Definition

Alkali-Silica reaction is the reaction between the alkalis (sodium and potassium) in Portland Cement and certain siliceous rocks or minerals, such as opaline chert, strained quartz, and acidic volcanic glass, present in some aggregates; the products of the reaction may cause abnormal expansion and cracking in concrete in service.

In Iowa (in our area), alkali aggregate reactions occur in two distinct forms;

1. alkali silica reactivity, which occurs in concrete with reactive coarse aggregate and
2. popouts, which is a surface blemish resulting from an expansive reaction in the fine aggregate near the concrete surface.

By far the most visible defect in our area is popouts. During the last Ice Age, central, north central and northwest Iowa as well as Minnesota and the Dakotas was covered by glacial deposits containing cretaceous shales that were exposed and distributed by glacial action. Opaline microfossils are present in these shales. These shales are contained in our concrete sands.

ASR or the deleterious reaction between alkalis and coarse aggregate is rare in our area. Few coarse aggregates are reactive and those few are well identified.

Contributing Factors

Alkali aggregate reactions need specific conditions to proceed; alkalis, reactive aggregate, appropriate temperatures and water. Concrete blemishes known as popouts can be a potential problem in central and northern Iowa. Researchers have established that these popouts result from a chemical reaction between alkalis in the cement and fly ash and cristobalite or opaline shale in the concrete sand.

The shale particles contain opaline silica. Researchers investigated whether alkali-silica reactivity (ASR) was the cause. Shale particles were embedded in parts of cement paste that contained either high-alkali or low-alkali cement. After curing for 18 hours, numerous popouts had formed on the high-alkali samples, while none had formed on the low-alkali mix.

When concrete dries, evaporating water brings alkalis to the surface, increasing the alkali concentration. Therefore the researchers investigated factors that could influence the rate and amount of evaporation, these included: temperature and humidity, slab thickness, covering before final finishing, and curing procedures.

The researchers also reasoned that the permeability of the concrete near the surface would also influence the formation of popouts. Concrete with low permeability would be more likely to trap ASR gel within the concrete, increasing the internal pressure and the chance for popouts. Therefore, the following variables were tested: cement content, finishing technique, air entrainment, and curing procedure.

Results

Low-alkali cements produced fewer popouts than high-alkali cements, and 30% replacement of cement with slag was also shown to significantly reduce popouts. However, the benefits of these materials were diminished when the concrete was exposed to high temperature and low humidity between the time of casting and troweling, which significantly increased the number of popouts. For example, popouts formed in significant numbers even with cement of 0.4% alkali content when the concrete was placed under hot and dry conditions.

Slabs that were protected from drying with a polyethylene cover before troweling developed fewer popouts than slabs that were not covered. Six inch thick slabs developed more popouts that three inch thick slabs.

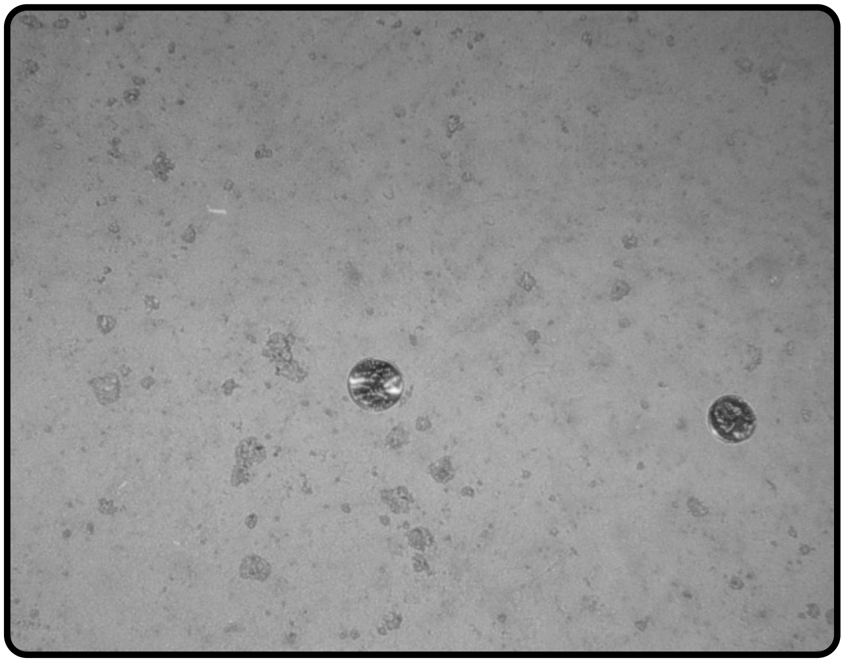
Slabs cured with a polyethylene film after troweling produced as many, if not more popouts than slabs that were air-cured. A liquid-membrane curing compound caused more popouts than polyethylene curing. However, curing the concrete with ponding or continually moist sand or burlap nearly eliminated popouts. To be effective, however, these curing techniques must be initiated soon after finishing is complete,

Concrete with a lower cement content suffered fewer popouts than concrete with a high cement content. Air entrainment had little effect on popout formation. Finishing technique was also found to have an effect on popout formation. Slabs that were finished by wood screed alone or with magnesium floating did not develop popouts, whereas slabs that were steel troweled did. Late steel troweling resulted in more popouts than earlier steel troweling.

There is one more form of surface blemish, not related to ASR. This blemish is similar to popouts but the action that forms this blemish is different and relies on freeze/thaw action. Some aggregates in this area have a soft porous layer in the limestone formation that is mixed in the stone during processing. This porous stone absorbs water. Upon experiencing freezing temperatures an expansion occurs and a "pop out" happens. The blemish is the same but the cause is different. These types of popouts usually do not occur until the slab has gone through a winter. These popouts, like those caused by ASR, are not structural and will not affect the serviceability of the slab. Because this type of popout occurs in the coarse aggregate, the blemish may be as large as the largest aggregate particle in a concrete mix.

Recommendations

Cure the concrete properly. Use a method for curing, which maintains water on the surface of the concrete. These include ponding, continuously spraying or saturated wet covers such as wet burlap or wet sand. Such methods provide some cooling of the surface and allow the reaction of the products to leave the concrete. It is essential before allowing the concrete to dry, to rinse and flush the surface to remove reactive products. It has been reported that proper wet curing can virtually eliminate pop outs.



Use the proper concrete mix. Use a concrete mix with workability suited to the type of mechanical placing and finishing equipment to be used. The greater the slump, the more likely small, lighter weight particles will be displaced to the top of the surface.

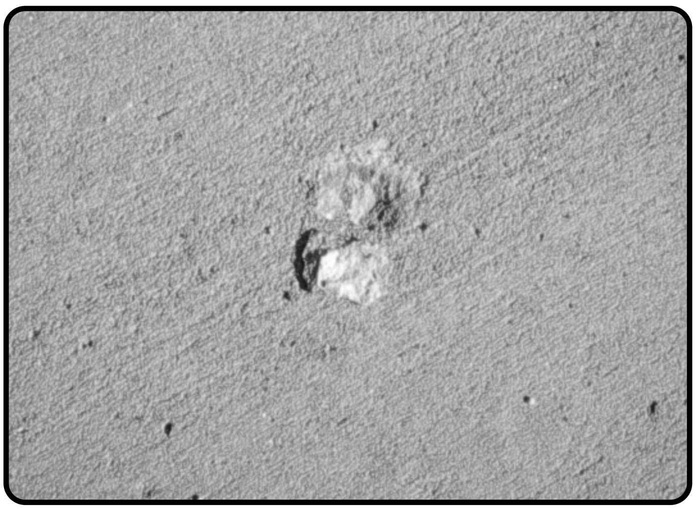
continued...

Recommendations continued

Reduce the temperature of the concrete. The rate of the alkali-silica reaction evidently increases with an increase in temperature. At lower concrete temperatures the possibility of popout development can be reduced. Provide pre-troweling protection to the concrete. Protect the concrete against rapid evaporation between the time it is placed, troweled, and afterwards. Proper protection might be achieved by use of windbreaks, fog sprays, polyethylene film or monomolecular film that retards evaporation.

Avoid a vapor barrier under the slab. Place a vapor barrier under the slab only when the floor is to receive an impermeable surface finish or be used for any purpose where the passage of water vapor through the floor is undesirable. If a vapor barrier is necessary, cover it with 2-3 inches of damp compacted sand before placing the concrete.

Adhere to the correct timing sequence when finishing. Do not begin any finishing operation while there is excess moisture or bleed water on the surface. Such action would only aggravate the concentration of alkalies at the surface.



References

Plastic Shrinkage Cracking, NRMCA, CIP #5, 1998