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Concrete Waterproofing Made Crystalline Clear

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Waterproofing From Within

Crystalline protection for concrete slabs and foundations

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THE MOST EFFECTIVE WAY TO OVERCOME THE DEFICIENCIES INHERENT IN A MATERIAL SUCH AS CONCRETE MAY BE TO TURN THE WEAKNESS INTO A STRENGTH.

Concrete is permeable to liquids and gases. For foundations and slabs below the water table (or even slabs on grade in damp soils), porous conditions can create multiple problems within the building due to moisture penetration. Infiltrating water—and aggressive chemicals dissolved within—can also compromise the concrete.

One of the most effective, efficient, and economical ways to protect concrete from water ingress is to use its own permeability as a delivery system for crystalline waterproofing chemicals. This method plugs the material's pore network and bridges micro-cracks that occur as the concrete dries and shrinks. The technology can even self-seal new micro-cracks after they occur, years after the original application.

Crystalline waterproofing can be applied to existing concrete from either the dry (negative) or wet (positive) sides with equal effectiveness. It can also be either mixed into or troweled onto fresh concrete to achieve an integral waterproofing system. The technology is generally less costly than external barrier solutions, and can be used in situations where membrane barriers cannot due to inaccessibility of the wet side of the concrete. It has been specified effectively for 40 years—a period traditionally cited in the construction industry as the 'proof' of an established technology.

Despite thousands of successful projects, crystalline waterproofing remains unknown to many design professionals. This is perhaps because the process is not as intuitive as the more readily visible external barrier approach. Consequently, manufacturers of crystalline technology products have had to overcome the perception by some that mystery or magic is involved; in fact, the crystalline waterproofing process is based on both a well-documented chemical reaction and a common principle of physics.

The problem

Concrete's capillary pore structure is formed by excess water in the mixture that is not used up during the cement hydration process. This 'water of convenience' bleeds out of the concrete, leaving behind microscopic capillary tracts and pores that form continuous channels, allowing liquids and gases to permeate the concrete mass.

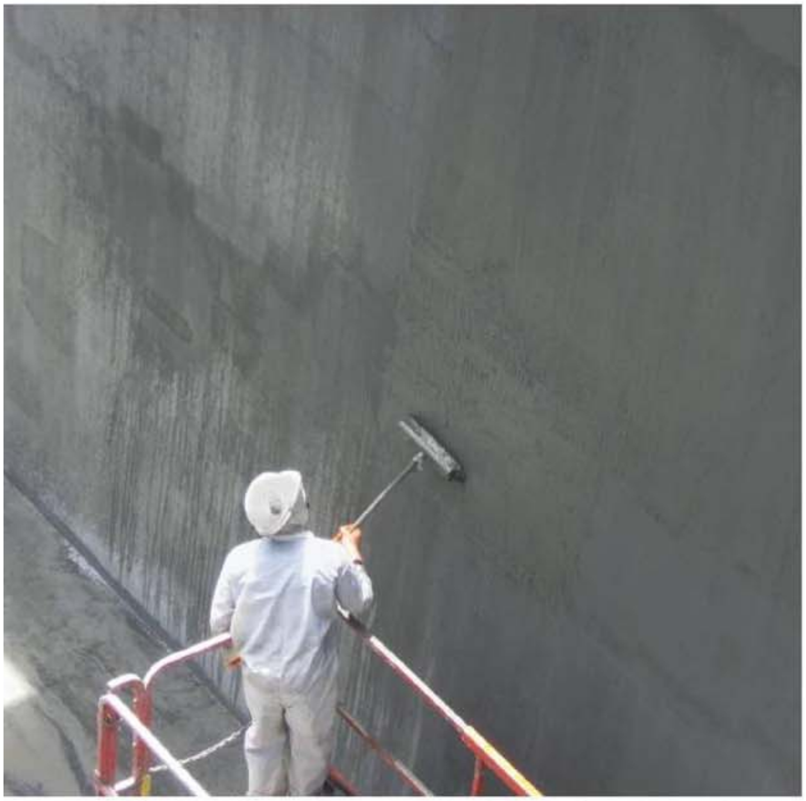
Moreover, portland cement concrete contracts as it dries, causing shrinkage cracking. Best practices may limit large, visible fissures, but micro-cracking is probably inevitable. Cracks too small to see can still be large enough to act as moisture pathways.

If a concrete foundation, wall, or floor slab is below the water table, or subject to occasional submersion, then it is surrounded by water under pressure. This pressure is derived from the 'column' of water acted on by gravity. It is referred to as 'hydrostatic pressure' or 'hydrostatic head,' and often expressed as the depth below the water table in feet or meters. The further below the water table, the greater the pressure that can drive water through a concrete foundation or wall.

If a floor slab is atop moist soil but above the water table, there is no pressure to force water upward through the concrete. However, capillaries soak up moisture like a sponge. As water gets closer to the concrete's interior side, it can evaporate into vapor.

The Embassy Suites, a 17-story hotel currently under construction in Denver, Colorado, used approximately 1150 m^3 (1500 cy) of concrete treated with crystalline waterproofing in the below-grade foundation walls and elevator pits. Despite its track record, such technology remains unknown by many specifiers.

Images courtesy Xypex Corp.



In Miami, Florida, crystalline waterproofing is brushed onto the walls of a clarifier/septic tank under construction at the Blackpoint South District Wastewater Treatment Plant.

This can make the interior perpetually humid, even though no liquid water has come through the concrete. Vapor emission can also cause problems with finishes such as blistering of coatings or lifting of adhered vinyl tile.

Further, water penetration promotes corrosion of steel reinforcement, especially if aggressive chemicals from the soils or surface (*e.g.* chlorides) are dissolved in the water. It can also encourage alkali-silica reaction (ASR), sometimes referred to an alkali-aggregate reaction (AAR)—a process that cracks concrete. In areas of high or moderate sulfate soils, infiltrating water can promote sulfate attack, in which formation of expansive etringite can destroy concrete from within.[1]

In places subject to freezing temperatures, the water itself can cause freeze-thaw problems. The pore network also allows gases to infiltrate, some of which —carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2)—cause carbonation or a softening of the concrete.

A solution

Crystalline technology uses water in the capillary tracts as a diffusing medium to carry waterproofing chemicals into the concrete. The chemicals migrate through the waterways of the saturated pore network, where they react and grow needle-like crystals that block the pores. Within a few weeks of crystal growth, liquid water can no longer pass through. (See "How It Works," page 28.) The effect is permanent.

Crystalline waterproofing can be thought of as a green solution to waterproofing. It is as durable as the concrete itself, odorless, possesses no chemical sealants to leach toxins into the ground, and produces no jobsite waste from excess membrane materials. Crystalline technology is non-toxic and contains no volatile organic compounds (VOCs). At the end of a building's service life, it remains part of the concrete, and can be recycled as such.

Another green aspect of crystalline waterproofing involves its ability to minimize or eliminate the need to over-excavate for gaining access to the foundation's wet side for membrane application. In other words, it can 'take back' the building footprint, and help a project be eligible for points in Sustainable Sites (SS) Credit 5, *Site Development*, under the Leadership in Energy and Environmental Design (LEED) program.

New concrete applications

Crystalline waterproofing chemistry can be introduced into new concrete as:

- admixtures;
- dry-shake products; or
- surface-applied coatings.

Admixture

Crystalline waterproofing integrated as an admixture during concrete batching is a clean and efficient waterproofing approach. The process ensures thorough dispersal of the chemistry throughout the concrete without altering the material's appearance. Crystalline admixtures require no effort, expertise, or labor on the part of the contractor. Curing of the concrete is simultaneous with that of the waterproofing application, and there is no coating or residue to remove afterward.

The dosage for the admixture is generally in the range of one to three percent of cement content by weight. Once the waterproofing chemicals are mixed into the concrete at the batching plant, most other operations are the same as with normal concrete. (Setting time may be slightly longer.) Normal best practices for proper curing must be observed. These would include a coat of surface-applied

Crystalline waterproofing coating can sometimes be effective with very porous concrete materials such as CMUs. As block porosities vary, tests must be done before committing to this method.

crystalline waterproofing at construction joints, including pours of integrally waterproofed mixes.

Concrete dosed with crystalline waterproofing may achieve higher compressive strength than similar 'standard' mixes—results vary with the dosage of waterproofing. One documented product test showed increases of 10 percent at 28 days, and 12 percent at 56 days.[2]

Dry shake

Using the dry-shake method, new concrete slabs can be treated with crystalline waterproofing during finishing. After the concrete reaches initial set, waterproofing powder is broadcast onto the wet surface and then troweled in. Care must be taken to evenly spread and work the powder for proper distribution.

This method may reduce material costs for waterproofing chemistry, with the addition of some labor to shake on the waterproofing. Crystalline waterproofing does not significantly change the slab's appearance—it should not be confused with dry-shake hardeners that often contain color.

Surface-applied coating

Surface-applied coating can be used on both new and existing concrete. For the former, it is preferable to apply the coating as soon as forms are stripped. If the surface is dry, it must be re-wetted before application.

Existing concrete applications

For existing (*i.e.* cured) concrete, surface-applied coatings are the only choice. Concrete surfaces must be clean and free of laitance, dirt, film, paint, coating, or other foreign matter before treatment. 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.

How It Works

Crystalline waterproofing technology is the process of delivering chemicals into the concrete's capillary tracts and plugging the pores with a non-soluble crystalline formation. Different means exist to get the chemicals there (*i.e.* mixed into fresh concrete or diffused into cured concrete), but the way they achieve waterproofing is the same.

The concrete must be wet for the chemicals to move through cured concrete and for the chemical reaction to occur. In a surface application (*i.e.* dry shake or coating), the high concentration of chemicals at the surface naturally seeks to spread out or 'diffuse' into the saturated substrate. As long as the concrete remains wet, there is a conduit for the chemicals to travel. A properly cured crystalline waterproofing application can spread 305 mm (12 in.) into the slab or wall interior.

The exact chemical formulations of crystalline waterproofing products are closely guarded trade secrets of the various manufacturers. However, in all cases, these materials must react with calcium hydroxide—a substance commonly called 'lime,' but more properly referred to as 'hydrated lime.'

Calcium hydroxide is a product of portland cement hydration; it resides in the concrete matrix but has no structural value. Its utilization is a common theme among many concrete additives and treatments including pozzolans and densifiers. Additives that 'consume' lime, such as crystalline waterproofing, have another benefit in that they reduce the potential for efflorescence that is sometimes visible on concrete surfaces.

Crystalline waterproofing chemistry reacts with lime to form small mineral-based 'needles' that are insoluble in water. Soon after the chemicals come in contact with water and lime, formation of these crystals begins. However, it is a gradual process—much slower than the time it takes fresh concrete to set. It can be two to three weeks before the crystals reach maturity.

The crystals grow across the diameter of the pore like stalactites, forming a microscopic, mesh-like barrier. Clear passage through the pore is greatly reduced—liquid water cannot get through it because of properties such as surface tension. Even extreme hydrostatic pressure cannot force liquid water through the blocked pore network. Independent laboratory testing in accordance with U.S. Army Corps of Engineers (ACE) CRD C-48-73, *Permeability of Concrete*, showed crystalline-treated concrete withstand up to 123 m (405 ft) of head pressure—1.2 MPa (175 psi), which was the limit of the testing apparatus.


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

In the form of vapor, water molecules are small enough to pass through the crystal formation, so moisture can migrate out on the downstream side, allowing the concrete to dry. This means vapor emission is reduced and carbonation is slowed down.

While crystal formation largely matures in two to three weeks, the process can continue virtually as long as there is water in the concrete. Cessation usually occurs due to natural drying of the concrete—the reaction effectively never runs out of lime. This means if water re-enters the slab years later, it reactivates the waterproofing chemicals and new crystallization will begin. In essence, it is an automatic waterproofing response.

At the micro-level, drying shrinkage cracking potentially creates passageways for moisture infiltration. If they occur while crystals are still forming, micro-cracks up to 0.4 mm (16 mil) 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 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. **CS**

If the surface is too smooth (*e.g.* where steel forms are used, or the surface is hard-troweled during finishing) or covered with excess form oil or other foreign matter, the concrete should be lightly sandblasted, waterblasted, or etched with muriatic acid before application. As well, the concrete substrate should be saturated with water, with excess surface water removed.

The waterproofing's 'active ingredients' come premixed with portland cement and fine sand. The applicator mixes in water to make a cementitious slurry that is either brushed or sprayed onto the concrete. It forms a thin 1.5-mm (1/16-in.) coating that adheres to both vertical and horizontal concrete, keeping the chemicals in contact with the surface. The slurry coating acts as a concentrated source

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of waterproofing chemicals that penetrate the pore network by diffusing through water.

For diffusion to take place, the concrete must be kept moist for two to three days after application; manufacturers offer specific instructions on curing time and methods for their products. Care must be taken not to over-wet the coating and cause leaching of chemicals away from the concrete in runoff.

The coating can be left in place permanently within certain practical and aesthetic limits. On floors, it will usually handle normal foot traffic and even light vehicles, although it will wear away over time, causing light dusting. If traffic includes forklifts, the coating should be removed. Likewise, in any location where a dull gray appearance is undesirable, it should be removed. High-pressure wash, light sandblasting, shotblasting, or diamond-grinding are all removal options. When performed at least 30 days after the waterproofing application, performance should not be affected.

If a cementitious system (*e.g.* topping, finish coat, mortar for tiling, grout, or cement parge coat) is to be used over the waterproofing coating, it is important to do it before the crystals plug the pores—this is usually within eight to 48 hours. A bonding agent is also recommended.

When paint or epoxy is applied over the waterproofing coating, the surface should be washed first with a three to five percent solution of muriatic acid, then flushed and allowed to dry before applying other coating.

Crystalline waterproofing coating can sometimes be effective with very porous concrete materials such as concrete masonry units (CMUs). As these blocks' porosities widely vary, tests should be conducted before committing to this method.

In certain situations, a barrier-type coating or membrane may be more appropriate than crystalline technologies. For example, in locations where movement and large cracks are expected, an

Setup for U.S. Army Corps of Engineers (ACE) test CRD C-48-73, *Permeability of Concrete*. Crystalline-waterproofed concrete withstood up to 123 m (405 ft) of head pressure—1.2 Mpa (175 psi).

elastomeric membrane should be considered. Where waterproofing is required to prevent entry of methane or other gases into concrete, a membrane would also be a better choice. (Crystalline-waterproofed concrete is breathable.)

Other considerations

Cast concrete is rarely monolithic; it usually has construction joints, control joints, and unplanned cracks. Any waterproofing system must also deal with openings through the concrete and around its perimeter.

Crystalline technology is effective for waterproofing faulty construction joints and visible cracks. In these cases, experts recommend a combination of the coating slurry and a stiffer patching mixture—a 'dry-pack'—made using the same material, but mixed with a much smaller percentage of water.

The crack or control joint is routed out to make a U-shaped slot. The concrete is thoroughly wetted; the areas inside and surrounding the routed crack are then coated with waterproofing slurry to achieve maximum chemical diffusion around the repair. The crack is filled with dry-pack, which bonds to both sides and supplies more waterproofing chemicals to diffuse in all directions.

Large repairs of faulty concrete, exposed rock, or 'honeycombs' 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 are made specifically for protection of control joints.

Conclusion

Concrete foundations, slabs, and below-grade walls can be chemically waterproofed with great effectiveness

ADDITIONAL **INFORMATION**

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Abstract

This feature examines integrally waterproofed concrete with an emphasis on the type of information specifiers need to make informed decisions, ranging from the impact on curing and selection of bond breakers to aesthetic considerations, joint detailing, and mix design.

MasterFormat No.

03 30 00–Cast-in-place Concrete
03 40 00–Precast Concrete
04 22 00–Concrete Unit Masonry
07 16 16–Crystalline Waterproofing

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A10–Foundations
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using crystalline waterproofing technology. In many situations (including those in which barriers cannot be applied), this has clear advantages over traditional methods. Crystalline waterproofing is also usually less costly, frequently in the range of 50 percent the price of liquid-applied membranes or bituminous built-up barriers.

Crystal formation to block the capillary network in concrete can take two to three 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. **CS**

This standard concrete masonry unit (CMU) was sealed across the bottom opening, and waterproofed using surface-applied crystalline technology. The cementitious coating, seen on the sides, contains waterproofing chemicals that diffuse through the concrete and form crystals that block water passage. The coating can be completely removed without affecting waterproofing performance.

Notes

[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.

[2] Testing conducted by Kleinfelder Inc., in accordance with ASTM C 39, *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.*