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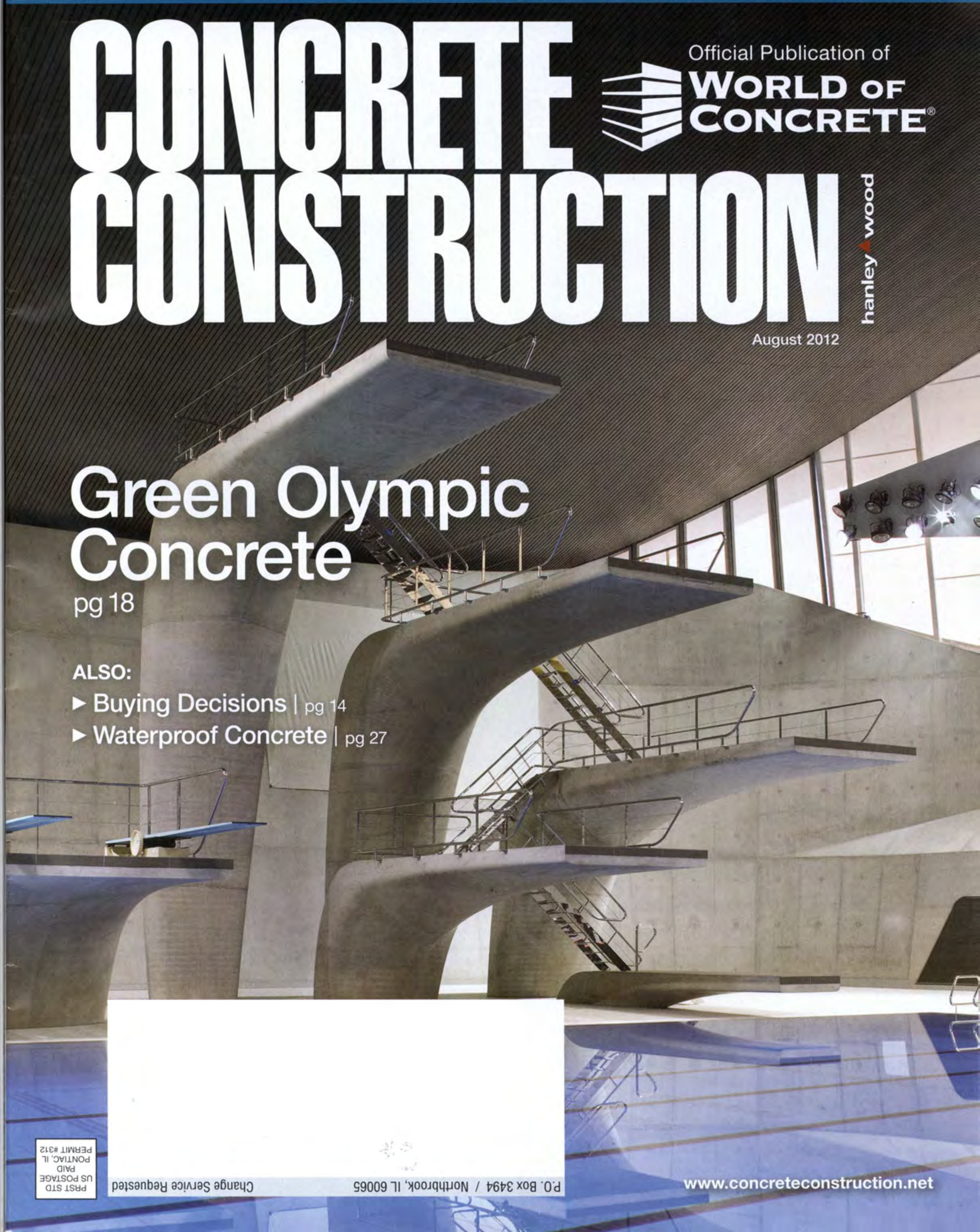

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By Ken Hooker

Waterproof Concrete

Going beyond surface treatments to reduce concrete permeability.

The Miami-Dade County South District Wastewater Treatment Plant is undergoing a two-phase construction using crystalline chemical waterproofing. Phase 1 includes 52,000 sq. ft. of surface area treated with a two-coat system, and phase 2 uses the crystalline technology, in admixture form.
PHOTO: XYPEX CORP.

Water is essential to concrete production, placement, and curing. But once it fulfills its role in those processes, water is no longer concrete's friend. Depending on its function and the nature of its exposure, concrete can of course perform well in wet environments. As a naturally porous material, though, and one that is prone to cracking, concrete is vulnerable to water infiltration. The unfortunate results can be freeze/thaw damage and deterioration due to corrosion of embedded steel reinforcement.

Any number of products and systems are available to help protect concrete structures from damage due to water, from coatings to sealers to membranes and more. Enormous amounts of effort and money are spent to design and apply such protection, with varying degrees of effectiveness.

One method that can simplify the protective process is to make concrete with admixtures that reduce its permeability—in effect to make the concrete itself waterproof. A variety of such admixtures are now on the market, and ACI Committee 212, Chemical Admixtures, offers some guidance on their use in its 2010 revision of ACI 212.3 "Report on Chemical Admixtures for Concrete."

TABLE 1. Reduction of Permeability of Concrete Using PRAs

Admixture type	Coefficient of permeability of reference concrete	Coefficient of permeability of test concrete	Percent reduction in permeability
Crystalline	4.29×10^{-14}	1.28×10^{-14}	70
Colloidal silica	1.98×10^{-13}	1.61×10^{-13}	19
Hydrophobic pore blocker	2.23×10^{-12}	1.14×10^{-12}	49

Source: ACI 212.3-R10, "Report on Chemical Admixtures for Concrete"

THE VALUE OF A PRA DEPENDS ON THE ENVIRONMENT THE CONCRETE WILL BE EXPOSED TO AND THE IMPORTANCE OF KEEPING WATER FROM PASSING THROUGH.

Chapter 15 of that report covers permeability-reducing admixtures (PRAs) and differentiates between those suitable for concrete exposed to nonhydrostatic conditions (PRAN) and concrete exposed to hydrostatic conditions (PRAH). Besides reducing permeability, some PRAs impart other beneficial characteristics, such as reduced drying shrinkage, reduced chloride-ion penetration, improved freeze/thaw resistance, and enhanced autogenous sealing.

Three types of PRAs

The materials used to produce PRAs vary, but they generally fall into three categories. The largest category consists of hydrophobic, or water-repellent, chemicals derived from soaps or fatty acids, vegetable oils, and petroleum. These materials form a water-repellent layer along pores in the concrete, but the pores themselves remain open.

The second category is finely divided solids—either inert or chemically active fillers such as talc, clay, siliceous powders, hydrocarbon resins, and coal-tar pitches. These materials densify the concrete and physically limit the passage of water through the pores. Some experts also consider supplementary cementitious materials (SCMs) to be in this category.

The third category consists of crystalline products—proprietary active chemicals in a carrier of cement and sand. These are hydrophilic materials that increase the density of calcium silicate hydrate or generate crystalline deposits that block concrete pores to resist water penetration. The various types of materials can be used alone or in combination to give different levels of performance.

According to the ACI report, concrete produced with hydrophobic chemical admixtures could theoretically resist some hydrostatic pressure. However, because the hydrophobic material does not uniformly coat all pores and because the concrete also contains larger voids, such products are not typically classified as PRAHs.

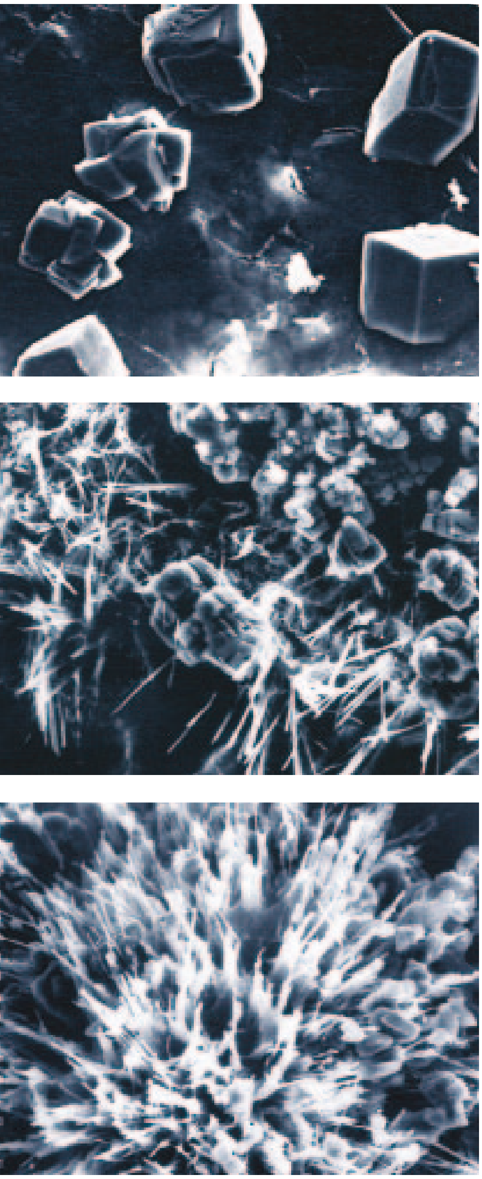
There are also some latex-polymer admixtures that can resist hydrostatic pressure, but they can't bridge cracks in concrete and thus don't produce truly watertight concrete structures. These admixtures are sometimes added to repair mortars, but are not typically used in ready-mixed concrete.

It is the hydrophilic crystalline admixtures that provide concrete with the greatest resistance to infiltration of water under hydrostatic pressure. Their active ingredients react with water and cement particles to form calcium silicate crystals that integrally bond with the cement paste. These crystalline deposits block both pores and microcracks in the concrete, to prevent the passage of water. This reaction continues over the life of the concrete, serving to seal not only initial shrinkage cracks, but also cracks that occur over time.

Table 1, reproduced from ACI 212.3, summarizes results from a series of permeability tests performed on concrete mixes with and without three different types of PRAs. Note that these results only indicate the reduction in permeability between the reference and test concrete for each admix type. They can't be used to directly compare the different admix technologies because the reference concrete mix for each type was different.

When to use them

In theory, a PRA could be added to any concrete mix without adverse effects, but it's not usually necessary in practice. The value of a PRA depends entirely on the environment the concrete will be exposed to and the importance of



In crystalline PRAHs, the reactive chemicals use water to migrate into and travel down the capillaries of the concrete. The process initiates a chemical reaction involving the crystalline chemicals, moisture, and the by-products of cement hydration, which forms a new non-soluble crystalline structure. This integral structure fills the capillary tracts and renders the concrete waterproof.

PHOTO: XYPEX CORP.

keeping water from passing through. For interior columns, beams, and floor slabs in a high-rise, permeability isn't a big issue. On the other hand, for structures that will be exposed to moisture, salt or salt water, wicking, or water under hydrostatic pressure, using a PRA can help prevent problems such as water migration, leaks, freeze/thaw damage, corrosion, carbonation, and efflorescence.

PRANs are often used in architectural concrete, precast panels, and concrete brick, block, and pavers to repel rain and minimize dampness. Reducing permeability can help minimize efflorescence and make it easier to keep walls clean.

PRAHs are needed for more extreme and continuous exposures, such as below-grade structures, tunnels and subways, water tanks and pools, bridges, and dams. Manufacturers of the crystalline PRAHs say the products can eliminate the need for membrane waterproofing systems and epoxy-coated reinforcement, thereby reducing the cost of waterproofing.

How to use them

Like other admixtures, PRAs are typically specified by the architect or engineer and added to the concrete at the ready-mix plant. Greg Maugeri, head of New England Dry Concrete, which distributes Kryton's line of PRAHs in the northeastern U.S., describes the process: "We market to ready-mix companies, but part of our role is to educate designers and applicators about the product. We'll help designers understand how to detail waterstops when they use our product, because that's different from conventional membrane waterproofing."

"Besides reducing permeability, the admixture acts as a mild retarder, so it helps to control the heat of hydration and consequently reduces shrinkage cracking. It doesn't drastically change the properties of fresh concrete, but it can improve workability somewhat. When someone considers using our product, we'll review the mix design and also send it to Kryton's lab for review, to make sure any interactions with other admixtures are taken into account. We also recommend that the contractor do a test pour, to check for air content, slump, and so on," Maugeri says.

"The typical dosage rate for crystalline PRAHs is 2% by weight of total cementitious materials," says John Ladas, a sales representative for Xypex Chemical Corp.'s waterproofing admixtures, "except in an extraordinary case, such as an exceptionally corrosive atmosphere. We can also modify the formula depending on the circumstances. We make one formulation that doesn't retard set at all. We might recommend that for large flatwork areas, cold weather, or a mix that contains a lot of slag."

Successful projects

Waterproofing admix was used in the renovation and expansion of the Mark Jefferson Science Complex at Eastern Michigan University in Ypsilanti, completed earlier this year. Concrete containing the Xypex crystalline PRAH was used for green roof slabs on the building addition and for an underground utility tunnel. It was the first experience with the material for Jennifer Emerick, project manager for general contractor The Christman Co. in Lansing, Mich., and she was favorably impressed. "The tunnel consists of a 1-foot, 2-inch-thick slab, with 1-foot-thick walls and lid. It was built about 2 years ago, and there have been no leaks since the initial shrinkage cracks were sealed by the crystallization of the admix. It worked just the way the manufacturer said it would. We also got a watertight roof on the addition, without any additional roofing materials. And the placement went smoothly, just like any concrete mix," Emerick says.

For projects and applications that need waterproof concrete, the use of PRAs is worth considering. Contractors need only follow sound placement and finishing practices to install it successfully, and owners may be able to cover the costs by saving the labor and materials required for other waterproofing methods. **CC**