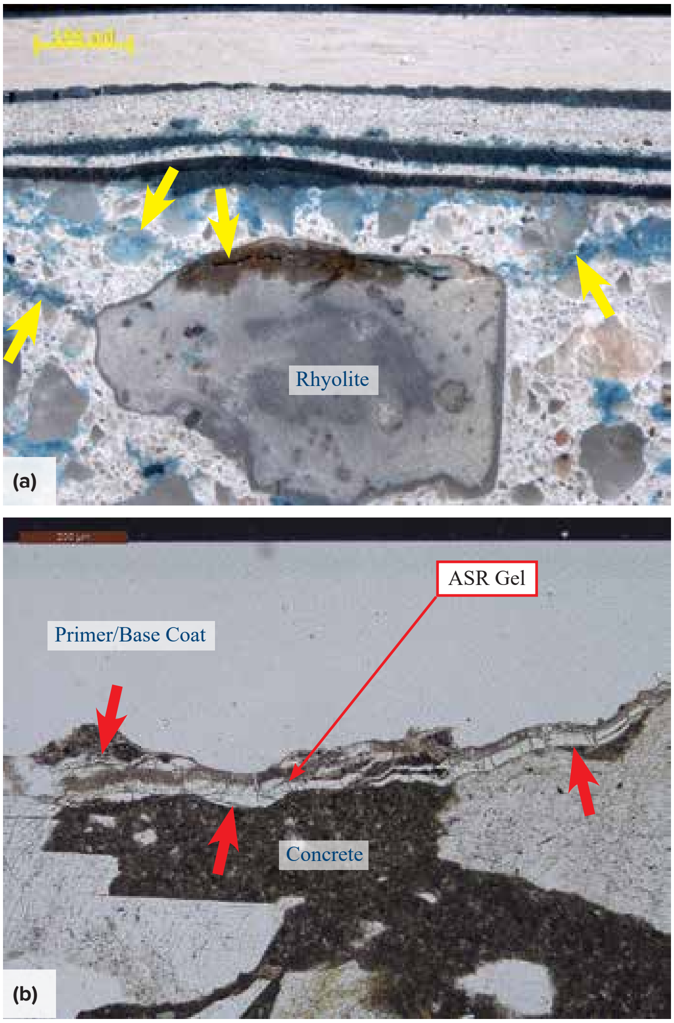

Fig. 4: Rhyolite aggregate: (a) close-up view showing a cracked particle below a blister with emanating cracks (yellow arrows); and (b) thin-section photomicrograph showing ASR gel lines in microcracks (red arrows) (Note: 100 mil = 2.5 mm)

appeared wet or glossy due to fresh production of ASR gel. In the case involving chert, ASR was observed only in the near-surface region.

In all cases, we estimated that the reactive aggregate component was less than 3% of the total aggregate content. This would comply with the limits for deleterious substances and physical property requirements of aggregates in ASTM C33/C33M.[4]

Previous Studies

In previous investigations by us (unpublished report) and other members of our firm,[5] the top surfaces of slabs covered with a relatively impermeable flooring material have been found to have a pH of up to 14 (highly alkaline). Many previous studies have emphasized the role of fine aggregate in near-surface ASR and concluded that coarse aggregate was generally less involved in distress caused by near-surface ASR.[6] Our case studies described herein did not support that conclusion.

It is important to understand that elevated alkali concentrations in near-surface regions are not uncommon. This feature is not necessarily caused by use of alkali-silicate hardeners or curing compounds but may often be due to bleeding at plastic or semi-plastic stage, moisture migration and alkali redistribution in service, increased paste or cement content compared to the bulk concrete (for example, due to finish densification), and other factors such as cleaning detergents.

ASR Determination

While the presence of reactive aggregate, a gel that appears to have ASR origins, associated cracks, and spatial connection between a blister and a reactive particle are necessary conditions, they may not have occurred in sufficient abundance to ascribe surface distress solely to ASR. Further, caution must be taken to positively attribute surface distress of flooring finishes to ASR, as some products commonly applied to concrete floors can result in nonexpansive gels that can be confused with ASR gel.[7]

A combination of field investigation, proper sampling, petrographic examinations, and chemical analysis is key to identifying ASR-related distress in flooring finishes. If a change in use will result in the need to apply a coating to an existing floor, we recommend a petrographic study per ASTM C856[8] to assess the potential for ASR-related distress. Most application requirements for resilient flooring and coating will also include slab moisture studies. Pertinent ASTM specifications, ACI recommendations, or flooring experts should be consulted.

Potentially reactive particles may be found in most aggregate sources throughout the United States. For new construction, testing in compliance with ASTM C457/C457M[9] can be used to determine the volumetric content of reactive particles in hardened concrete. Petrographic examinations in accordance with ASTM C295/C295M[10] can be conducted on aggregate samples to identify potentially alkali-silica reactive and other deleterious constituents, quantify such constituents, and recommend additional tests to assess aggregate constituents of poor performance. Information gathered through these assessments can be used to adjust mixture components to reduce problems prior to construction, or to address anticipated problems in existing construction.

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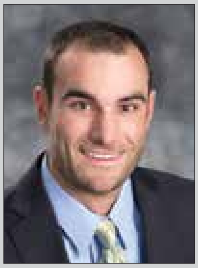
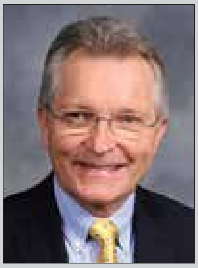
Selected for reader interest by the editors.

Xiaoqiang (Hugh) Hou is an Associate III at Wiss, Janney, Elstner Associates, Inc. (WJE), Northbrook, IL. He is a member of the Illinois Chapter – ACI, ASTM International, the International Cement Microscopy Association, and the Society of Concrete Petrographers. He received his BS in geology from Taiyuan University of Technology (formerly Shanxi Mining College), Shanxi Province, China; his MS in coal geology from China University of Mining and Technology, Beijing, China; and his PhD in geology from the University of Illinois at Urbana-Champaign, Urbana, IL.

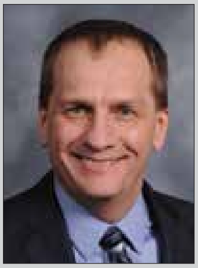
Richard A. Cechner is a Senior Associate at WJE. He has been involved with investigations of polymeric materials, concrete, mortar, coatings, sealant, and adhesive failures, and analysis of a wide variety of construction materials. He is a member of the Illinois Chapter – ACI and the Association for Preservation Technology International. He received his BS in chemistry from Roosevelt University, Chicago, IL.



ACI member **Terrence M. McGovern** is a Senior Associate at WJE, Lakewood, CO. He is a member of ACI Committees 546, Repair of Concrete, and 563, Specifications for Repair of Structural Concrete in Buildings. He is also a member of the Structural Engineers Association of Colorado. He received his BS and MS in civil engineering from the University of Michigan, Ann Arbor, MI. He is a licensed professional engineer in Colorado.



ACI member **Kevin A. Michols** is a Principal and Director of Janney Technical Center at WJE. He is a member of ACI Committees 546, Repair of Concrete, and 563, Specifications for Repair of Structural Concrete in Buildings. He is also a member of the American Society of Civil Engineers, International Concrete Repair Institute, and Structural Engineers Association of Illinois. He received his BS in civil engineering and his MS in structural engineering from the University of Illinois at Urbana-Champaign. He is a licensed professional engineer in multiple states and a licensed structural engineer in Illinois and Nebraska.



ACI member **Todd Nelson** is an Associate Principal at WJE. He is a member of ACI Committees 302, Construction of Concrete Floors, and 360, Design of Slabs on Ground. He is also a member of the American Concrete Pavement Association, the American Concrete Pipe Association, and ASTM International. He received his BS in civil engineering from the University of Minnesota, Minneapolis, MN. He is a licensed professional engineer in Illinois.