Concrete Waterproofing With Crystalline Technology

Turning Concrete's Weakness into Strength

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Concrete is porous and therefore permeable to liquids and gases. This weakness can create multiple problems in all types of concrete structures; from building foundations which need to keep water out, to water tanks and structures designed to hold water. Water infiltration, chloride diffusion and chemical attack can cause rapid deterioration that will lead to expensive repairs and even compromise the structural integrity itself.

Traditional methods of protecting concrete typically involve the application of a coating that forms a barrier at the surface. While effective in the short term, coatings deteriorate over time losing their adhesion to the surface, blistering, peeling and eventually failing.

A more effective, efficient, and economical way to waterproof concrete is to use its own permeability as a delivery system for waterproofing chemicals; a technology called Crystalline Waterproofing. This method plugs the concrete's natural porosity and bridges cracks up to 0.4mm with a non-soluble crystalline formation that becomes an integral, permanent part of the structure. Crystalline Waterproofing can be applied to existing concrete as a surface treatment or added to the concrete mix for new construction.

Concrete's Weakness

Although concrete appears to be a solid mass it is in fact riddled with interconnected capillaries (pores) which allow liquids and gasses to pass through especially when under pressure. These are formed as the excess water, known as the 'water of convenience', used to produce a flowable mix evaporates out of the concrete.

As the concrete dries it also shrinks causing drying shrinkage cracking. While best practices should limit large visible cracks, micro-cracking is probably inevitable. Cracks too small to see can still be large enough to act as moisture pathways. Combined, the voids caused by the 'water of convenience and micro-cracks will typically make up to 10-15% of the concrete's total volume.

If a building's concrete foundation wall or floor slab is below the water table, or subject to occasional submersion, it is surrounded by water under pressure, the pressure being supplied by the 'column' of water being acted on by gravity. This is called "hydrostatic pressure" or "hydrostatic head" and is usually measured in feet (or meters), therefore, the deeper below the water table, the greater the hydrostatic pressure. This pressure can drive water to leak through a concrete foundation or wall.

If a basement wall or floor slab is in contact with moist soils but above the water table, there is no pressure to force water through the concrete. Nevertheless, if improperly waterproofed, concrete will absorb water through capillary action – just like a sponge. As water moves through the pore network closer to the inside surface of the concrete, it turns into water vapour and exit the concrete – a process known as vapour transmission which can make the interior perpetually damp. This can also cause problems with interior finishes such as blistering of coatings or lifting of adhered vinyl tile.

Along the way, water will also promote corrosion of steel reinforcement, especially if it has aggressive chemicals dissolved in it. In areas of high or moderate sulfate soils, infiltrating water can promote sulfate attack, in which formation of expansive etringite within the concrete can destroy it.[1] In marine environments chloride diffusion will accelerate reinforcing steel corrosion and significant deterioration. The pore network also allows gases to infiltrate, some of which - CO, CO_2, SO_2 and NO_2 - causing carbonation; a process in which the natural alkalinity if reduced and concrete's pH and compressive strength.

Photo courtesy of Xypex Corp.

Crystalline Waterproofing admixture was used to waterproof two tunnels located below the water channel which connect several man made islands that form part of the massive redevelopment of Cape Town's harbor.

Defending the Perimeter

So, if the concrete's pore network and micro-cracks are the pathway for water and chemical ingress, they are also the logical place to stop it. Crystalline technology uses water and these passageways to deliver its reactive chemicals into the concrete. For existing structures this means that the concrete must be

[1] In locations where soils are known to have high or moderate sulfate levels, concrete should be made using Type II or Type V Portland cement, reducing vulnerability to sulfate attack.

thoroughly saturated prior to surface application of the Crystalline Waterproofing treatment whereas for new concrete, water is already present in the mix.

When applied as a surface treatment, the crystalline waterproofing chemicals will spread through the saturated concrete's permeable voids by the process of chemical diffusion, where they react with calcium hydroxide and other by-products of Portland cement hydration causing the formation of needle-like crystals that fill and plug the void space. Within 2-3 weeks the crystal growth is mature and water can no longer pass through. (For a detailed explanation of the process, see sidebar *How It Works*.) Once the crystals are formed, their effect is permanent.

This represents a very green solution to for the waterproofing and durability of concrete. It is non-toxic, has no odor, approved for use in potable water tanks and minimizes jobsite waste. Crystalline technology contains no volatile organic compounds (VOCs) making it safe for use in confined spaces and allows concrete to be recycled at the end of a building's service life because it has no adhered membranes or coatings.

Photo courtesy of Xypex Corp.

The Bank of Tanzania, Five large vaults for the storage of money below grade and exposed to 8 metres of water pressure were treated with two coats of Xypex Concentrate and Patch 'n Plug products were used to seal the construction joints and waterproof the exterior walls.

Application of Crystalline Waterproofing

Crystalline waterproofing chemistry can be introduced into concrete by applying it to a saturated substrate or included in the concrete mix as an admixture.

Admixture: Crystalline waterproofing chemicals can be introduced into the concrete mix at the time of batching as an admixture. This is a very clean and efficient approach. It ensures thorough dispersal of the chemistry throughout the concrete and does not alter the compressive strength or appearance of the hardened concrete. It requires no effort, expertise or labor on the part of the contractor. Curing of the concrete is simultaneous with the curing of the waterproofing chemistry.

The dosage rate varies depending on the concrete mix design, but it is generally in the range of 1% - 3% of cementitious materials content. Once the waterproofing chemicals are mixed into the concrete at the batching plant, all other operations are the same as with normal concrete. Best practices for proper curing must be observed.

Concrete dosed with crystalline waterproofing may achieve higher compressive strength than similar mixes absent the waterproofing. One documented test showed increases in the range of 5% - 20% at 28 days, varying with the dosage of waterproofing.

When waterproofing concrete structures with Crystalline Waterproofing, construction 'best practices' would include a coat of crystalline waterproofing at construction joints and patching of tie holes.

Surface Applied Treatment: For existing concrete structures, surfaces to be treated must be clean and free of laitance, dirt, film, paint, coating and form release agents. Surfaces must also have an open capillary system to provide 'tooth and suction' for the coating to adhere and gain access to the pore network. Smooth surfaces should be sandblasted, water-blasted, or etched with muriatic (HCL) acid prior to application.

Photo courtesy of Xypex Corp.

Two costs of Xypex Crystalline waterproofing were applied to waterproof the filtration tanks at the Winneba Water Works in Ghana. Cracks were repaired with Xypex products prior to the surface application.

Concrete should be saturated with water, or as close to saturated as practical. Excess surface water must be removed prior to the application as it would otherwise dilute the crystalline mixture.

Crystalline Waterproofing is packaged in powder form and is mixed with water into a cementitious slurry for application with a masonry brush or specialized spray equipment. The coating thickness should be 1.5 mm. The mixture adheres to concrete surfaces keeping the waterproofing chemicals in contact with the saturated concrete substrate. The coating acts as a concentrated source of waterproofing chemicals, which then slowly diffuse into the wet pore network.

For very porous concretes such as concrete masonry units (CMUs), two coats of Crystalline Waterproofing are recommended. Because the porosity of CMU's varies widely, tests should be conducted before committing to this method of waterproofing.

Photo courtesy of Xypex Corp.

This standard concrete masonry unit was sealed across the bottom opening and waterproofed using two coats of surface-applied crystalline technology. It holds water without leaks. The cementitious coating, seen on the sides, contains waterproofing chemicals that diffuse (penetrate) through the concrete's porosity forming crystals that block water passage. Afterwards the coating can be completely removed without affecting waterproofing performance.

Good Construction Practices

Cast-in-place concrete is, alas, rarely monolithic. It usually has construction joints, control joints, and unplanned cracks. Any waterproofing system must deal with these openings in the perimeter.

Crystalline technology is effective at waterproofing faulty construction joints and visible cracks. A combination of the coating slurry, and a stiffer patching mixture called a dry-pack, are used. Dry-pack is made using the same material as the slurry, but the mix contains much less water.

The crack or joint is routed out to make a slot large enough to hold a substantial patch, minimum 1 inch wide and 1.5 inches deep. The concrete is thoroughly wetted. The areas inside and surrounding the routed crack are coated with waterproofing slurry to achieve maximum chemical diffusion around the repair. The routed crack is then filled with dry-pack, which bonds to both sides of the crack and supplies more waterproofing chemicals to diffuse in all directions.

Large repairs of faulty concrete, exposed rock, ‘honeycombs,’ etc. can be waterproofed during repair. Crystalline waterproofing slurry is applied to the repair site and then covered with a mortar patch.

Control joints must be left open and allowed to move, making crystalline technology inapplicable. Flexible sealants made specifically for control joints should be used.

Conclusion

Concrete foundations, slabs, and below-grade walls and water infrastructure can be chemically waterproofed with great effectiveness using crystalline technology. In many situations, this has clear advantages over traditional barrier methods. This includes places where barriers cannot be applied. Crystalline waterproofing is also usually far less costly than barriers.

Because this technology involves the growth of crystals to block the pore network of the concrete, it is not instantly effective. Crystal formation can take 2-3 weeks to fully mature. However, it offers a long term solution to many water-infiltration vulnerabilities, since its effects are permanent, and it can be re-activated by water at any time to self-seal new points of infiltration.

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Sidebar: How It Works

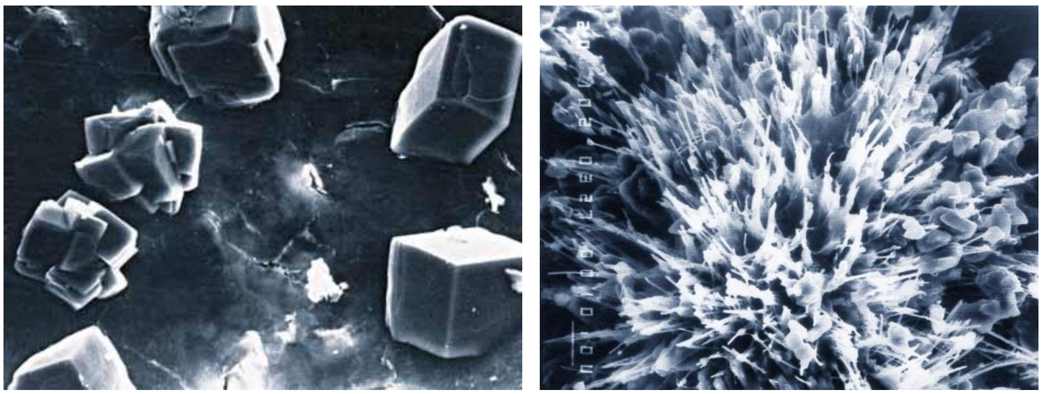
Crystalline technology involves delivering chemicals into the pore structure of the concrete. There are different means to get the chemicals there – as an admixture in the concrete mix or applied on the surface and diffused into the pore network of existing concrete – but the result is the same.

As the crystalline chemicals diffuse through the concrete pore network the generate a chemical reaction with calcium hydroxide (aka lime) and other by-products of Portland cement hydration causing the formation of a non-soluble crystalline structure that fills and plugs the pores and capillaries against passage of water and other liquids. The flow of gases is significantly restricted but not eliminated thus allowing the concrete to ‘breath’ and dry-out.

On existing structures the concrete must be saturated with water for this process to work. When applied at the surface as a slurry mixture, the waterproofing chemicals will diffuse through the water in the concrete’s pores. When properly cured, the crystalline formation can penetrate up to 30 cm into a concrete slab or wall.

The Crystalline waterproofing chemistry reacts with lime to form small, needle-like mineral crystals that are insoluble in water.

Crystal formation begins soon after the chemicals come in contact with water and calcium hydroxide, but requires two to three weeks for the crystals to reach maturity. The small, needle-like mineral crystals are insoluble except in contact with strong acids.



Photos courtesy of Xypex Corp.

Scanning electron microscope images of waterproofing crystals growing inside a concrete pore approximately 0.1 mm across.   Left: early stage growth; Right: fully developed.

The crystals grow across the diameter of the pore, stalactite-like, forming a microscopic mesh-like barrier. Clear passage through the pore is greatly reduced. Liquid water cannot get through it because of liquid properties such as surface tension.

Even extreme hydrostatic pressure cannot force liquid water through the ‘crystallized’ pore network. Independent laboratory testing in accordance with U.S. Army Corps of Engineers CRD C-48-73 “Permeability of Concrete” showed that crystalline-treated concrete withstood up to 405 feet (123.4 m) of head pressure (175 PSI/1.2 MPa), which was the limit of the testing apparatus.

Photo courtesy of Xypex Corp.

NOTE: This digital image may not be available any larger than 600X900

Setup for U.S. Army Corps of Engineers test CRD C-48-73 "Permeability of Concrete". Crystalline-waterproofed concrete withstood up to 405 feet (123.4 m) of head pressure (175 PSI/1.2 MPa).

Although Crystal formation is largely complete after 2-3 weeks, there are generally enough residual waterproofing chemicals to reactivate the crystalline formation in the presence of water.

Drying shrinkage cracking may be present in concrete, at least at the micro-level. These micro-cracks potentially create passageways for moisture infiltration. If cracking occurs while crystals are still forming, micro-cracks up to 0.4mm can be bridged. If micro-cracks occur later and allow water infiltration, the water will reactivate the waterproofing chemicals, making the concrete self-healing on the micro scale.

In the case of a surface application to an existing foundation that is continuously wet on the exterior side, the water could theoretically convey the chemicals all the way through the wall or floor.

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