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The Alkali-Aggregate Reaction Known as Popouts

The Technical Committee of the Iowa Ready Mixed Concrete Association has prepared this information sheet on the subject of small sized popouts in hardened concrete.

What are alkali-aggregate popouts?
These popouts are concrete surface blemishes resulting from a chemical reaction between alkalis (sodium and potassium) found in Portland cement or other sources, expansive sand particles (usually silica in the shale), and sufficient moisture. Popouts are characterized by an inverted cone-shaped fracture 1/8 to 1/2 inch in diameter and range in density from one or two to in excess of one hundred per square foot. The expansive sand particle can be seen at the bottom of the cone. These popouts, although undesirable since they detract from appearance, do not affect the structural integrity of the concrete.

Where is the affected geographical area?
The Keewatin Glacier deposited the shale containing the reactive silica in central, north central and northwest Iowa as well as parts of Minnesota, the Dakotas and Canada.

Why do popouts occur?
It is generally agreed that these popouts are caused by a chemical reaction of the shale particles and the alkali content of the concrete at the slab surface. The alkalis migrate with the excess water in the concrete (bleed water) to the surface of the concrete where they can be concentrated as much as seven-fold during the drying of the surface. This concentration of alkalis on or near the surface increases the likelihood of contact and reaction with the expansive sand particle. With moisture available, a chemical reaction takes place which results in expansion. The popout occurs when the pressure of this expansion is greater than the concrete can resist.

How can popouts be minimized or possibly eliminated?
The degree and rate of most chemical reactions is controlled by the **concentration of the reactants** and the **temperature**. As such, the severity and speed at which popouts occur, being a surface phenomenon, is dependent on the amount of reactive material brought to the surface during finishing and that temperature at the concrete surface. The total amount of alkalis in the concrete can be affected by factors such as alkalis in cement, water and admixtures. Generally, high-alkali cement will be involved with popouts more than very low alkali cements, but it is an incorrect assumption that high-alkali content cements must always cause more popouts. Popouts can occur with low-alkali cement of other contributing factors are ignored. It should be noted that popouts could occur even though the fine aggregate and Portland cement meet standard specifications.

Close attention to the following factors can minimize or possibly eliminate the popout reaction:

1. **Cure the concrete properly.** Use a method for curing that 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 reaction products concentrations to be reduced. It has been reported that proper wet curing can virtually eliminate these popouts.

   Before allowing the concrete to dry, it is essential to rinse and flush the surface to remove reaction products. Where reactive popouts may occur, two widely used methods of curing, a sprayed on membrane or polyethylene film, are not recommended. Evidence from laboratory and field studies indicates these methods may aggravate the reactive popout condition by sealing the surface.

2. **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 surface.

   A concrete mixture with little bleed water restricts the migration of alkalis from within the concrete that can cause a higher concentration at the surface of the slab. The use of purposefully entrained air will reduce the tendency for aggregates to segregate and also reduce bleeding.

3. **Reduce the temperature of the concrete.** The rate of the alkali-siliceous reaction evidently increases with an increase in temperature. At lower concrete temperatures, the possibility of popout development can be reduced.

4. **Provide pre-troweling protection to the concrete.** Protect the concrete against rapid evaporation between times it is placed, troweled and afterwards. Protect the surface from direct exposure to sunlight during finishing operations to reduce the migration of alkalis to the surface. Proper protection might be achieved by use of windbreaks, fog sprays, polyethylene film or monomolecular film that retards evaporation.

5. **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 alkalis at the surface and also cause other surface problems.

   Avoid hard steel troweling the surface where it is not needed.

6. **Avoid placing a vapor barrier under the slab**. Vapor retarders/barriers should only be used when vapor sensitive floor coverings are used or in humidity controlled areas. The vapor retarder/barrier should be placed immediately below concrete slab when vapor sensitive floor coverings are used, in humidity controlled areas where the base materials and the slabs will be placed without a water-tight roofing system in place, or in a humidity controlled area where the granular base is subject to future moisture infiltration. It should be noted that this can increase the potential for popouts and slab curling. In areas that are humidity controlled, have water-tight roof systems in place, and the granular base is not subject to future water infiltration the vapor barrier should be placed under several inches of clean, dry, fine-graded granular material with at least 10 to 30%of the particles passing a No. 100 sieve not contaminated with clay silt or organic material.

This sheet is based on information available to the committee. Its purpose is to provide data and general guidelines on the subject to ready mixed concrete producers and contractors.