

Waterproof? Watertight? Water-Repellent?



By Susanne M. Papas

Figure 1 – Testing for the presence of hydrophobic admixtures. A droplet of water is applied to the exterior finished surface or broken concrete surface representing nonhydrostatic water exposure.

As a chemist who consults on materials used in or on construction products, I am frequently asked, “Will this product work?” My answer often is, “It depends.” This seems particularly true when I am asked about water-penetrating concrete. There appear to be lots of confusion and opinions when it comes to preventing water penetration through concrete. Terms such as “waterproof,” “watertight,” and “water-repellent” seem to be used interchangeably; however, these words can describe some very different conditions. This article will look at admixtures that can be added to the concrete mix to prevent water penetration and chemical barriers that are applied to the surface of the concrete after hardening. Physical barriers such as membrane sys-

tems are not discussed.

Concrete that is proportioned well has a low water/cement (w/c) ratio, is well cured, is of durable material, and has low permeability. It will have resistance to liquid water penetration; however, it will not totally prevent water from passing through it. Water can and will pass through concrete due to two main mechanisms: capillary absorption and hydrostatic pressure.

Capillary absorption is the movement of water through the pores and microcracks in the concrete itself. Microcracks are fine cracks up to 0.02 mm (0.74 mil), typically around 0.004 mm (0.16 mil). Microcracks include most shrinkage cracks as well as some settlement cracking. Mesocracks are typically 0.1 mm (3.94 mil). Macrocracks are larger still, ranging from 0.15-0.3 mm (5.9-11.8 mil) (ACI Committee 224 2001).

Halvorsen, in ACI SP-104 (Halvorsen 1987), suggested that the narrowest crack a human eye can detect, depending on surface texture and other factors, is 0.13 mm (5 mil). This is somewhere between a mesocrack and a macrocrack.

Capillary absorption can occur when the exterior surface of the concrete is wetted, such as rain hitting a vertical exterior wall of a building. Hydrostatic pressure occurs when water moves through concrete due to pressure differences. Examples of water moving due to hydrostatic pressure are groundwater surrounding an underground vault or tank, or water ponding on the roof of a structure.

Systems that provide reduction in the passage of liquid water through concrete fall into two categories: waterproofing and dampproofing. Waterproofing systems pre-

vent the passing of liquid water under hydrostatic pressure. Dampproofing systems resist the passage of liquid water when hydrostatic pressure is absent. Neither system will prevent water from moving through larger cracks (macrocracks) in concrete.

Cold joints form in concrete when it is cast against existing hardened concrete. Cold joints can also occur during casting of concrete where the time between pours was excessive or if new concrete is poured without preparing the existing concrete.

Concrete shrinks as it cures, so if a new slab or section of concrete is poured against an older or existing section of concrete, the joint between the two will appear initially to be filled; however, as the new concrete cures, shrinkage will leave a space between the two slabs or sections of concrete. The degree of shrinkage is dependent on several factors—cement content, w/c ratio, and aggregate content—and can be significant. For example, for a concrete with a w/c of 0.5 and an aggregate content of 70%, shrinkage would be approximately 0.0008 in./in. (0.02 mm/mm) of concrete (Ainso and Tronzo

1986). For a 25-foot slab with this w/c and aggregate content, shrinkage would be 0.24 in. (6.1 mm). Gaps in concrete systems due to cold joints can therefore be significant sources of water intrusion. Experience shows that neither dampproofing systems nor waterproofing systems have been absolutely effective in the prevention of water moving through cold joints.

There are two basic methods for preventing or stopping water from passing through concrete: admixtures that are integral to the concrete itself and barriers applied to the exterior surface of concrete.

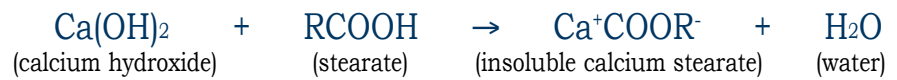
ADMIXTURES

The American Concrete Institute (ACI) classifies admixtures that control moisture or water movement through concrete as permeability-reducing admixtures (PRA). There are three main types: hydrophobic chemicals, finely divided solids, and crystal-

line admixtures.

Hydrophobic chemicals represent the largest group of these admixtures (ACI Committee 212 2010). Trade name products such as W.R. Grace's Darapel or Dry-Block¹ are examples of common hydrophobic chemicals. This group consists of materials made from long-chain fatty-acid derivatives, vegetable oils, and petroleum-based products. Hydrophobic chemicals create a water-repellent layer along the concrete pores, but the concrete pores remain physically open (*Figure 1*). These types of products are useful for dampproofing but will not prevent the transmission of liquid water through concrete when hydrostatic pressure is present (*Figure 2*).

The most common type of hydrophobic admixture is a stearate-based system such as calcium stearate. These systems work as shown in *Equation 1*.

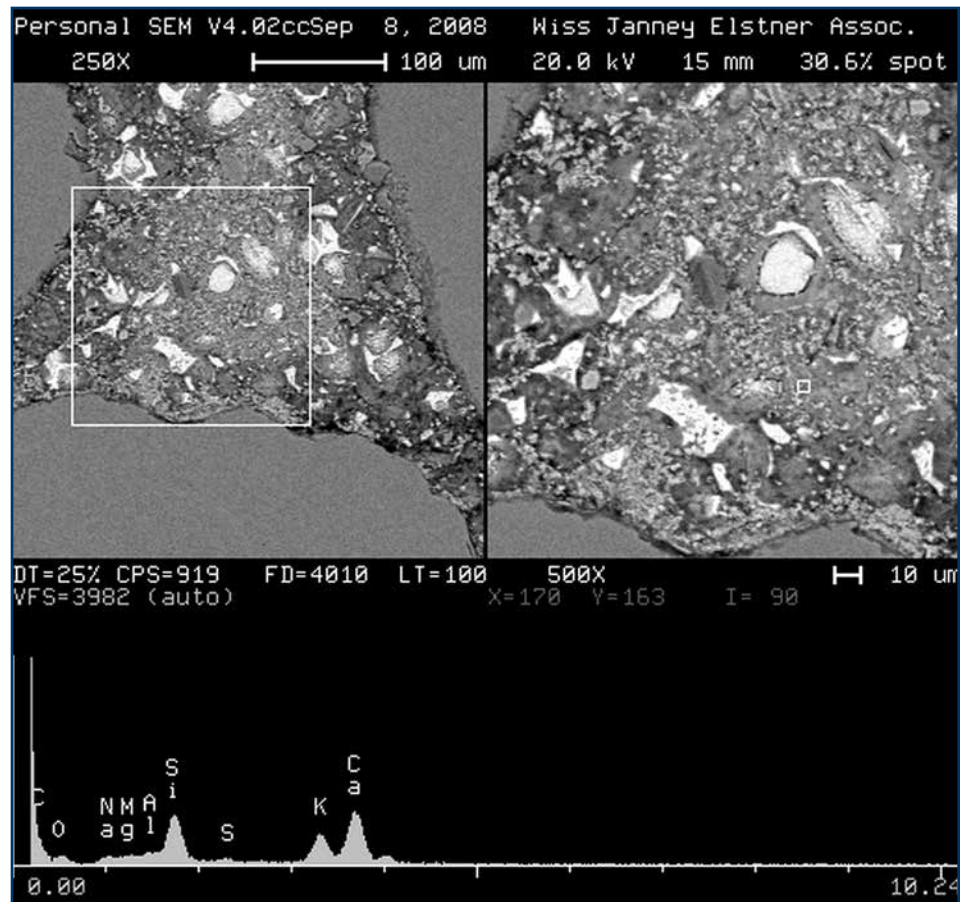


Equation 1



Figure 2 – An example of concrete that contains a hydrophobic admixture. Notice how the water droplet forms a tight bead and does not disperse into the concrete. Photo courtesy of Laura J. Powers of Wiss, Janney, Elstner Associates, Inc. (WJE).

Figure 3 – SEM micrograph of an area of concrete that contains a crystalline admixture. The image on the right is the area contained within the box in the left image. The elemental composition of the material in the right image is shown in the spectrum on the bottom of the figure. High levels of potassium (K) combined with high levels of silicon (Si) and calcium (Ca) indicate the presence of a water-glass-type crystalline permeability-reducing admixture. 250X magnification. Micrograph courtesy of Laura J. Powers, WJE.



Calcium hydroxide produced by the hydration of Portland cement reacts with the stearate admixture to form insoluble calcium stearate and water. Hydrophobic admixtures also include polymers, which coalesce within the concrete to form a water-repellent film. While polymer admixtures effectively block the concrete pores, they lack the ability to bridge cracks within the concrete and, therefore, can allow liquid water to pass through the concrete. Integral petroleum-based products do not react with the cement in the concrete system; and, like polymer admixtures, have limited or no ability to bridge cracks, again allowing liquid water to pass through the concrete.

The second type of PRA is finely divided solids. Some are chemically inert, and some are chemically active. This type of admixture works by filling the pores of the concrete and restricting the movement of water through the concrete. Examples of these are talc, bentonite clay, lime, silicate, and colloidal silica. This type of admixture works by increasing density or filling the voids in the concrete; however, they only provide dampproofing or water-repellency rather than completely blocking the passage of liquid water through concrete. This type of admixture should only be used where hydrostatic pressure is absent.

The third type of PRA for concrete is a crystalline admixture. BASF's Rheomac 300D and IPA Systems, Inc.'s Ipanex are examples of crystalline admixtures. These admixtures, like the stearate-type admixtures, react with the calcium hydroxide produced by hydration of the Portland cement. Crystalline admixtures are most commonly provided in a mixture of cement and sand. This type of admixture reacts with the water and the calcium hydroxide in the hydrating cement to form calcium silicate hydrates and pore-blocking precipitates (Figure 3). This type of admixture

will continue to react after the concrete has passed the plastic state. If water and calcium hydroxide are present (concrete is not fully carbonated), they can provide some level of microcrack bridging and capillary-pore blocking for many years after initial placement of the concrete. While this type of admixture will resist water penetration when some hydrostatic pressure is present, it cannot bridge meso- and macro-cracks that form in concrete with time.

BARRIERS APPLIED TO CONCRETE SURFACE

Barriers applied to the surface of concrete can contain similar compounds to those used as integral admixtures. Barriers can consist of hydrophobic materials such as stearates, pore-blocking materials such as bentonite, and crystalline admixtures such as sodium metasilicate (water-glass systems). The performance issues with these admixtures are similar when applied as a barrier as when used integrally in concrete. They can provide dampproofing and some degree of water-repellency; however, the same limitations—the absence of hydrostatic pressure and limited crack-bridging capacity—also apply.



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SUMMARY

The key to a successful water-protection scheme is knowing whether the substrate will be exposed to hydrostatic pressure or not and then selecting an appropriate system. Integral PRAs can affect properties of plastic concrete. Levels of air entrainment, setting time, and water reduction can be increased or decreased, depending on the admixture used. These types of admixtures can also affect concrete finishing, mix consistency, and scheduling of placement. Once hardened, PRA concrete can exhibit changes to compressive strength, freeze-thaw resistance, and shrinkage. It is critical to review product data information as well as to perform trial batches with a selected PRA to ensure that the selected concrete mix will meet expectations. Working directly with a PRA admixture manufacturer can provide needed information on addition rate, order of addition, mixing time, and compatibility with other materials in the cementitious system.

Success of barrier PRA systems also requires careful review of product data sheets to determine if a given system is appropriate for a given application. Surface preparation is a key factor in the success or failure of a PRA barrier system. Strict adherence to the manufacturer's instructions on surface preparation, coating film thickness, cure time before application of subsequent coats, and ultraviolet protection (if needed) are necessary for proper system performance. In addition, barrier systems may require periodic reapplication to perform properly.

Both integral permeability-reducing admixtures and barrier permeability-reducing admixtures can have an effect on the performance of subsequently applied membrane systems. The surface preparation—including the potential need for a sur-

face-applied primer or bonding agent—may be required for good performance of the membrane. It is critical that communication with the membrane vendor include the type of permeability-reducing system used, as well as the approximate age of the concrete system. Mock-ups should be considered to determine if the permeability-reducing system is compatible with the proposed membrane system. 

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FOOTNOTE

1. Brand name products mentioned in this article are given as examples only. No endorsement or recommendation of a specific brand name product should be inferred.

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Susanne Papas is a senior associate at Wiss, Janney, Elstner Associates with 29 years of experience as an analytical chemist. She has analyzed a wide variety of construction materials, including concrete, mortar, brick, stone, wood, soil, and water to determine the cause of construction material failures. She is active in ASTM Committees C01, Cement; and C09, Concrete and Concrete Aggregates.



RCI FOUNDATION ESTABLISHES LEWIS W. NEWLAN EDUCATIONAL FUND

The RCI Foundation (RCIF) has established the Lewis W. Newlan Educational Fund. According to Chairman Joe Hale, the fund's purpose is to assist individual students with scholarships, tuition, internships, etc. The initial fundraising goal is \$25,000.

Mr. Newlan, who died in August 2012, was a long-standing RCI member and a strong supporter of the work of the RCIF. Foundation Vice Chairman Mike Blanchette, along with Thompson Engineering, Mr. Newlan's employer, initiated this effort with a \$1,000 donation. Blanchette noted, "It is gratifying for the Foundation to be able to establish this fund, which will carry on the great legacy of this very generous member of RCI."

To download a form to contribute to the fund, visit rcifoundation.org/downloads/RCIF-Lewis-Newlan-Donation-Form.pdf.