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Crystalline technology waterproofs water treatment systems

Engineers and contractors are adopting crystalline concrete waterproofing solutions to increase the service life of water treatment and storage systems worldwide. **Jim Caruth**, P. Eng. of XYPEX Chemical Corporation, explains the reasons for this growing trend.

Every public drinking water system varies by source, type, and quality of raw water, as well as the treatment processes to remove contaminants – and every water treatment system depends on concrete to hold, treat, or distribute this vital resource.

Although properly designed, mixed, placed, and cured concrete has good durability, its tendency to crack and its porous nature renders it permeable to liquids and gases. This makes it susceptible to deterioration caused by water and chemical ingress. Both of these will jeopardize the long-term integrity of the structure and result in increased operating, maintenance, and environmental costs.

In the past, the most commonly accepted way to ensure long life and low permeability of a concrete structure in a water system environment was to install a spray-applied or specialized coating, or a peel-and-stick sheet membrane system.

More recently, owners, engineers, and contractors have turned to crystalline technology to make the concrete impervious to moisture. These permeability-reducing admixtures for concrete exposed to hydrostatic conditions (PRAHs) are considerably less costly and more convenient than external barrier/membrane solutions without the exposure disadvantages such as tearing, puncturing, or detachment.

After extensive testing and investigation, leading independent scientific laboratories and regulatory bodies – including the American Concrete Institute (ACI) – agree. The ACI committee, responsible for ACI 212.3R-10 (Report on Chemical Admixtures for Concrete), documented the applications and capabilities (durability, permeability and chemical resistance) of PRAHs. The Report on Chemical Admixtures for Concrete, published by ACI in November 2010, spotlighted the uses and benefits of crystalline admixtures, which incorporate active ingredients that "react with water and cement particles in the concrete to form calcium silicate hydrates and/or pore blocking precipitates in the existing microcracks and capillaries."

The authors of the ACI report further state, "The resulting concrete has significantly increased resistance to water penetration under pressure. PRAHs are appropriate for water-containment structures, below-grade structures, tunnels and subways, bridges and dams, and recreational facilities such as aquatic centers." The PRANs are "normally for repelling rain and minimizing dampness" and "can improve the quality of concrete pavers, tiles, bricks, blocks, and cladding panels."

Inside the crystalline structure

The chemical formulations of crystalline waterproofing products are a manufacturer's trade secret. However, in all cases these materials react with the by-products of cement hydration, such as calcium hydroxide – commonly called "freelime" – and other mineral salts within the cement matrix.

Crystalline waterproofing chemistry reacts with these materials to form small, mineral-based "dendritic crystalline structures" that are insoluble in water. The formation of the crystals is a gradual, cement chemistry-based process, requiring several days to several weeks for the crystals to reach maturity. As the crystals grow across the diameter of the concrete's pores, they form a microscopic, mesh-like barrier that plugs the pores and prevents the flow of liquids, even in extreme hydrostatic pressure.

Independent laboratory testing, in accordance with US Army Corps of Engineers (ACE) CRD C-48, Permeability of Concrete, demonstrated that crystalline-treated concrete could withstand up to 405 ft (123 m) of head pressure – 1.2 MPa (175 psi), which was the limit of the testing apparatus.

In the form of vapor, water molecules can gradually work their way through the crystal formation, allowing it to escape out on the downstream side, and thus permitting the concrete to dry. Although crystal formation largely matures in two to three weeks, the process can continue as long as there is moisture in the concrete. The reaction effectively never runs out of lime, meaning that if water re-enters the concrete years later, it automatically reactivates the waterproofing chemicals and new crystallization begins.

The necessity for the right method used to waterproof concrete is crucial to the operation and longevity of a water treatment system. As demand for water grows, the integrity and efficiency of water treatment systems will become more critical.

Above: The Ras Laffan Reservoir in Qatar was waterproofed by application of the two-coat Xypex system.

At the micro-level, shrinkage-cracking from drying potentially creates passageways for moisture infiltration. If they occur while there is still mix water in the concrete and crystals are still forming, micro-cracks (and macro cracks up to (16 mil) 0.4 mm) can be bridged. If they occur later and allow water infiltration, the water reactivates the waterproofing chemicals, making the concrete self-healing on the micro and macro scale.

A waterproof barrier

Water purification involves both significant capital and operating costs, which are spread over every liter of water produced. Thus, leakage of water will not only lead to early maintenance of the structures, but it will also increase the cost of water processing by allowing leakage of processed water to the environment.

Water storage or process tanks are often buried, with the likelihood of water on the negative side due to high water tables or periodic high water tables that occur during rain events. If water is present on the back side during times of water draw down in the tank, the vapor drive from the negative side can cause blistering and delamination of the coatings. Similarly, most tanks are subject to periodic cleaning to remove algae growth. While coatings may improve the ease of removal of the growth, they are subject to deterioration causing them to gradually break down. Ultimately, they will need to be replaced as they fail under use or cleaning.

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However, crystallization becomes an integral, permanent part of the concrete matrix. It cannot be punctured or damaged like a liner or surface coating; it withstands high hydrostatic pressure from both the positive and negative side; and is not affected by humidity, ultraviolet light, or oxygen levels. A crystalline technology such as Xypex-developed solution, is a modification of the concrete itself and hence is permanent and will not blister or fail. Xypex Chemical Corporation is based in Vancouver, British Columbia, Canada.

In addition, the crystalline technology protects the concrete from chemical attack and protects reinforcing steel from corrosion. It will self-heal cracks (up to 0.4 mm), and when used as an admixture can increase compressive strength and reduce shrinkage cracking.

Crystalline waterproofing technology is non-toxic, contains no VOCs (volatile organic compounds), and is NSF-61 approved for potable

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Concrete waterproofing at a glance

At least five methods of concrete waterproofing serve as alter-natives to concrete waterproofing with crystalline technology, each with its own set of advantages and disadvantages.

Coatings include epoxies, urethanes, polyurea, and bitumen. They are 100 percent imper-meable, resistant to chemicals, visible, and provide some crack bridging. However, they also require significant surface preparation. Installation errors can lead to pin holes and thin spots. They offer no crack healing and require specialty installation contractors.

Cement-based coatings are easy to apply, inexpensive, and can be applied to moist concrete. However, they also require significant surface preparation, and offer limited resistance to hydrostatic pressure, abrasion, and chemicals. They provide poor crack bridging and no crack healing, so one scratch can affect the integrity of the entire system.

Hydrophobic admixtures can be added during batching, incur low labor costs, and offer low error risk. Their disadvantages include diminishing performance over time, per ACI 212.3R they are recommended for concrete under hydrostatic pressure, and offer no crack bridging and crack healing.

Injection systems that use epoxy and polyurethane for crack repair offer several advantages: epoxies reinstate structural integrity; polyurethanes allow movement and can be applied to wet concrete; and they are effective for wider cracks. Their disadvantages include high cost, complicated re-working, required high level of application expertise and specialty equipment, and poor aesthetics of the typical injection job.

Rout and repair systems are inexpensive; can be applied to wet or moist concrete, and actively leaking cracks; and require no special equipment. However, they are not considered a full-depth repair, cannot heal new cracks, and are unacceptable for continuously moving cracks.

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water by NSF International, a widely accepted, independent source of public health and safety standards around the world.

One of the other advantages of crystalline waterproofing is that it can be introduced into new concrete as an admixture, a dry-shake product, or a surface-applied coating. It's also the waterproofing technology of choice on one of the largest potable water reservoirs in the world.

Reinforcing a reservoir

The Ras Laffan Reservoir in Qatar, part of the highly prestigious Ras Laffan-C IWPP project, holds 65 million gallons and produces 275,000 cubic meters of potable water per day. The reservoir project received approval from Qatar's Government Water and Public Health Department. It is one of the largest single-structure, potable water reservoirs in the world, serving 40 percent of Qatar's water requirements. The two-coat system of Xypex Concentrate and Modified was used to waterproof and protect 37,999 square meters of potable water tanks.

The benefits of crystalline technology, such as waterproofing, enhanced structural durability, and the ability to resist aggressive chemicals – and in this case, very high salt contents in the surrounding high water table – made products employing the crystalline concrete waterproofing products the preferred choice for this project.

Adding to its appeal in the Middle East – North Africa (MENA) region, Xypex crystalline treatment is pH specific, not chemical specific. Its ability to prevent corrosion due to aggressive chemicals is measured by its ability to withstand a pH range of 3.0 to 11.0 constant contact (and 2.0 to 12.0 in periodic contact). It has received the United Kingdom's Water Regulations Advisory Scheme (WRAS) approval for potable water for use with water at a temperature up to 50°C as per MENA region Water Authorities statutory requirement (WRAS Test Report MA4049/K).

Xypex Chemical Corporation states that Xypex modified concrete is not affected by a wide range of chemicals, per ASTM C 267 Chemical Resistance of Mortars. It is pH specific (not chemical specific) and can protect concrete constantly subjected to a pH range of 3.0 to 11.0, and those periodically subjected to a pH of 2.0 to 12.0.

Crystalline technology has been used to waterproof, protect, and repair concrete structures over the past 40 years in more than 70 countries. Contractors have found it easy to use and economical on a range of water projects. For instance, contractors used Xypex solutions to waterproof and protect the concrete-holding tanks and reservoirs of the Seymour-Capilano Filtration Plant in Vancouver, Canada. This plant supplies up to 70 percent of the drinking water to Metro Vancouver. In Cardedeu, Spain, crystalline technology helped repair and waterproof filter channels to the Cardedeu Water Purifying Plant, and in Accra, Ghana, the technology helped repair cracks of filtration plants at the Winneba Waterworks.

The necessity for the right method used to waterproof concrete is crucial to the operation and longevity of a water treatment system. As demand for water grows, the integrity and efficiency of water treatment systems will become more critical.

Author's Note

Jim Caruth has a Bachelor's of Applied Science in Civil Engineering from the University of Waterloo in Ontario, Canada. He is a professional engineer, member of the Board of Directors of the BC Chapter of the American Concrete Institute, and is a past Committee Chair for the BC Ready Mixed Concrete Association. Jim is a past voting member of the Canadian Standards Association A3000, Cementitious Materials Compendium, and has more than 20 years of experience in British Columbia's cement and concrete industry.