

the construction **specifier**

Best of Series

Brought to you by



SMART CONCRETE®

How Best to **WATERPROOF CONCRETE**



MAKE YOUR CONCRETE WORK FOR YOU



SMART CONCRETE®



Discover how our award-winning **waterproofing** and **durability** admixtures ensure your concrete structure is built to last.

www.kryton.com

Published by
Kenilworth Media Inc.
266 Elmwood Ave. #289,
Buffalo, NY 14222,
(866) 572-5633
www.constructionspecifier.com

The information and contents in this publication are believed by the publisher to be true, correct, and accurate, but no independent investigation has been undertaken. Accordingly, the publisher does not represent or warrant the information and contents are true, correct, or accurate, and recommends each reader seek appropriate professional advice, guidance, and direction before acting or relying on all information contained herein. Opinions expressed in the articles contained in this publication are not necessarily those of the publisher.

© 2021. CSI.
All Rights Reserved.



SMART CONCRETE®

Contents



5 Making Concrete a Barrier Against Water

It is vital to protect concrete from moisture intrusion as it is the main harbinger of corrosion-causing chemicals. Integral concrete waterproofing (ICW) technology stops the problem at its root by preventing the flow of water through the material.

Alireza Biparva



10 Crystalline Waterproofing and Protection for Concrete

Crystalline waterproofing technology improves the waterproofing and durability of concrete by filling and plugging pores, capillaries, and micro-cracks with a non-soluble, highly resistant crystalline formation.

Dave Ross



19 The Evolution of Fluid-applied Membranes

Over the years, there has been much advancement in fluid-applied waterproofing material chemistry and technology. However, even with new developments, proven performance in previous technologies warrant their use around the world.

Isaac Sorensen, CSI, Russ Snow, CSP, CTR, BSS, LEED AP, Scott Wolff, CSI, CDT, BEC, Conleigh Bauer, CSI, Stacey Bogdanow, CTR, Taylor Wodzinski, Patrick Raney, CSI, ICRI, and Roger Smith, CSI, ICRI

MAKE YOUR CONCRETE WORK FOR YOU



SMART CONCRETE®

Optimize the **sustainability** of your structure without **sacrificing design**. Kryton's award-winning concrete admixtures remove the limitations of surface-applied concrete waterproofing and hardening products.

Design without limits.

www.kryton.com



Make Smart Concrete

A study on self-sealing

by Alireza Biparva

Photo © BigStockPhoto.com

DESIGNING FOR DURABLE CONCRETE PRESENTS A SPECIAL CHALLENGE FOR SPECIFIERS. CONCRETE IS USUALLY SPECIFIED BASED ON A VERY PARTICULAR PHYSICAL PROPERTY SUCH AS COMPRESSIVE STRENGTH, BUT THERE IS NO SINGLE TEST TO EVALUATE 'DURABILITY.' THERE IS A SIGNIFICANT DIFFERENCE BETWEEN MEASURING THE DURABILITY OF CONCRETE STRUCTURES AND MEASURING THE STRUCTURES' STRENGTH. COMPRESSIVE STRENGTH IS A CLEARLY DEFINED PROPERTY THAT CAN BE MEASURED DIRECTLY AT A PARTICULAR POINT IN TIME BY UTILIZING STANDARDIZED TEST METHODS. ON THE OTHER HAND, THE PROPERTIES MAKING CONCRETE DURABLE ARE MANY IN NUMBER. THEREFORE, DURABILITY IS MORE COMPLEX TO DEFINE, MEASURE, AND SPECIFY.

Concrete durability is defined by the material's ability to resist weathering action, chemical attack, and abrasion while also maintaining its desired engineering properties such as its compressive strength, permeability, soundness, and overall serviceability. To outline what makes concrete durable, many factors must be taken into consideration, including how long the structure is designed to last and whether the building will be subjected to hydrostatic pressure, abrasion, erosion, freeze-thaw cycles, or chemical exposure.

It is important to understand achieving durability is not a one-size-fits-all mechanism. A mix suitable for making a structure durable in the Midwest may be unsuitable for another project exposed to a different environment. For instance, air entrainment is a necessity when a structure is being built in freeze-thaw climates. However, it is not a requirement in dry, desert-like conditions.

Despite the complexity of the many factors affecting concrete durability, the main culprit of deterioration is moisture penetration. As a porous material, concrete allows

water (and waterborne contaminants such as chloride ions and sulfates) to migrate through it. Therefore, in order to make a structure durable, permeation of water through concrete must be prevented. Lowering permeability is the first line of defense against sulfate attack, chloride ingress, corrosion of steel reinforcement, carbonation, alkali-aggregate reaction, and other deterioration mechanisms

When produced using good construction practices, concrete mixes have low permeability. Some good construction practices include using the right mix design, following the relevant building codes, and ensuring adequate measures are taken to place and cure the concrete properly. Well-designed, placed, and cured concrete that follows the American Concrete Institute's (ACI's) guidelines remains relatively impermeable and durable as long as it does not crack.

However, cracks and micro-cracks can occur due to various factors, such as early-stage plastic shrinkage, drying shrinkage, thermal changes, excessive stress due to loading, or other elements that can affect the service life of the structure. When water is introduced into the environment, the cracks create a direct pathway for moisture and harmful chemicals to enter the concrete and reach the reinforcing steel. Estimates of durability generally do not take the cracking into account. The underlying danger is the effects of cracks have not been accounted for, which compromises the long-term durability and structural performance of concrete.

Crystalline admixtures

Some type of waterproofing protection is essential to secure the durability and resulting sustainability of concrete structures. Protective systems can be classified based on their application method: surface-applied systems consist of coatings and sheet membranes (described in ACI Report 515.2R-13, *Guide to Selecting Protective Treatments for Concrete*), while integral systems consist of an admixture that is added to concrete and protects it from within (described in ACI Report 212.3R-16, *Report on Chemical Admixtures for Concrete*). Some problems exist with sheet membranes. The installation of membranes calls for careful finishing, temperature control, clean and dry concrete, and dependable surface



This image shows initial leaks in concrete during the construction of a new facility at the Newburyport Wastewater Treatment Facility (NWWTF) in Massachusetts.

Images courtesy Kryton International

adhesion. Even the simplest membrane system requires a level of skilled application and the most dedicated tradesperson can make mistakes while applying it, often while battling poor weather conditions. Membrane sheets have to be individually applied, and even the smallest gap between them makes concrete highly susceptible to the influx of water. Moreover, membranes have been known to peel, tear, rip, debond, or puncture, especially during backfilling. Membranes are also usually inaccessible for repairs after installation, increasing the cost of maintenance.

Integral crystalline waterproofing (ICW) technology addresses this issue in a more permanent way. Crystalline waterproofing admixtures are usually a dry-powder mix of Portland cement, fine silica sand, and a proprietary blend of other chemicals. The admixture (typically up to two percent of cementitious content by weight) is used during the mixing stage of concrete.

The principles of ICW technology are similar to the process that occurs during concrete hydration. When cement particles are mixed with water, a chemical reaction occurs. As a result of this chemical reaction, two main types of crystals (calcium silicate hydrate [CSH] and calcium hydroxide [CH]) are generated.

Conventional concrete

The hydration reaction that takes place when cement is mixed with water is responsible for concrete's setting, hardening, and strength development.

However, when crystalline technology is used, the passive admixture in the matrix gets activated as soon as it comes in contact with moisture. On activation, this particular admixture starts crystallization and develops a microstructure of needle-like crystals in concrete.

Concrete modified using crystalline technology

The needle-shaped crystals grow to fill and block the microscopic capillary pores and micro-cracks. As long as moisture is present, crystals continue to grow throughout the concrete, filling up voids, cracks, and capillary pores. Once the concrete has dried, the crystalline chemicals sit dormant until another dose of water (such as a through a new crack) causes the chemical reaction (*i.e.* crystallization) to restart.

The ability to reactivate in the presence of water gives concrete treated with this admixture the ability to self-seal. When cracks form due to drying shrinkage, setting, seismic activity, or similar, water entering through them causes new crystals to form and grow, blocking the cracks. In the case of this specific admixture, crystals can seal cracks up to 0.5 mm (0.02 in.) in width. Enabling the self-sealing ability of concrete is one of crystalline technology's most useful features because it helps maintain durability in service and reduce the long-term maintenance costs of a concrete structure. Unlike sheet membranes that could separate from the structure over time—thereby removing all waterproofing—the crystalline admixture stays integral to the slab, protecting concrete from water penetration.

A case study in self-sealing

The Newburyport Wastewater Treatment Facility (NWTF) in Massachusetts is a sludge treatment facility providing biological treatment of wastewater prior to discharge into the Merrimack River.

It can handle up to 12.9 million L (3.4 million gal) per day of wastewater. Originally constructed in 1984, improvements to the plant were recommended in 2012 to modernize



Less than two weeks after the leakage test, the crystals in the admixture self-sealed, leaving zero leaks.

and improve its ability to handle current and future water flows. The construction of a new operations, control, and laboratory building on a lot adjacent to the existing facility was part of the renovation. The architects were looking for a permanent waterproofing solution that would continue to self-seal over time.

A crystalline waterproofing admixture was therefore specified for the project. After the concrete had set, a newly constructed containment tank was filled with water for a leak test to ensure the crystals in the admixture had begun to take effect. After a week, a significant amount of leakage had stopped, but water still seeped through the structure. The contractor

onsite was concerned about a potential delay in project completion and was ready to employ a polyurethane injection to stop the leaks. However, waterproofing consultants onsite advised him to wait, assuring him the crystals would form. If the injection was still necessary after two weeks, they promised to recommend an extension of the deadline.

The proprietary crystals in the admixture did begin to take effect, and the walls were completely devoid of moisture. At the end of the two-week period, the injection was not needed. The crystals, having reacted with the water and unhydrated cement, had self-sealed, blocking all the pathways of water through concrete.

Initially skeptical about the concept of self-sealing, the contractor expressed delight with the final result. He was happy with the savings of time and the elimination of additional expenses for injection repairs.

The interlocking needle-like crystals in the waterproofing admixture will continue to grow and protect concrete from water penetration. Six years after the concrete was first poured, the concrete structure remains durable and waterproof.

Conclusion

The crystalline admixture used in the Newburyport case study will provide waterproofing for the life of the concrete structure and enhance the structure’s durability. When specifying the integral admixtures, it is vital the application instructions are followed correctly and good construction practices are put in place onsite.

Crystalline admixtures can be used with existing mix designs, but advice should be sought from the admixture supplier, especially if the concrete provider has limited experience with such materials. The supplier can also provide recommendations for joint detailing, penetrations, and remedial repairs if cracks form that are too large to self-seal.

Crystalline admixtures are useful while waterproofing foundations, even in regions with a high water table. In fact, any concrete subjected to water pressure can use crystalline admixtures for permanent waterproofing. Waterproofing admixtures can be employed in underground parking structures, tunnels, bridges, marine structures,

water containment applications, canals, and elevator pits. Further, they can be used with precast, cast-in-place, and shotcrete applications as they are integral to the concrete. By combining the waterproofing step with the placing of concrete, integral admixtures avoid labor-intensive, costly, time-consuming surface preparation and installation costs. They also have the added benefit of eliminating silica-dust exposure in the workplace.

Crystalline admixtures help transform concrete into a waterproofing barrier and enhance the durability and longevity of structures, thereby contributing toward building a better, more sustainable future.

CS

ADDITIONAL INFORMATION

Author

Alireza Biparva, M.A.Sc., LEED GA, works as research and development (R&D) manager and concrete specialist at Kryton International. He has more than 10 years of experience in the field of concrete permeability. Biparva oversees a variety of research projects on Krystol Technology, focusing primarily on concrete permeability studies and the development of innovative products and testing methods for the concrete, waterproofing, and construction industries. He is an active member of the American Concrete Institute (ACI). Biparva can be reached at alireza@kryton.com.

Key Takeaways

The durability of a concrete mix is often more difficult to measure than strength. However, it is an important factor in determining the sustainability of a structure. Since water is the main contributor to corrosion, it is

vital to protect concrete from moisture intrusion. Integral concrete waterproofing (ICW) stops the problem at its root, preventing the flow of water through concrete by plugging or blocking natural pores, capillaries, and micro-cracks, thereby making concrete its own waterproofing barrier.

MasterFormat No.

03 00 00–Concrete
07 16 16–Crystalline Waterproofing

UniFormat No.

A10–Foundations
B10–Superstructure

Key Words

Divisions 03, 07	Crystalline admixtures
Concrete	Waterproofing
Cracks	

MAKE YOUR CONCRETE WORK FOR YOU



SMART CONCRETE®

Maximize the **service life** of your **concrete structure**. As a proven technology, Kryton's waterproofing admixture permanently waterproofs concrete while our hardening admixture doubles concrete wear life.

Specify with confidence.

www.kryton.com





Crystalline Waterproofing and Protection for Concrete

by Dave Ross

All images courtesy Xypex Chemical Corp.

CONCRETE HAS BEEN USED FOR THOUSANDS OF YEARS AND IS THE MOST WIDELY EMPLOYED BUILDING MATERIAL IN THE WORLD. ACCORDING TO THE CEMENT ASSOCIATION OF CANADA (CAC), MORE THAN TWICE AS MUCH CONCRETE IS USED IN CONSTRUCTION AROUND THE WORLD THAN THE TOTAL OF ALL OTHER BUILDING MATERIALS, INCLUDING WOOD, STEEL, PLASTIC, AND ALUMINUM.

Yet, despite its apparent solidity, strength, and durability, concrete is porous. It is also permeable to fluid and vapor infiltration and migration. Water and dissolved chemicals, such as chlorides, sulfates, and acids, can penetrate deep into concrete, sometimes resulting in premature damage, such as reinforcing steel corrosion, freeze/thaw cracking, spalling, and chemical attack.

Added to this 'natural' porosity is the fact newly poured concrete develops cracks. This can be due to excess water, rapid drying, improper strength, settlement, and shrinkage. When it comes to building foundations, elevator pits, water/wastewater treatment and water containment structures, and many other applications, waterproofing and protecting the concrete is critical.

The porous and permeable nature of concrete

Concrete is a mixture of rock, sand, cement, and water. Rock and sand form the aggregate base of the concrete. The mixture of the cement and water provides a paste, which binds the aggregates together. As the cement particles hydrate and form calcium silicate hydrates, the whole mixture hardens into a solid, rock-like mass.

To make this mixture workable, easy-to-place, and consolidate, more water than necessary is used to hydrate the cement. This extra water, known as the water of convenience, bleeds out of the concrete, leaving behind pores and capillary tracts.

Despite the use of admixtures to reduce the amount of water in the mix, pores, voids, and capillary paths still form in concrete. These pathways carry water and aggressive chemicals that can corrode steel reinforcement and deteriorate the concrete, thus jeopardizing the structure's integrity.

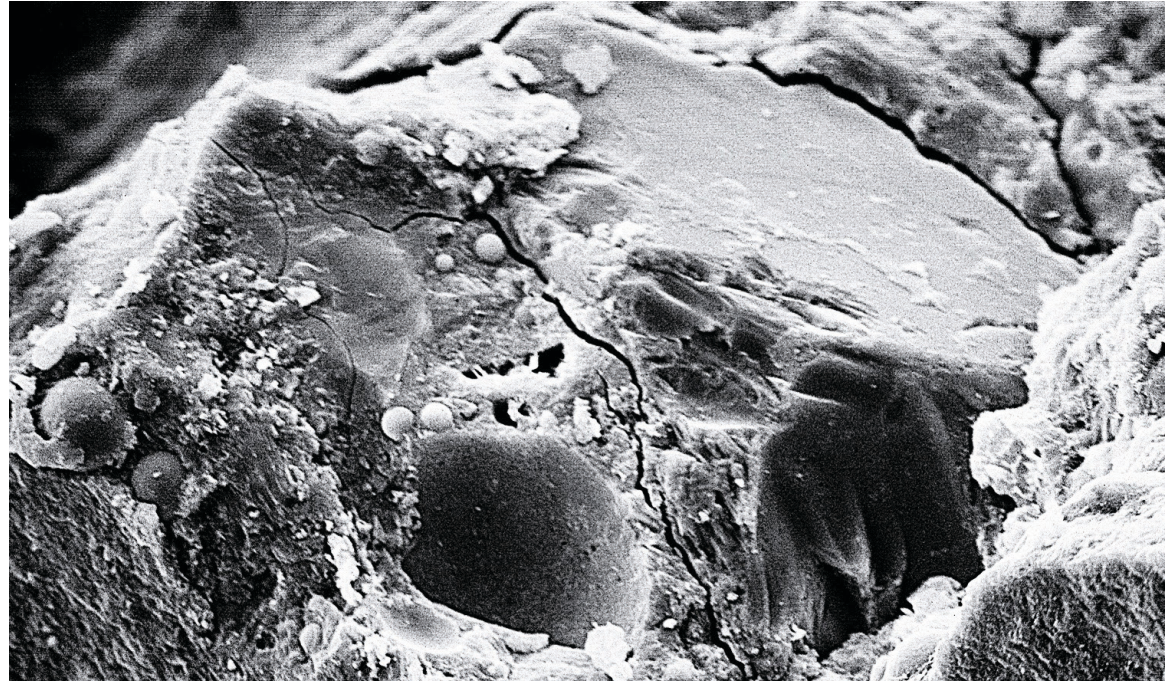
Porosity

Porosity is the amount of holes or voids left in concrete, expressed as a percentage of the total volume of a material. Since it is porous, concrete is also permeable.

Permeability

A broader term than porosity, permeability is an expression of how well the voids are connected, providing the ability of water to flow through a material. Together, these pathways allow the movement of water into and through the concrete. Permeability is described by a quantity that is known as the 'permeability co-efficient,' also called Darcy's Co-efficient. The water permeability of concrete is a good indicator of its quality and durability. The lower the permeability co-efficient, the more impervious the concrete and the higher its quality and performance. Nevertheless, concrete with low permeability may still need a waterproofing agent to seal micro-cracks.

It is possible to reduce the permeability of concrete with certain admixtures. These admixtures can be divided into three categories per



Magnified view of micro-crack.

the American Concrete Institute (ACI) 212.3 R-10, "Report on Chemical Admixtures":

- hydrophobic or water repellent admixtures;
- mineral fillers such as talc, bentonite, and clays; and
- crystalline admixtures.

Vapor flow in concrete structures

Water can also migrate through concrete in the form of vapor. The flow travels from high vapor pressure, generally the source, to low vapor pressure by a process of diffusion and can vary based on environmental conditions.

Vapor flow direction is critical when applying a waterproofing treatment in situations where an unbalanced vapor pressure gradient exists. Some typical examples of this are as follows:

- applying a low vapor permeable membrane, such as a traffic deck coating over a damp concrete surface (even if the very top surface is dry) on a warm day results in vapor pressure buildup and pin-holing or blistering;
- adding a coating or sealant to the outside of a building wall may trap moisture if the sealant is not sufficiently vapor permeable; and
- installing low vapor permeable flooring over a slab-on-grade with high subsurface moisture content may result in delamination.

As a general rule, a coating with low vapor permeability should not be placed on the downstream face (negative or dry side). Either vapor or water pressure will ‘push’ the coating from the surface, causing it to blister. Some types of coatings (e.g. cement-based ones) and water permeability-reducing admixtures accommodate considerable vapor movement, thus allowing them to be placed successfully on the downstream side.

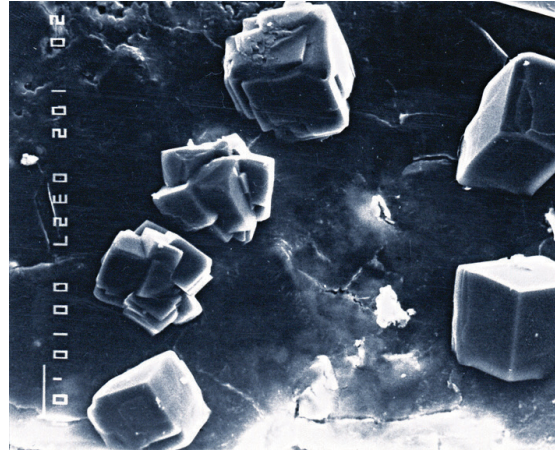
How crystalline waterproofing works

Crystalline waterproofing technology improves the waterproofing and durability of concrete by filling and plugging pores, capillaries, and micro-cracks with an insoluble, highly resistant crystalline formation. The process is based on two simple properties—one chemical and the other physical.

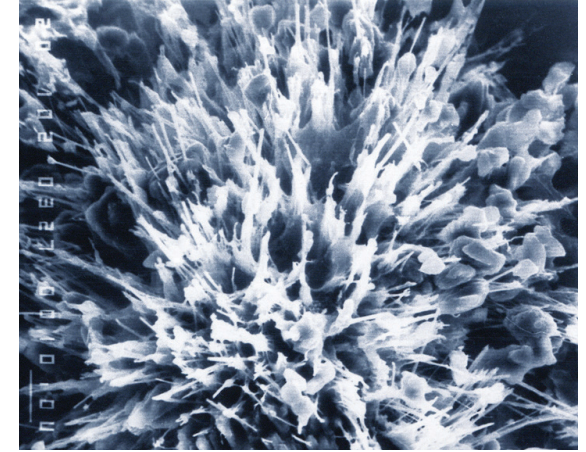
Concrete is chemical in nature. When a cement particle hydrates there is a reaction between water and the cement, which causes it to become a hard, solid mass, but there are also chemical byproducts given off that lay dormant in the concrete.

Crystalline waterproofing introduces a second set of chemicals. When these two groups are brought together (*i.e.* the byproducts of cement hydration and the crystalline chemicals) in the presence of moisture, a reaction takes place, resulting in the formation of an insoluble crystalline structure.

This crystalline structure can only occur where water is present, and thus, will form in the pores, capillary tracts, and shrinkage cracks in



Scanning electron microscope (SEM) view of a concrete pore.



SEM view of a concrete pore as it fills with multiplicative crystalline formation.

concrete. Wherever water can penetrate the concrete, the crystalline formation will follow.

When crystalline waterproofing is applied to the surface as a coating, a process called chemical diffusion takes place. The theory behind diffusion is a solution of high density migrates through a solution of lower density until the two equalize.

Water in the capillary tracts provides the solution of low chemical density. When crystalline waterproofing is applied to saturated concrete a solution of high chemical density is created at the surface, triggering the process of diffusion. The crystalline waterproofing chemicals must now migrate through the water (the solution of low density) until the two equalize.

The crystalline waterproofing chemicals now spread through the concrete and become available to the byproducts of cement hydration, allowing the chemical reaction to take place and the formation of a crystalline structure. As chemicals migrate through water, this

crystalline growth will form behind an advancing front of chemicals. This reaction continues until the crystalline chemicals are either depleted or run out of water.

Chemical diffusion can take these chemicals about 300 mm (12 in.) into a completely saturated concrete substrate. Where concrete is not completely saturated, the crystalline chemistry only diffuses to the depth of water saturation. However, the crystalline structures still have the potential to travel deeper into the concrete in the future if water penetrates the material from the opposite direction, thus reactivating the crystalline chemistry.

Instead of just reducing the porosity of concrete, like water reducers, plasticizers, and super plasticizers, the crystalline formation engages the material filling and plugs the voids in concrete to become an integral and permanent part of the structure.

Since the crystalline formation occurs within the concrete it cannot be punctured or otherwise damaged like membranes or surface coatings. Crystalline technology also improves the durability of concrete structures, lowering their maintenance cost and extending their lifespan by protecting them against the effect of aggressive chemicals. Crystalline waterproofing is resistant to chemicals where the pH range is between three and 11 under constant contact and two to 12 under periodic contact.

Crystalline waterproofing tolerates temperatures between -32°C (-25°F) and 130°C (265°F) in a constant state. In the author's experience, humidity, ultraviolet (UV) light, and oxygen levels also have no impact on the material's ability to perform.

Crystalline waterproofing offers enhanced protection against the following agents and phenomena.

Carbonation

This is the result of the dissolution of carbon dioxide (CO_2) in the concrete pore fluid, which reacts with calcium from calcium hydroxide and calcium silicate hydrate to form calcite (CaCO_3). This process reduces the pH of concrete and its natural protection of reinforcing steel.



Tower 155 in Boca Raton, Florida, is a 14-story condo complex featuring 170 luxury units. The foundation is constructed 6 m (20 ft) below grade and has a two-level, below-grade parking garage. Crystalline admixture waterproofing was added to the 5199 m^3 (6800 cy) concrete used to pour the foundation slab, walls, swimming pool, and spa fountain.

Alkali aggregate reactions

By denying water to these processes, crystalline waterproofing helps prevent these types of swelling reactions.

Chloride attack

Extensive chloride-ion diffusion testing shows concrete structures protected with a crystalline waterproofing treatment slows the diffusion of chlorides, thus extending the time-to-corrosion of the reinforcing steel.

Due to their limitations, membranes and coatings may leave concrete susceptible to water and chemical damage. The addition of crystalline technology can seal the pores and micro-cracks.

Matching the right crystalline technology with the application

Crystalline waterproofing and protection technology is sold in powder form and is mixed with water. It can be used in two ways:

- as a coating applied to the surface of existing or new concrete structures, such as foundation walls, floor slabs, or the inside of underground structures; and
- an admixture added directly into the concrete batch at the plant or truck for new construction, shotcrete, and precast applications.

Crystalline waterproofing coating

As mentioned earlier, when applied to clean, bare, and previously saturated substrate as a slurry mixture, the reactive chemical ingredients in crystalline waterproofing can penetrate up to 300-mm deep inside the concrete by using water as the migrating solution. As these chemicals penetrate through the capillaries and pores, the reaction with the mineral byproducts of cement hydration creates the crystalline formation that fills the cracks and pores.

Crystalline waterproofing can be applied by a brush or with spray-on equipment. To ensure the success of the application, care must be taken to ensure correct surface preparation, substrate saturation, coverage rate, and curing time.



Since the crystalline waterproofing coating system has a unique chemical diffusing characteristic, proper surface preparation of the concrete is critical to the performance of the treatment. Concrete surfaces need to have an open pore texture to allow the transfer of the reactive crystalline chemicals from the coating into the concrete substrate. The surface also needs to be clean and free of form oil, laitance, and other foreign matter to ensure proper adhesion of the coating.

Crystalline waterproofing admixture

When used as an admixture the same chemical reactions take place, but cost is lowered by eliminating the labor associated with the application of a

Tower 155 features a 40,413-m² (43,500-sf) matt foundation with concrete ranging from 1067 mm (42 in.) to 2 m (6 ft) deep. The concrete was fully treated with an admixture to provide integrated crystalline waterproofing.

surface treatment. Additionally, the utilization of crystalline waterproofing as an admixture moves labor offsite, eliminating scheduling and delays.

Since the admixture is added to the concrete mix at the batch plant or a ready-mix truck, it ensures the crystalline formation occurs uniformly throughout the structure rather than penetrating from the surface as would be the case with a surface application. In addition to waterproofing, crystalline admixture can reduce shrinkage cracking as well as increase compressive strengths. This may be because the water is taken up into the crystalline structure, leading to a longer, internal moist cure that is beneficial for shrinkage reduction and compressive strength development. For most mix designs, the dosage rate is two to three per cent based on the Portland cement content.

While crystalline waterproofing admixture is compatible with super plasticizers, air-entraining agents, water reducers, fly ash, pozzolans, and other ingredients used to improve the performance of modern concrete mixes, it is best to check with the manufacturer to ensure there is no incompatibility with other elements of the concrete mix, particularly concrete set retarders.

Negative-side waterproofing

Where existing underground structures are experiencing water seepage because of failed exterior membrane or coating systems, the problem can be remedied by the application of crystalline waterproofing on the negative side (inside) of the structure. Under these conditions, surface coatings—depending on the adhesion—blister and peel when moisture seeping through the concrete from the exterior dissolves soluble minerals and deposits them under the coating in the form of efflorescence. Since crystalline waterproofing penetrates into the concrete and plugs the pores beneath the surface, it stops water seepage in the concrete before it reaches the inside surface. This does not depend on its adhesion to the surface and will not blister and peel off like surface barriers.

Vapor transmission through basement floors and walls is also a common problem leading to unpleasant damp, musty odors. Testing in Japan



A mix of crystalline waterproofing admixture, coating, and repair products were used to ensure a watertight foundation for the new Columbia College headquarters near downtown Vancouver, British Columbia, Canada.

and countries in Europe has shown the application of crystalline technology can reduce vapor flows as much as 50 percent by reducing the size of the capillary tracts in the concrete as well as making some of them discontinuous, which, in most cases, provide a drier, more pleasant atmosphere.

Crystalline waterproofing materials also have the ability to self-heal micro-cracks ($<30\text{ }\mu\text{m}$ [1181 μin]) in the concrete substrate as well as macro-cracks up to 0.4 mm (16 mils) in width. The rate of self-healing depends on the size and nature of the crack (static or moving) and the hydrostatic pressure the crack may be subjected to. Self-healing could be evident in only a few days or as long as a few months depending on the ambient conditions.

When cracking takes place over a longer period of time water penetration activates the crystalline chemicals and the self-healing process will take place. Testing conducted in Japan on a cracked bridge deck 10 months after being treated with reactive crystalline waterproofing demonstrated cracks self-healed very quickly compared to control samples.

Real-world examples

Several examples of how crystalline waterproofing technology products were employed in real-world construction applications situations are illustrated by the following projects.

May Bank Headquarters

The triple tower development designed as a new headquarter building for May Bank in Kuala Lumpur, Malaysia, involved diaphragm wall construction incorporating a nine-level underground parking garage. A crystalline technology admix was selected for the project to assist with controlling hydration heat, reduce shrinkage cracking, give the slab the capacity to ‘self-heal,’ and waterproof the concrete as well as increase its strength and durability.

The basement slab required approximately 24,000 m³ (31,391 cy) of crystalline admix-dosed mass concrete. Commencing on September 26, 1997, the initial pour of approximately 13,200 m³ (17,265 cy) was conducted over a 60-hour period; it was then and remains today the third largest continuous pour conducted in the world and the largest in Southeast Asia.

Tower 155

This 14-story mixed condominium complex in Boca Raton, Florida, features 170 luxury residential units with one, two, or three bedrooms, as well as two-story townhomes and penthouse units. Along with its rooftop spa and in-ground swimming pool, Tower 155 also features two levels of below ground parking.

Located near the water, the area’s high water table meant foundation waterproofing was essential. Designers considered a membrane system, but rejected it due to space constraints and the difficult installation it would require. By choosing an integrated crystalline waterproofing admixture as its waterproofing system, the builders saved an estimated 28 days on the construction schedule.

The crystalline admixture was included in the post-tensioned slabs, foundation walls, 130-m² (1400-sf) swimming pool and spa fountain.



Crystalline waterproofing in water soluble bags is added to the back of a ready mix truck.

A total of 5199 m³ (6800 cy) of crystalline admixture-treated concrete was used in Tower 155 structures. The complex required a matt foundation constructed 6 m (20 ft) below grade and measuring 40,413 m² (435,000 sf) with concrete ranging in depth from 1067 mm (42 in.) to 2 m (6 ft).

According to the lead architect Derek Vander Ploeg, of Vander Ploeg and Associates, “Despite the use of cold joints in the slab and walls due to the amount of concrete used and many separate pours, there is not a leak anywhere.”

Columbia College

Columbia College is the oldest university transfer college in Vancouver, British Columbia, Canada. The main campus is housed in a five-story, 6782-m² (73,000-sf) building just east of Vancouver’s downtown core at 438 Terminal Avenue. The building has a one-level, below-grade parking garage falling just above sea level from the nearby False Creek

Inlet. Due to the local climate and high-water table, the structure was subject to ongoing groundwater and below-grade hydrostatic pressure. To waterproof the foundation slab, walls, and elevator pit, without the uncertainty and extra labor of membranes or coatings, the project designers selected a crystalline admixture to add to the 500 m³ (17,657 cf) of ready-mix concrete that was required for the project. The crystalline admixture was introduced at a two per cent dosage (based on the total weight of the cementitious ingredients).

Crystalline waterproofing patching material and coating products were used in combination with a polyvinyl chloride (PVC) waterstop to permanently seal the joints where exterior walls landed on the slab. Additionally, crystalline waterproofing admix was also used as a modified grout to ensure a well-consolidated wall/slab interface. Once completed, all walls and joints in the foundation structure were dry and free of leaks.

Other applications

Crystalline waterproofing admix is also used by precast concrete producers to add value and enhance the performance of concrete pipes, manholes, septic tanks, and architectural panels. Apart from waterproofing these products, crystalline technology enhances chemical resistance and reduces shrinkage cracking, thus prolonging service life. Since it is sold in powder form, crystalline waterproofing can also be included in the mix design for bagged cement products such as shotcrete, mortar mixes, and stuccos.

The effectiveness of crystalline waterproofing technology can be limited by the concrete mix design. As the active chemicals in crystalline waterproofing react with by-products of cement hydration, there needs to be a certain amount of Portland cement or reactive cementitious materials (e.g. slag cement) in a concrete mix design. Additionally, the porosity of the concrete should also be taken into consideration, and this will be directly related to the water/cement ratio of the concrete. As a general rule, crystalline waterproofing is effective in concrete mix designs where the compressive strength is 20,684 kPa (3000 psi) or greater and a maximum water/cement ratio of 0.65.

Conclusion

Although concrete may appear to be a simple product to manufacture, it requires a highly engineered approach. In today's design and construction environment, where more stringent requirements, such as longer life cycles, more durable concrete, and value-engineering concepts are expected, careful consideration must be paid to not only the basic requirements, such as the water/cement ratio and materials, but also to more sophisticated chemical admixtures. With its ability to reduce the porosity and permeability of conventional concrete, crystalline waterproofing technology is a valuable addition to building sciences.

CS

ADDITIONAL INFORMATION

Author

David Ross is the technical services director for Xypex Chemical Corp. of Vancouver, British Columbia, Canada. Xypex is a manufacturer of crystalline waterproofing materials. He can be reached at dave@xypex.com.

Key Takeaways

Concrete is the most widely used building material in the world. Despite its apparent solidity, strength, and durability, the material is porous and permeable to fluid and vapor infiltration and migration. Water and dissolved chemicals, such as chlorides, sulfates, and acids, can penetrate deep into concrete, sometimes resulting in premature damage, such as reinforcing steel corrosion, freeze/thaw cracking, spalling, and chemical attack. When it comes to building the

foundations, elevator pits, water/wastewater treatment and water containment structures, and many other applications, waterproofing and protecting the concrete is critical.

MasterFormat No.

07 16 16—Crystalline Waterproofing

UniFormat No.

A2010.90—Subgrade Enclosure Wall Supplementary Components
A4090—Slab-On-Grade Supplementary Components
B3040.30—Horizontal Waterproofing Membrane

Key Words

Division 07
Concrete
Waterproofing

MAKE YOUR CONCRETE WORK FOR YOU

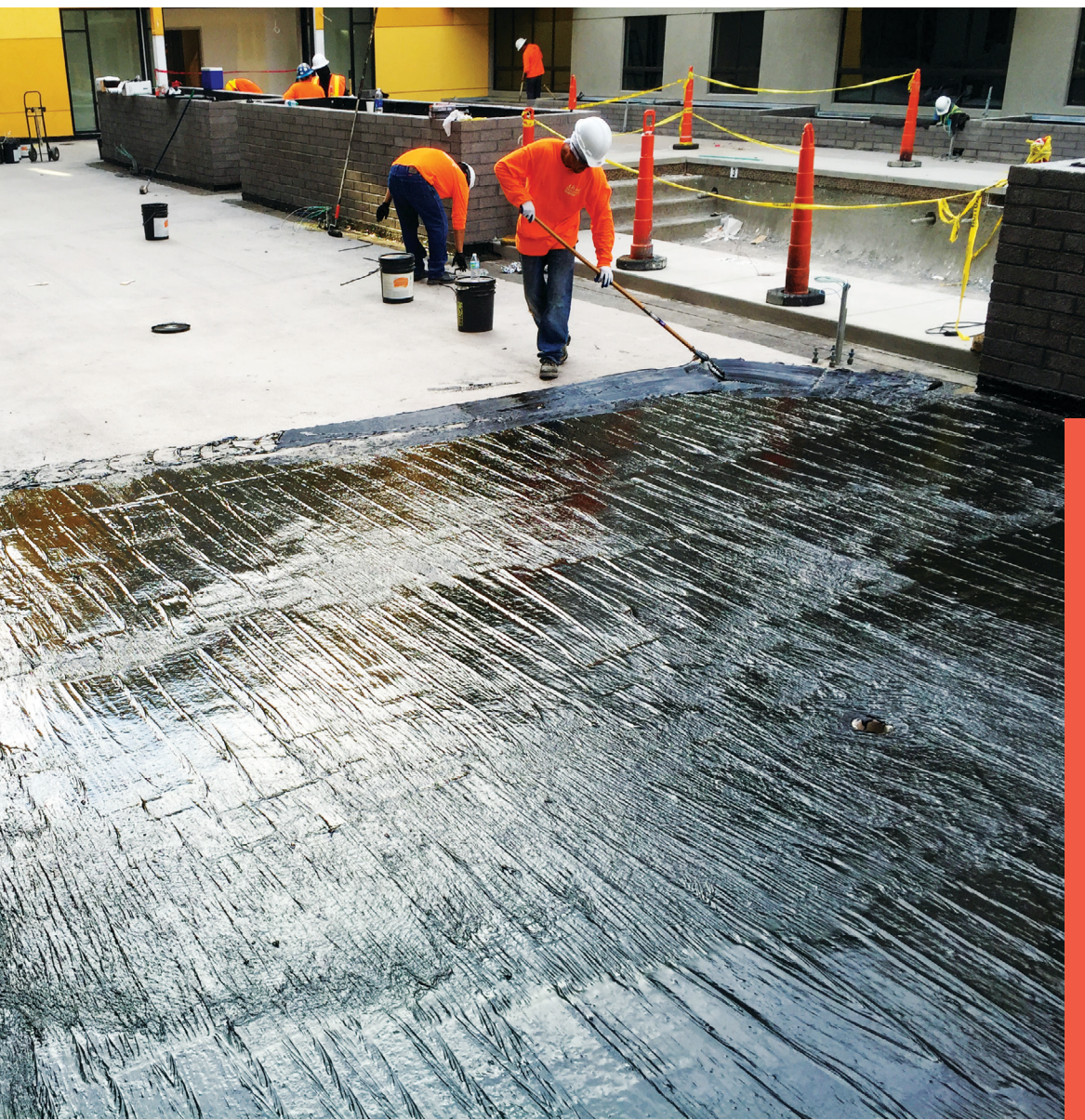


Kryton's integral admixtures **are added** to the concrete at the **time of batching**, eliminating the time required to accommodate surface-applied products.

Build with efficiency.

www.kryton.com





THE EVOLUTION OF FLUID-APPLIED MEMBRANES

by Isaac Sorensen, CSI, Russ Snow, CSP, CTR, BSS, LEED AP, Scott Wolff, CSI, CDT, BEC, Conleigh Bauer, CSI, Stacey Bogdanow, CTR, Taylor Wodzinski, Patrick Raney, CSI, ICRI, and Roger Smith, CSI, ICRI

Photos courtesy W.R. Meadows

AFTER CENTURIES OF USE, FLUID-APPLIED WATERPROOFING CONTINUES TO EVOLVE AS THE PRIMARY METHOD OF STRUCTURAL WATERPROOFING. ACCORDING TO GRAND VIEW RESEARCH, FLUID-APPLIED WATERPROOFING IS PREDICTED TO BE A \$37-38 BILLION MARKET BY 2025. HISTORICALLY, HUMANS HAVE EMPLOYED VARIATIONS OF LIQUID MEMBRANES TO WATERPROOF THEIR STRUCTURES SINCE HUNTERS AND GATHERERS USED LARGE LEAVES AND TREE SAP TO PROTECT THEIR EXCESS GRAIN FROM MOISTURE. IN THE NEOLITHIC ERA, BOATS WERE SEALED WITH BITUMEN EMULSION FROM PEAT BOGS TO PREVENT WATER FROM DETERIORATING THE WOOD. ANCIENT EGYPTIANS PERFECTED BITUMEN EMULSION TO SEAL AND PROTECT WALLS FROM THE NILE RIVER. WITH ALL THE TECHNOLOGICAL ADVANCEMENTS OVER THE YEARS, IT IS REMARKABLE THESE BASE CHEMISTRIES ARE STILL USED.

Fluid-applied waterproofing materials offer certain advantages over self-adhered sheet membranes, primarily the ease of installation, simplified detailing, and cost efficiency. Many challenges associated with sheet membrane waterproofing systems, such as ‘fish mouths,’ uneven seams, difficult end lapping, and

complexity of installing a straight flat sheet on a polygonal structure, are eliminated in a fluid-applied system. With liquid membranes, minor substrate imperfections, small gaps, and irregularities are easily addressed. The seamless, monolithic quality of a liquid membrane reduces the concern of failures at joints, laps, seams, and changes in plane. The elastomeric properties of a fully adhered, fluid-applied system will accommodate minor settling and structural movements due to temperature and humidity changes.

Whether sprayed, rolled, or troweled on, liquid membranes reduce waterproofing installation costs by eliminating time and labor associated with substrate priming, taping, and rolling seams, and measuring and cutting large prefabricated sheets. While many variables, such as the skill of the installer and the specific site conditions, influence the final installation cost, some estimators report a labor cost reduction of up to 60 percent by using a fluid-applied membrane over a traditional sheet-applied membrane. When it comes to surface preparation, although a fluid-applied membrane is a little more forgiving with regards to surface profile, proper preparation is still required. The installation schedule is similarly dependent on many variables, but a sheet-applied membrane system usually requires an estimated two to three times the installation time compared to a spray-applied waterproofing membrane system. The ability of cold fluid-applied membranes to be installed over 'green' concrete is another advantage in regard to the ever-shortening construction schedule.

Liquid-applied waterproofing materials

Liquid-applied waterproofing can be categorized into bituminous materials, coal tar, and polymeric materials. Bituminous binders result from the petroleum refining process and are commonly known as 'asphaltic' or 'asphalts'. The earliest discovery of bitumen dates back thousands of years to Europe and Africa. Despite being inherently combustible, bitumen is a sticky, naturally occurring and adhering, semi-solid, and innately hydrophobic material, highly suited for use in waterproofing membranes. With all of the technology for below-grade waterproofing, the use of bituminous membranes is still popular, and can be accomplished using a large array of accessory materials. It is imperative adequate research is done with regards to any materials that it will come into contact with these membranes to ensure both chemical and adhesive compatibility.

First discovered in the mid-1660s, coal tar is a byproduct of coke and coal gas production. It was commonly used in roads, sidewalks, and the preservation of railroad ties by 1865. The combination of coal tar and organic saturated felts became one of the earliest roof membranes.



Installation of hot rubberized asphalt membrane.

However, coal tar was limited to low-slope roofs due its low viscosity. Coal tar is also highly susceptible to ultraviolet (UV) degradation, often resulting in severe craze cracking in its cured form. For better UV stability, various resins, epoxies, and other materials were added as UV-resistant enhancers, including aluminum flakes. Despite the challenges, coal tar maintained a nearly 100-year popularity until the product was discovered to be carcinogenic. State and local volatile organic compound (VOC) restrictions banned its use for roofing applications and significantly reduced its use today. One other consideration is this material is also combustible, another limitation restricting its use.

Polymeric require complex formulations to cure to a solid membrane material. Most polymer technologies are highly processed and consequently more expensive than asphalt or coal tar. Polymer technologies are also less hydrophobic and have inherently lower viscosity than asphalt or coal tar. However, the installation advantages to these technologies continue to encourage their use in the field. These polymer technologies include polyurethane, acrylic (polymethyl methacrylate [PMMA]), silicone, acrylic urethane hybridization (polyurethane methacrylate [PUMA]), and silicone urethane (SPUR). As these materials are not produced from crude oil, they are deemed to be a more sustainable building material when compared with bituminous membranes.

Bituminous membranes

In the early 1900s, cold fluid-applied membranes were developed primarily for the maintenance of roadways and dust mitigation. Cold-applied membranes include cutbacks, cold-process, and emulsions, which refer to slight variations in the chemistry.

An asphalt cutback is simply heavy-grade asphalt thinned with lighter grade petroleum solvent to provide a higher viscosity and easier workability. Solvent-based cutbacks are rarely used today, and the term cutback has essentially vanished from product literature. These products are still available but limited by state and local codes due to their flammability, odor, and higher VOC content. These limitations often outweigh the benefits of cooler weather application and styrene butadiene styrene (SBS) membrane compatibility.

An asphalt emulsion replaces most of the solvent found in an asphalt cutback with water. Both cutbacks and emulsions contain asphalt cement, a finely ground or milled asphalt mixed with an appropriate solvent. Emulsions suspend the asphalt in the material through chemical emulsifiers and surfactants, and naturally contain very low VOC content. Standard asphalt emulsions remain viable for light-duty waterproofing in areas of low hydrostatic head pressure, commonly referred to as dampproofing. Polymer or rubber-modified asphaltic emulsions provide improved waterproofing protection against hydrostatic head pressure. These products are used primarily due to significantly lower cost compared to higher performing membranes. Applications requiring greater flexibility, improved performance, or faster setting times might be better served with alternate product types.

Modern bituminous asphalt is distilled from crude oil, oil sands, and well sources. It was first synthesized with other polymers into useable rubberized asphalt in the early 1950s. This early 'polymer-modified' asphalt contained styrene butadiene rubber (SBR), and found immediate use in the production of the nation's rapidly growing roadway networks



Spray installation of polymerized asphaltic emulsion.

at that time. In the late 1960s, scientific development led to the invention of SBS-rubberized asphalt with markedly higher levels of durability. The SBS asphalt formulation ages better, provides elastomeric qualities and strength while significantly improving abrasion resistance compared to its SBR predecessor.

During the early 1960s, a tire manufacturer commercially marketed SBR and later SBS-rubberized asphalt. Approximately 10 years later, a sheet version of SBS asphalt was developed into modified asphalt roofing, or 'mod-bit'. This new chemistry includes all

the benefits of hot fluid-applied SBS in a polyester or glass-reinforced, factory-controlled thickness sheet good.

Hot-applied SBS membranes are unrestricted by low temperature site conditions. The Blue Cross Blue Shield Headquarters project in Egan, Minnesota, installed a majority of the 8361 m² (90,000 sf) application in below -18 C (0 F). Hot-applied SBS sets immediately as a fully adhered continuous membrane. In its nearly 60-year track record, hot-applied SBS membranes have one of the lowest installed costs for a waterproofing membrane. They provide robust protection for plaza decks, steam tunnels, vegetated roofing, and parking garage deck applications. Conversely, respirable emissions and unpleasant odors from the melted asphalt should be considered when working in or near densely populated areas. Additionally, the material is nearly 204 C (400 F) when installed. The high temperatures can be dangerous even to an experienced installer.

Polymeric materials

In the latter half of the 20th century, the industry expanded toward new material possibilities, including polyurethanes. However, polyurethanes represent a broad category. Specifying the correct polyurethane requires precise terminology and detailed information regarding the product's physical property requirements. Subcategories include two-component, single-component, hybridized, unhybridized, modified, and unmodified. Advantages to polyurethane products in general include better elongation and flexibility. Additionally, these products adhere well to a wide variety of substrates. In restoration or maintenance applications, older surfaces may have unknown coatings or pre-existing adhesives. A polyurethane allows the contractor a greater chance of success despite any unknowns over other more substrate-specific products. At a molecular level, urethanes form a spring-like structure that allows for strength and flexibility. This molecular spring also recovers well, which creates high tensile strength, elongation, hardness, and flexibility even at extreme high and low temperatures.

Unfortunately, compatibility between polyurethanes and other waterproofing materials can be tricky. Polyurethanes are often modified with asphalt. The transfer of oils or plasticizers between adjacent asphaltic materials can negatively impact adhesion and create other compatibility challenges. Many injection grouting materials contain polyurethane technology. If injection grouting is used to repair a failing waterproofing system, the compatibility with the existing waterproofing system must be determined before installation. Likewise, transitions, detailing membranes, and protection course should always be confirmed for compatibility prior to installation. Testing information is widely available for polyurethane



Finished planter box installation of polyether membrane.

waterproofing, but modified or partial terminology within the testing criteria can create confusion when comparing products. Due to the various chemistries within this larger group, it can be difficult to establish true 'equals.'

Two-component polyurethane membranes were introduced in the early 1980s. These solvent-free products cure through a chemical or 'crosslinking' reaction. Two-components often have no added solvents, lower VOC levels than subsequent solvent-

based, single-component products, less odor, and negligible flammability risk. While they provided a more consistent cure time than the air/moisture-cure single-components, the inconvenience of field mixing led to the development of single-component products later in the decade.

Moisture-cure single-component polyurethanes were developed in the late 1980s to eliminate the onsite mixing required by two-component membranes. Reduced site waste and improved moisture tolerance provide additional advantages over two-component polyurethane products. Single-component polyurethanes are dependent on ambient humidity to initiate the curing reaction, also known as 'moisture-cure'. The addition of solvent cutbacks assists in workability and extends the recoat time. However, moisture-cure technology presents challenges such as foaming, bubbles, and blisters if installed incorrectly or over the presence of substrate moisture. Solvent content shrinkage may also be observed. Shrinkage is directly related to solids content. The higher the solids content in the liquid membrane, the less shrinkage will occur.

Single-component polyurethanes are generally cost competitive with other waterproofing systems. The simplicity of installation, and versatility in both vertical and horizontal applications, make it an attractive option for most projects. Maintaining the proper thickness and applying multiple coats if necessary are critical to the success of these systems. Two lifts may be necessary on vertical surfaces to achieve a 1.5-mm (60-mil) thickness. For more robust horizontal waterproofing, many single-component polyurethane products can be applied at 3 mm (120 mils) with non-woven reinforcement sheets.

Another newer, single-component technology, moisture-cure, silyl-terminated polyether (STPE), materials combine the solvent-free advantages of a two-component polyurethane with the simplified installation of a one-component product. Other names for this chemistry include silyl-modified polyurethanes, polyether, silyl-terminated polymer, silicone-modified polyester (SMP), and MS polymer. There is no flammability risk or odor, and they are lower in VOCs. These products also contain significantly higher solids content, meaning little to no shrinkage as the product cures.

However, this technology is susceptible to the challenges of a moisture-cure. The membrane cures from the exposed edge inward, meaning the surface 'skins over' very quickly, while the interior remains a liquid for longer. When the concrete substrate is heated by the sun, water vapor from within the concrete will push its way through the still liquid portion of the membrane, creating bubbles and blisters on the waterproofing surface. Proper installation of these membranes includes application at the correct time of day and only over substrates that have low moisture content. Many manufacturers recommend the use of a

Fluid-applied waterproofing materials offer certain advantages over self-adhered sheet membranes, primarily the ease of installation, simplified detailing, and cost efficiency.

primer in situations likely to produce blistering. This recommendation may be written into the specifications, if necessary.

One response to the bubbling challenges of moisture-cure membranes is the recent development of polyurethane water-cure technology. These products are only applicable for horizontal surfaces and must be water-saturated to cure. Moisture-cures set slower in comparison because the required moisture absorption from the air is gradual, curing from the edge-inward. With water-cure technology, the entire membrane cures simultaneously. Water-cure membranes set extremely quickly, some in as little as two hours, before escaping water vapor can create blisters or bubbles in the membrane.

Acrylic resins

PMMA's are two-part acrylic resins offering quick cure times through use of a catalyst. First synthesized in the 1930s, PMMA's did not become a viable waterproofing product until the early 1970s. When compared to asphaltic polyurethane membranes, these resins exhibit tremendous hardness as noted in their Shore Hardness data. The high-achieving abrasion and impact resistance of PMMA resins can be found in the manufacturing of aircraft windshields, safety glasses, dental fillings, and even contact lenses. Additionally, their water and chemical resistance and tolerance to heat and cold make these membranes applicable to a wide-range of construction applications. PMMA's provide the base to most traffic coatings, although polyurethanes can also be used for this purpose.

Around the turn of the millennium, a variant of PMMA was developed with the addition of polyurethane. PUMA couples the elastomeric properties of polyurethane with the durability of PMMA. The resulting PUMA membrane adds three to four times the elongation over a typical PMMA membrane. This is particularly important in northern climates where temperature extremes are greater than southern climates. Reinforcement material may be required at penetrations and transitions to ensure the material is applied at the specified thickness, but

PUMA membranes are strong enough to forgo fleece reinforcement fabric that is common among PMMA membrane systems.

With the use of an epoxy primer, both resin versions feature the advantage of green concrete application approximately 72 hours after form removal. Substrate and ambient application temperatures are accommodated as low as -6 C (20 F). PUMA membranes require careful understanding of ambient conditions. Application must take place at not less than -15 C (5 F) above the dewpoint. Installers are advised to be trained and authorized by the manufacturer. These waterproofing systems are generally designed for horizontal applications such as split-slab, paver systems, planters, and vegetated roofs.

While these technologies are extremely effective, PMMA/PUMA systems are estimated at up to twice the cost of an SBS, hot-fluid-applied rubberized asphalt system. However, quick production times and the elimination of protection course, termination bars, and other accessories are to be considered.

Conclusion

While fluid-applied waterproofing products have recently surged in popularity, fluid-applied materials have existed in various forms for centuries. Instead of new technologies replacing previous products, new fluid-applied technologies are added to an expanding portfolio of waterproofing chemistries. Almost all fluid-applied waterproofing technologies that were ever developed are still offered in some form today. With numerous options available, selecting the right system can be confusing. Balancing durability, material cost, and difficulty of installation, as well as construction schedules and budgets can seem overwhelming. However, the best waterproofing material is a well-installed one. No matter which product is selected, a knowledgeable installer will have the greatest impact on the success or failure of the waterproofing system. Concise specifications to communicate product information and quality standards, along with comprehensive detailing to provide explicit installation guides to the installer, will set the groundwork for a quality installation of any fluid-applied waterproofing system.

CS

ADDITIONAL INFORMATION

Authors

Isaac Sorensen, CSI, is architectural specialist, New York and Northeast Region, W.R. Meadows. He can be reached at isorensen@wrmeadows.com.

Roger Smith, CSI, ICRI, is architectural specialist, Southern California, W.R. Meadows. He can be reached via e-mail at rsmith@wrmeadows.com.

Stacey Bogdanow, CTR, is responsible for outside sales, Toronto and Eastern Ontario, W.R. Meadows. Bogdanow can be reached via email at sbogdanow@wrmeadows.com.

Russ Snow, CSP, CTR, BSS, LEED AP, is product group manager—building envelope, W.R. Meadows. He can be reached at rsnow@wrmeadows.com.

Conleigh Bauer, CSI, is architectural specialist, Texas, LA, OK, AR, W.R. Meadows. She can be reached via email at cbauer@wrmeadows.com.

Scott Wolff, CSI, CDT, BEC, is architectural specialist, Upper Midwestern States, W.R. Meadows. He can be reached via e-mail at swolff@wrmeadows.com.

Patrick Raney, CSI, ICRI, is architectural specialist, Northern CA and Northern NV, W.R. Meadows. Raney can be reached at praney@wrmeadows.com.

Taylor Wodzinski is the architectural specialist for Illinois, W.R. Meadows. She can be reached via email at swodzinski@wrmeadows.com.

Key Takeaways

Fluid-applied waterproofing materials have been used for centuries. Over the years, there have been many advances in material chemistry and technology.

Dating back to the mid-1800s, bitumen has been a part of major developments in hot and cold applied waterproofing. The 1960s introduced acrylics, styrene butadienes, and other waterproofing materials that provide better quality and durability. The 1980's saw a movement toward various resin technologies with the introduction of two-component polyurethanes providing greater ultraviolet (UV) resistance. The latter part of the decade advanced to single-component, moisture-cured polyurethanes. Today, polyurethane chemistry seems to be the majority of fluid-applied materials used. However, with all of this development, proven performance in previous technologies still warrant their use around the world.

MasterFormat No.

07 10 00—Dampproofing and Waterproofing

UniFormat No.

A2010.90—Subgrade Enclosure Wall Supplementary Components

A4090—Slab-on-grade Supplementary Components

B3040.30—Horizontal Waterproofing Membrane

Key Words

Division 07

Acrylic resin

Bituminous asphalt

Fluid-applied membranes

Polyurethanes

Waterproofing

CASE STUDY

The Whitney Museum of American Art

Ensuring the Preservation of Contemporary American Art



SMART CONCRETE®

The Whitney Museum was relocated to a new facility in 2015. The new six-story space is not only well thought out but also a marvel of architectural expression.

To make sure the building remained watertight, **one of Kryton's distributors, Dry Concrete, was called in.** They knew that in order to thwart water infiltration and the danger of early deterioration it posed, they needed a **permeability-resistant admixture for hydrostatic pressure (PRAH).** As a result, the team chose to use Kryton's KIM, a PRAH product that was best able to perform in such a challenging high-risk environment.

www.kryton.com/projects/whitney-museum-of-american-art/