SPECIAL CONCRETE EDITION

THE BLUE BOOK NETWORK®

THE Who's Who IN BUILDING & CONSTRUCTION

WORLD OF CONCRETE 2020

The Blue Book Network's Exclusive Magazine and Buyers' Guide

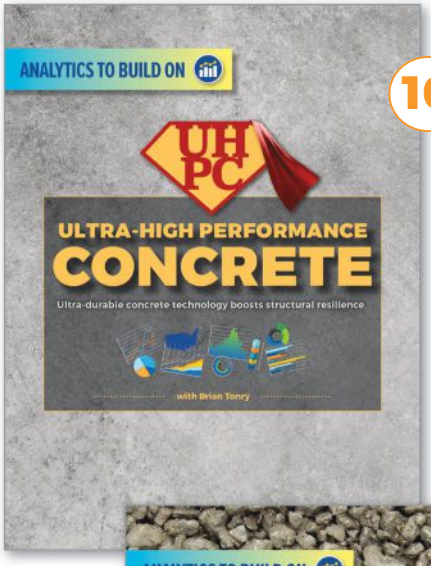
ANALYTICS: The Right Foundation for Rock-Solid Decisions

INSIDE: NATIONAL CONCRETE BUYERS' GUIDE!

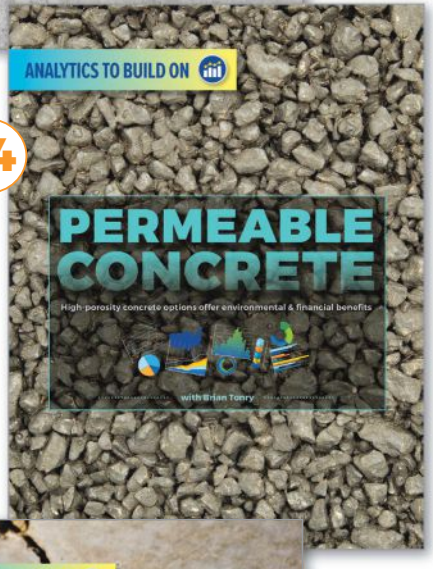
TheBlueBook.com

THE Who's Who
IN BUILDING & CONSTRUCTION
TheBlueBook.com

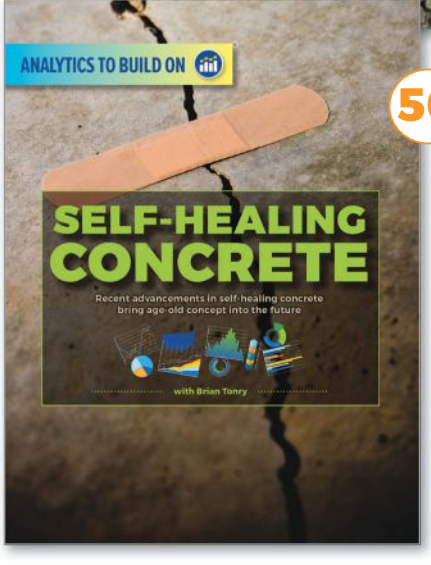
SPECIAL EDITION
WORLD OF CONCRETE 2020



10



34



50

CONTENT

FEATURES

DEPARTMENTS

22

A crew from Advanced Coring & Cutting Corp. at work at the Kinder Morgan, Inc. storage facility in Perth Amboy, NJ.

Photo: Advanced Coring & Cutting Corp.

ARA Contractors, Inc. frequently teams with Unlimited Environmental, Inc., an industry leader in demolition and remediation.

Photo: Unlimited Environmental, Inc.

44

The Blue Book Network® ***Intelligence and Analytics*** team focuses on discovering the trends and data relationships that drive labor and materials throughout the construction supply chain. Leveraging the extensive Blue Book Network of project information, connected companies and key contacts--as well as construction documents that list products and brands--the team conducts research and analysis to provide your business with important insights. We help you make informed, data-driven decisions. Research results are shared with the industry through published articles, white papers and on our website.

In this **Analytics to Build On** piece, we will take a look at Self-Healing Concrete. The Pantheon in Rome was built as a temple by Hadrian around 117 A.D. and is still in use today, 2000 years later. Why? Perhaps because the Romans knew something about concrete that we don't, thus our pursuit of self-healing concrete today. Let's find out more.

SELF-HEALING CONCRETE

Sounding more like the plot to a sci-fi thriller than the latest technological advancement, limestone-generating bacteria may be the long-term solution the industry has been searching for to address destabilization of concrete due to cracking. Considered to be one of the industry's greatest challenges, early detection and management of microcracking can dramatically extend the lifecycle of structures, resulting in greater public safety, decreased maintenance costs and a more sustainable and eco-friendly building material. Recent advancements are bringing the 2,000-year history of self-healing concrete into the future.

IS SELF-HEALING CONCRETE NEW?

Despite the recent buzz, concrete that can heal itself is not a new idea. The Romans developed the first known autogenous self-healing concrete, creating structures like the Pantheon and Colosseum that have lasted 2,000 years. Autogenous self-healing capabilities are intrinsic to the material itself, produced by altering the chemical or biological composition of the concrete mix. These early builders mixed a form of lime mortar with volcanic ash, quicklime and water. As the concrete cures, the materials react to create a crystal formation that holds together the mortar and coarse aggregate.

Crystalline waterproofing can improve durability and performance of concrete structures and remains one of the most used autogenous self-healing concrete products worldwide.

Autogenous healing relies on the presence of water as well as unhydrated cement. In the early life of a concrete structure, water enters the formation and hydrates cement particles, naturally (intrinsically) filling microcracks. Later in the life of the concrete, water and carbon dioxide react to create calcium carbonate (limestone), a natural substance that also fills microcracks. Concrete's innate ability of autogenous self-healing is limited, however, since it is only effective with microcracks of 0.1 mm or less. That would be fine if cracks developed first as tiny fissures and developed slowly. But with exposure to forces such as freeze-thaw cycles, expansion and contraction, tensile loads, and deteriorating steel reinforcement, just to name a few, larger cracks can occur quickly and growth of microcracks can outpace concrete's intrinsic self-healing capability to form sufficient crystals to fill in the widening gap. Because these forces effectively ensure that cracking will continue to be a quality of concrete, it is not surprising that advancements in self-healing concrete are focused on early corrective action, repeatable healing and healing of ever wider gaps.

NEW APPROACHES TO AUTOGENOUS SELF-HEALING

The industry has taken a number of different approaches to repairing cracks in concrete. More traditional approaches involve fluid-applied waterproofing products, injection of healing agents directly into cracks and gap-widening with concrete patching. These are primarily concerned with sealing the concrete to keep water from penetrating and widening the gaps.

PHOTO COURTESY OF ISTOCK.COM/KLOSFOTO

Advancements in autogenous self-healing solutions include the use of additives within the cement mixture, such as microfibers, superabsorbent polymers (called hydrogels) or pozzolanic materials like fly ash. The use of microfibers results in microcracks spidered with criss-crossing fibers, thereby reducing the gap and allowing intrinsic self-healing (natural hydration of the cement and the formation of calcium carbonate). Hydrogels enable the absorption of huge amounts of water, up to 100 times their volume. When added to the concrete mixture, they swell, blocking the entrance of the micro-crack. After swelling, the hydrogels desorb, providing fluid to the surrounding matrix for autogenous healing. Like hydrogels, pozzolanic materials promote autogenous self-healing of cracks.

In 1969, Xypex, a Canadian company, ushered in crystalline waterproofing technology using a proprietary mix of chemicals that react with water to close cracks up to 0.4 mm. The product comes in several forms, allowing it to be applied as a coating to existing concrete structures or as an admixture or dry-shake application for new concrete. As with standard self-healing concrete, crystalline waterproofing products react with unhydrated cement particles to form mineral-based "dendritic crystalline structures." Much of the self-healing benefit of crystalline waterproofing is realized during initial concrete hydration and curing, although a sufficient amount of the product remains in place to seal cracks appearing early in the life of the structure. Additional product can be applied as a coating to extend self-healing properties. Crystalline waterproofing can improve durability and performance of concrete structures and remains one of the most used autogenous self-healing concrete products worldwide.

One of the newest techniques to enhance intrinsic self-healing—and the one that is receiving the most attention recently—involves the addition of mineral-producing bacteria (Bacillus subtilis or Bacillus sphaericus), which produce calcium carbonate when mixed with water. These spores can survive for decades without food or oxygen and are able to withstand the high alkalinity of concrete as well as the mechanic stresses experienced during the mixing process. Once activated by water, the bacteria feed on calcium lactate to form limestone. The bacteria spores can be added to the wet concrete directly, but are often added to the wet concrete mix in the form of microcapsules made from biodegradable plastic.

AUTONOMOUS SELF-HEALING

When self-healing agents, whether chemical or biological, are encapsulated or delivered via a vascular network, they are referred to as autonomous. These agents remain separate from the formation until damage releases the healing agent into the structure. Capsules contain minerals, epoxy or polyurethane. As a crack forms, these capsules are ruptured. The polymer flows into the crack, bonding together the crack faces and healing the formation. In the case of bacteria, a rupture to the capsule exposes the agent to water, activating the generation of calcium carbonate. The challenge with this particular technique is creating a capsule that can survive the mixing and pouring process yet is brittle enough and has a low enough tensile strength so the capsule breaks when needed. Further, the technology must balance the need for a large number of capsules—to increase the chance for self-healing—with the potential impact on cost and on the resulting strength of the concrete itself from this added mixture.

Another autonomous self-healing technique draws its inspiration from the human body. Vascular self-healing relies on a network of hollow tubes embedded in the concrete matrix. These tubes contain the healing agent. When cracks occur, these microcracks eventually lead to the vascular network, breaking the tube. The healing agent then flows to the microcrack with the help of gravity or capillary forces.

A vascular network can contain a single healing agent in its tubes, or the system can contain multiple types of healing agents delivered through several separated networks. While capsules are self-contained, a vascular system can be connected to the exterior of the structure, allowing the healing agent to be added from the outside. Like a capsule-based healing system, the vascular network must be brittle, have a good bond with the concrete and must not compromise the integrity and strength of the concrete itself.

WHERE IS IT USED?

Self-healing concrete, typically in the form of crystalline waterproofing, is frequently specified for sewer and water treatment projects, tanks, tunnels, roadways and marine applications. This approach as well as other autogenous solutions, is considered to be more efficient, cost effective, safer and easier to use in full-scale applications.

Self-healing concrete that is effective at filling larger cracks, not just for waterproofing but to maintain structural integrity, is an emerging technology that is being extensively researched and tested. Bacteria-based self-healing concrete has reached the commercial market. Dutch company Green Basilisk employs bacteria-based self-healing agents encased in polymer capsules or mixed directly into the concrete. The company carries three products: a healing agent for concrete mixtures, a self-healing repair mortar and a liquid repair spray. The bio-based healing agent is mixed directly into the concrete mixture. The company recommends using the product for tunnel sections, fluid reservoirs, basement walls, bridge decks and flooring systems.

Applications include a 2019 project for Het Loo Palace in Apeldoorn, The Netherlands. The healing agent was used in the construction of a large underground extension to the basement of the palace, which will ultimately function as a museum. The bacteria-based addition to the concrete mixture is expected to repair cracks autonomously and keep the structure watertight.

The product was also used in a project for the Port of Rotterdam in 2017. The healing agent was added to the concrete mix in the construction of the water basin. Once subjected to water contact, the healing agent precipitates the formation of limestone to heal microcracks.

WHY IS IT IMPORTANT TO THE INDUSTRY?

As is commonly known, concrete forms microcracks over time due to its low tensile strength. The formation of microcracks provides a pathway for liquids and gases. While concrete very rarely crumbles when it encounters water, wind or stresses within its design capability, the growth of these microcracks can lead liquids and gases to the steel reinforcement placed within concrete. Corrosion of the steel causes an expansion reaction where rust occupies a greater volume than the steel, ultimately compromising the integrity and durability of the concrete formation.

Concrete degradation not only impacts safety, but also requires major repair costs. While self-healing concrete may require an additional investment upfront, its costs are expected to be offset in the long-term by reducing the costs for maintenance and repair.

While biological self-healing concrete is spreading into the market across

Cracks in concrete can lead to corrosion of the steel reinforcement, ultimately compromising the integrity and durability of the formation.

PHOTO COURTESY OF BIGSTOCKPHOTO.COM/KOONSIRI BOONNAK

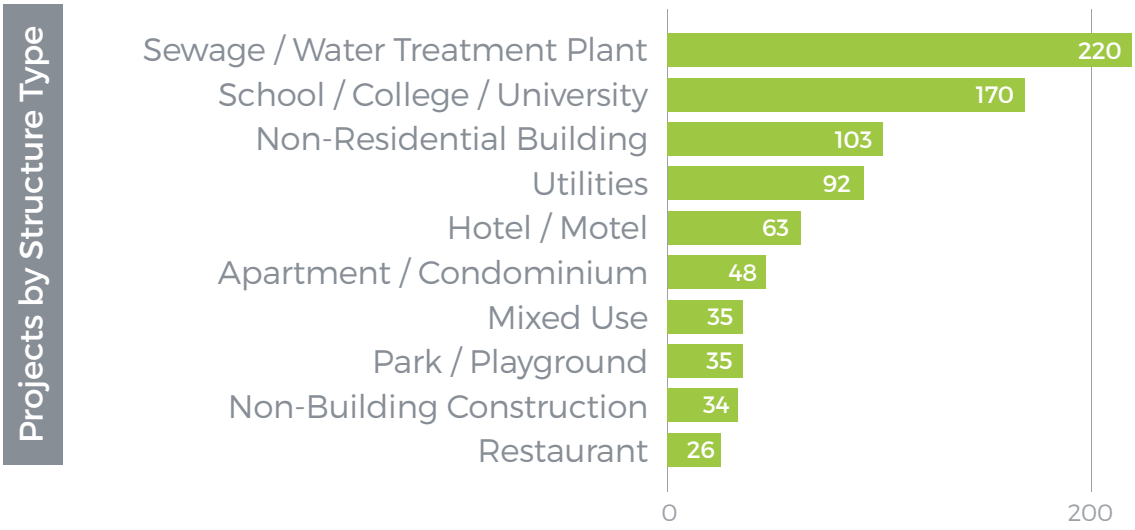


Table 1: Crystalline Waterproofing Projects 2014-2019 by Top 10 Structure Types
Source: Blue Book Network Intelligence & Analytics

Europe, the market in the U.S. has been slower to adopt the technology. Self-healing concrete is expected to be most beneficial in projects such as bridges, tunnels and highways, where maintenance and repairs are extremely costly and maintaining the structural integrity of the concrete over a long period of time is essential.

Failure in a concrete structure like a bridge or tunnel is not only expensive to repair, but it is also a risk to public safety. Millions of Americans travel on a vast network of roads and bridges each day. But according to a new report from the American Road and Transportation Builders Association, more than 47,000 bridges in the U.S. are in poor condition and in need of urgent repairs. Increasing maintenance costs and transportation delays caused by the poor condition of bridges and roads have a huge impact on the U.S. economy according to economists.

When microcracks form, self-healing concrete technologies can repair these cracks before they have a chance to form larger cracks and channels that can ultimately corrode the steel reinforcement. By preventing these pathways from forming, self-healing concrete lengthens the life span of a structure and reduces maintenance and repair costs.

In addition to its impact on safety and long-term costs, self-healing concrete can also improve the industry's impact on the environment. Today, the cement industry is the third-ranking producer of man-made carbon dioxide, accounting for up to 5% of the world's total carbon dioxide emissions. By creating longer-lasting, more sustainable structures, the industry could potentially decrease its production and, in turn, reduce carbon dioxide emissions.

Autogenous self-healing products are being specified for projects in the U.S. but not for the mineral-producing admixtures that enhance structural integrity as of yet. These products primarily use crystalline waterproofing coatings or integrated admixtures designed to reduce permeability of concrete to the passage of water. The biological-based agents capable of healing larger gaps and remaining viable for up to 200 years have yet to break into the U.S. market. Overall cost of the product (either to import from Europe or develop in the U.S.) as well as limited research into performance of the product is slowing adoption.

SELF-HEALING CONCRETE IN THE BLUE BOOK NETWORK

Table 1 lists the top 10 structure types from specification searches for crystalline waterproofing products found in The Blue Book Network. Commonly specified brands include BASF, Euclid, Kryton, Sika, Tremco and Xypex.

In addition to use in foundations for waterproofing, crystalline products are often specified for sewer and water

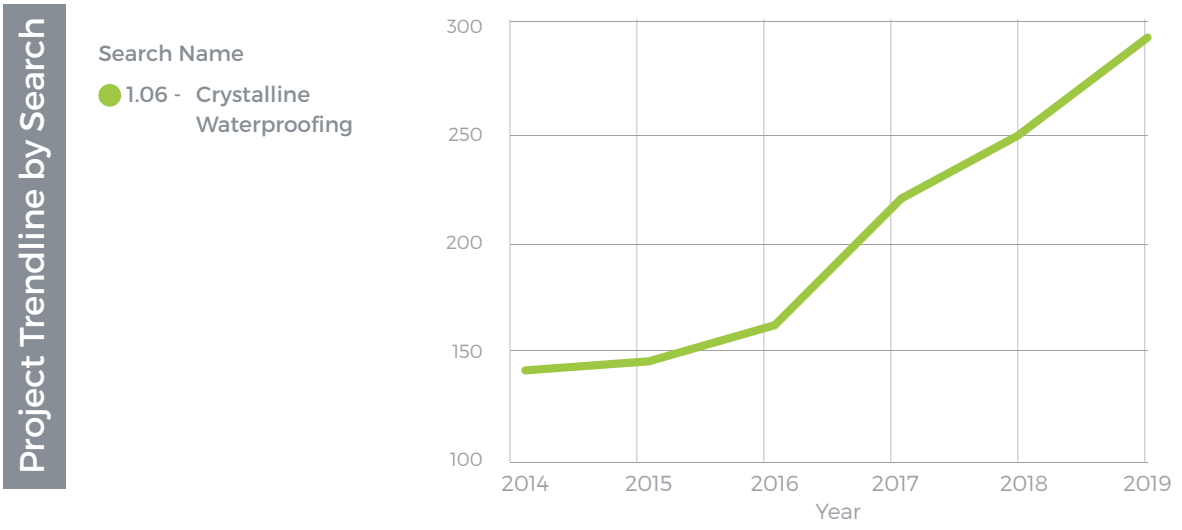


Table 2: Crystalline Waterproofing Projects 2014-2019 by Year **Source: Blue Book Network Intelligence & Analytics**

treatment plants, tunnels and exposed concrete where freezing can turn microcracks into substantial structural concerns, such as parking facilities and other exposed concrete decks. These products are also specified for swimming pools, tanks, water retention installations and precast concrete components.

Top General Contractors of Crystalline Waterproofing Projects

General Contractors:	State
West Construction, Inc.	FL
Integrated Construction	FL
English Construction Co., Inc.	VA
KAST Construction	FL
March Associates	NJ
Ortega Industrial Contractors	FL
Del-Sano Contracting Corp.	NJ
eciConstruction LLC	PA
Fortney & Weygandt, Inc.	OH
Gorman & Co., Inc.	WI
GPC, Inc.	NJ
Nauset Construction Corp.	MA
The Struthoff Co., Inc.	TX

Table 3: Top General Contractors (from Principals)
Source: Blue Book Network Intelligence & Analytics

Table 2 illustrates the growth in specifications for crystalline waterproofing from 140 projects in 2014 to more than double that in 2019. As with ultra-high performance concrete, crystalline waterproofing offers solutions to aging infrastructure with products that can be used to jacket concrete and extend the usable life of existing structures. As bio-generated solutions being used now in other countries begin to prove themselves out, expect to see these bacterial-agent products used in important civil projects where structural integrity is required over longer and longer infrastructure lifecycles. In the meantime, crystalline waterproofing will continue to fill the gap(s).

Table 3 shows the top general contractors who primarily use crystalline waterproofing in projects; the most active concrete subcontractors are shown in Table 4; and the most active concrete suppliers who employ crystalline waterproofing are shown in Table 5.

Growth opportunity for self-healing concrete remains strong into 2020 with more than 4,500 bidding opportunities for sewers and water treatment facilities in 2019 and more than 15,000 bridge, tunnel and utilities projects. For manufacturers, distributors and subtrades with experience using crystalline waterproofing, federal, state and local departments of transportation are good targets for infrastructure projects. In addition, the use of self-healing products in foundations, exposed decking, and similar concrete applications is expected to see a lift from the buzz generated by

Top Concrete Subcontractors of Crystalline Waterproofing Projects

Concrete Subcontractors:	State
Concrete Protection & Restoration, Inc.	MD
Structural Contracting Services, Inc.	NY
Finley Asphalt & Concrete	VA
Sanderson Concrete Construction	FL
Duel Concrete Construction	WI
North Star Foundations, Inc.	MD
Cavan Construction Company Inc.	PA
Compaction Grouting Services, Inc.	PA
D'Amico Concrete Construction, Inc.	NJ
Elite Restoration, Inc.	PA
Industrial Floorworks	NY
Meyer Concrete Pumping & Conveyor Service, LLC	IL
Meyer Consulting Engineers Corporation	MD
Structural Maintenance Systems, Inc.	PA

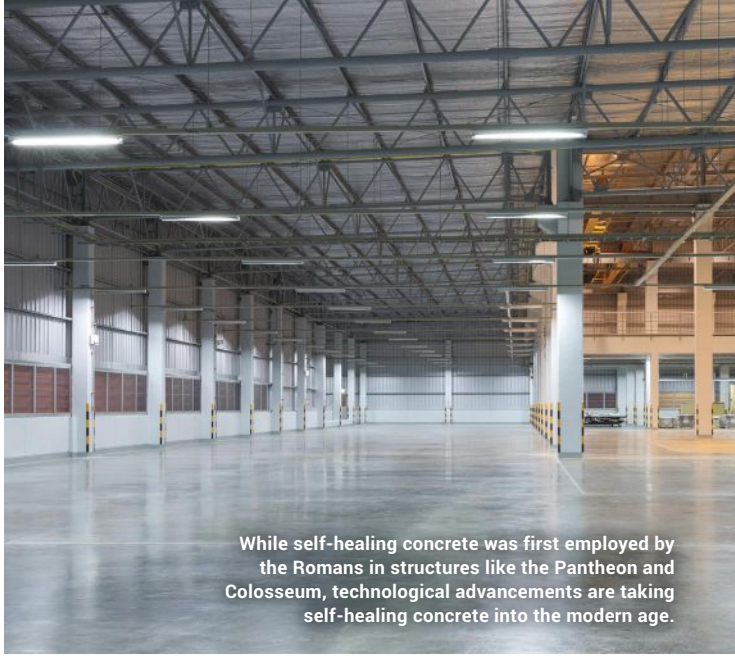
Table 4: Top Concrete Subcontractors
Source: Blue Book Network Intelligence & Analytics

Top Concrete Suppliers of Crystalline Waterproofing Projects

Concrete Suppliers:	State
American Floor Systems, Inc.	PA
East Coast Poured Floors	FL
Hot Shot Supply	CO
K & E Chemical Co., Inc.	OH
Leesburg Concrete Company, Inc.	FL
The Ark-Concrete Specialties, Inc.	TX
American Eagle Concrete Sawing	FL
Arco Concrete, Inc.	CO
Atlantic Concrete Products, Inc.	PA
Coral Cast Architectural Stone	NY
Intron Technologies, Inc.	FL
Lee Commercial Contracting	FL
Rolling Plains Construction, Inc.	CO

Table 5: Top Concrete Suppliers
Source: Blue Book Network Intelligence & Analytics

PHOTO COURTESY OF BIGSTOCKPHOTO.COM/ LOVEPHY



While self-healing concrete was first employed by the Romans in structures like the Pantheon and Colosseum, technological advancements are taking self-healing concrete into the modern age.

bio-solutions and the prospect of extending the lifecycle of traditional concrete by 50 years or more.

After researching this topic for our Network, I don't think we are catching the Romans quite yet, but it seems very clear we are making significant strides in extending the life of our concrete structures.

Additional details and analyses are always available exclusively for our Blue Book Network Members. Be a step ahead of your competitors by being part of the industry's most active and intelligent commercial construction network. Our ***Network Intelligence and Analytics*** team is eager to work with you to better understand the next "big thing" that will help you win more work and grow your business.

Brian Tonry
Vice President of Network Intelligence and Analytics
The Blue Book Network
btonry@mail.thebluebook.com
800-431-2584 ext. 3632