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shotcrete magazine

Volume 19, Number 3 • Summer 2017

FEATURES



Aiming for Extended Service Life with Migrating Corrosion Inhibitors

By Ray Schallom III, Jessi Meyer, and Julie Holmquist



Bridge and Highway Repairs Using Shotcrete and Cathodic Protection By Dennis Bittner and Erik Bertrand



Overcoming Existing Corrosion When Using Shotcrete for Repair By Rachel Stiffler



ACI RAP Bulletin 8 Installation of Embedded Galvanic Anodes Reported by ACI Committee E706

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The opinions expressed in *Shotcrete* are those of the authors and do not necessarily represent the position of the editors or the American Shotcrete Association.

Editor's Note: Shotcrete is a placement method for concrete. However, for the sake of readability, the word "shotcrete" is often used either to identify the shotcrete process (method of placement) or the shotcrete mixture (product materials).

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On the cover: Understanding conditions that facilitate corrosion gives insight into preventive measures. Refer to the Sustainability article on page 54.



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Featured Events:

- Full-day ASA Contractor Qualification seminar
- Full-day of Shotcrete Technical and Project Presentations
- ASA Spring Committee meetings (replacing meetings at The ACI Concrete Convention and Exposition – Spring 2018)
- Tabletop Exhibits
- First ASA Golf Tournament at one of Silverado's championship golf courses included in the PGA Tour
- The ASA Annual Outstanding Shotcrete Projects Awards Banquet at nearby Inglenook Winery & Wine Caves (replacing the banquet at World of Concrete 2018)
- Optional wine tours, spouse programs, and other resort offerings



O. ASA PRESIDENT'S MESSAGE

ASA—THE Leading Resource for the Shotcrete Industry

By Scott Rand



As I mentioned in my last Message, a select number of our Association participants, ranging from Executive Committee and Board members to Committee Chairs and Past Presidents, traveled to ACI headquarters in Farmington Hills, MI, on Friday, March 24, for our full-day 2017 Strategic Planning Update Session.

Heading into the meeting, we had completed over half of our original plan's 40 objectives, created 3 years earlier, and were well on our way to completing another 10. The timing was imperative to both maintain the success that we were experiencing as an Association since our pivotal Denver, CO, meeting (November 2015) and to provide new direction to those committees quickly exhausting their current objectives.

We started our meeting by reviewing all accomplishments to date. This included our critical statements, such as our Vision and our Mission. While our Vision remains valid, we agreed that part of our Mission has changed because we are now much more of a resource than a training association. It actually resulted in the removal of the word "training" from our Mission statement and replacing it with "resource."

Not long ago, it was common for some of our members

to proclaim in committee meetings that we are not meant to be a "how-to" association. Although that was an expressed opinion, there have always been a variety of viewpoints. Considering our achievements as an Association over the past few years, you would have to agree that we have become not only a resource for our industry but also the leading resource for our industry.

We must lead. To provide true value to specifying authorities, to have the shotcrete process seriously considered head-to-head against common options such as form and pump/pour, or ground support in mining and tunneling, we must offer credible resources from all perspectives. These resources—of value to our members, and indeed the entire shotcrete industry—include safety, inspection, certification, and qualification, as well as recognizing and promoting numerous examples of successful projects.

We analyzed our accomplished objectives to date and reprioritized those not yet completed. We were conscious to stay true to our four key categories: professional development, credibility, outreach, and organizational strength.

As the day played out, a few things became abundantly clear. Regardless of category or committee description, our focus needed to be placed on our four largest remaining



goals: the completion of our Inspector Education Program, our Contractor Qualification Program, and our new Safety and Underground Presentations. We also changed numerous past and present goals into annual objectives, agreeing that what they were providing needed to become part of our continuous plan.

A quick update based on the Farmington Hills meetings: we are very close to rolling out both the Inspector Education and Contractor Qualification Programs. The Inspector

Education Program will be piloted twice over the summer to large US DOTs and is expected to be available on a continent-wide scale by this fall. The Contractor Qualification Program has passed ballot, some finishing touches are being worked on, and it also is expected to be available at a site yet to be determined this fall. The Safety Presentation will be unveiled at our summer Board meeting and the Underground Presentation is complete. Thank you to the many members who have participated in the completion of these enormous objectives! Each of them took numerous hours, often, unfortunately, by a select few, but will undoubtedly help to raise the credibility of not only our Association but our industry as well.

The one new goal that came out of Farmington Hills was based on a statement made back in Las Vegas, NV, at our Outstanding Shotcrete Project Awards Banquet. Next year, 2018, is going to be ASA's 20th Anniversary as an association. A task group was formed to consider ideas to acknowledge the achievement. The result is a move away from our annual World of Concrete Awards banquet to a 3-day Shotcrete Convention to be held March 11-13, 2018, at the Silverado Resort and Spa in Napa, CA. While the specifics will be discussed over the next few weeks, the preliminary program ideas being considered include an early arriver's social program on Sunday consisting of a potential golf outing, to non-ASA events such as the Napa Valley Wine Train or Wine Cave Tour. We would also host our new Contractor Qualification Program that day. Monday would include our Spring Committee and Board meetings and would be followed by a dinner. Tuesday's program would offer state-of-the-art

shotcrete technology seminars followed that evening by our Outstanding Shotcrete Project Awards Banquet at the famous Inglenook Winery & Wine Caves, founded in 1879.

This is a bold new step for ASA. We will celebrate not only the success of our Association to date but also the numerous accomplishments we've realized as an industry over the past 20 years. Mark your calendars for March 11-13, 2018, and watch ASA correspondence for further details of the convention to be available in the coming weeks.

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D. COMMITTEE CHAIR MEMO

ASA Underground Committee

The Underground Committee has developed a new seminar for underground shotcrete

By Axel Nitschke



"Shotcrete, the method of spraying concrete onto a surface, is ideally suited for the support and construction of underground excavations in earth and rock structures. The pneumatic projection of shotcrete onto a surface at high velocity provides specific quality enhancements that interact with the ground surface and

prepared substrates, providing superior bond characteristics; increased density; and resultant strength, durability, and toughness."

"Underground construction and shotcrete application are unique and very demanding. The primary focus is worker safety and the need to provide immediate and effective ground support."

"Early 8-hour to 1-day strength is critical to the performance of underground shotcrete. Much of the shotcrete is applied overhead to irregular tunnel profiles immediately following blasting or other modes of excavation."

"The use of accelerating admixtures is a unique feature of underground shotcrete application in that it provides a means of controlled and rapid strength gain immediately following application."

"The systems of batching and handling of shotcrete materials admixture, and placing equipment require experienced supervisory shotcrete and production personnel."

"Quality assurance, quality control, and the associated inspection and testing activities are equally important in achieving a successful shotcrete program."

The aforementioned quotes are from the Introduction and Scope chapter of ACI 506.5R-09, "Guide for Specifying Underground Shotcrete." I spend most of my professional career in conventional tunneling, primarily in soft ground or weak hard rock, where shotcrete is the key support element for what tunnel builders call "ground support" and miners call "ground control." I like the term "ground control" a lot because, if done properly, shotcrete gives you a key tool to "control" the ground.

It is important to realize that immediately after the excavation of a new round of tunnel—especially in soft ground or weak hard rock—the ground conditions deteriorate over time to a varying degree. This fact was labeled by our predecessors as "stand-up time." "Stand-up time" is still widely used by tunnel builders and miners as a qualitative and descriptive assessment of the ground conditions, which defines the time span after the excavation until the tunnel would eventually become unstable if unsupported and would eventually collapse. Stand-up time also gives you guidance about the timeframe that allows the miner to safely install the required support measures.

Shotcrete is one key support element to arrest the deterioration and significantly improve the actual stand-up time by sealing the ground surface and providing temporary and/ or final support in combination with or without other support measures. Therefore, proper knowledge and experience about shotcrete at all project levels is essential for underground applications.

The ASA Underground Committee is a diverse group of contractors, engineers, and suppliers centered on the use of shotcrete in tunneling and mining. The mission of the Underground Committee is "to educate and promote the use and proper application of shotcrete to the underground construction and mining industry."

In October 2015, the Underground Committee committed to two objectives to achieve this goal:

- Develop a PowerPoint presentation to "promote and educate" the use of shotcrete based on ACI 506.5R, "Guide for Specifying Underground Shotcrete."
- 2. Present at seminars, by webinars, at conferences (WOC, SME) or to specific clients (DOTs, government agencies, contractors, A/E companies).

During the last 1-1/2 years, the committee has worked on the development of the presentation. The presentation includes contributions of numerous members of the committee and was reviewed, finalized, and balloted within the Underground Committee in March 2017. Beginning April 2017, the presentation was balloted by the ASA Board of Direction and was accepted without comments on May 3, 2017. This date is important for the Underground Committee twofold: it marks the completion of the first objective but, more importantly, it provides the Underground Committee with a product and tool to reach out into the industry to present at seminars, by webinars, and at conferences or to specific clients to work on the committee's second objective.

The purpose of the presentation is to act as a door opener to professionals who have no or limited experience with shotcrete, but are tasked to specify, design, inspect, or accept shotcrete for an underground application. The official course description and learning objectives of the seminar titled "Shotcrete for Underground Applications – An Introduction to ACI 506.5R-09 Guide for Specifying Underground Shotcrete" reads as follows:

COURSE DESCRIPTION

The course will provide engineers, architects, and specifiers with an introduction and basic understanding of the shotcrete process for placing concrete in a wide variety of underground applications. Using ACI 506.5R-09, "Guide for Specifying Underground Shotcrete" as a guidance document, the course touches the process itself, typical underground applications, materials, anchorage and reinforcement, mixture proportioning, performance requirements, QA/QC, submittals, preconstruction trials and testing, construction acceptance, inspection, batching/mixing and supply, placing equipment, preparation, curing and protection, repair and rehabilitation, safety, and measurement and payment.

LEARNING OBJECTIVES

The objective of the course is to provide an introduction and basic knowledge on how to specify, inspect, and accept shotcrete for underground applications.

At the end of the course, participants will be able to:

- 1. Understand the basic process for both wet- and dry-mix shotcrete in underground applications;
- 2. Understand the typical uses and advantages of the shotcrete process;
- Understand the critical issues to be addressed in a shotcrete project specification; and
- 4. Understand how to inspect and accept shotcrete in the field.

The Underground Committee is ready to reach out and present. If you are new to shotcrete and tasked with the use of shotcrete in an underground application, please do not hesitate to contact ASA (info@shotcrete.org or 248-848-3780) to arrange for a presentation to your team. The presentations are in person or via webinar, free of charge, and participants will receive Professional Development Hour (PDH) credits.

If you are interested in joining the ASA Underground Committee, please contact us. We are always interested in bringing experienced underground practitioners into our committee to broaden our experience and breadth of interest in all things related to underground shotcrete work.

ASA Underground Committee

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D. EXECUTIVE DIRECTOR UPDATE

Moving Forward...New Programs and Events Rolling Out

By Charles Hanskat, PE, FACI, FASCE, ASA Executive Director



First, I note with sadness that one of our founding members, Russ Ringler, passed away in May. Though I only met Russ at a couple of ASA meetings over the years, his knowledge and dedication to the shotcrete industry and ASA was obvious. He will be missed...by family, by friends, by co-workers, by ASA members past and

present, and our shotcrete industry. We've printed a short memorial to Russ in the Association News section, with some remembrances from members who worked closely with him.

It's unfortunate that as our Association matures and grows, we lose those who brought us together back in 1998. As we look forward to celebrating our 20th anniversary and the progress we've made as an association and an industry, we must not forget those we've lost and on whose shoulders we now stand.

ASA 20TH ANNIVERSARY EVENT AND SHOTCRETE CONVENTION— MARCH 11 TO 13, 2018

The ASA Board decided to hold ASA's first full Shotcrete Convention in March next year. This will be a unique networking and learning opportunity, culminating with our Annual Outstanding Shotcrete Projects Awards Banquet! With ASA's laser focus on the shotcrete industry, we bring together exhibitors and speakers that exemplify the stateof-the-art in shotcrete today, hosted in a format and venue that provides plenty of time for interaction with the leaders and decision makers in the shotcrete business. This 3-day ASA Shotcrete Convention includes our Annual Awards Banquet, Spring Committee meetings, an ASA Contractor Qualification seminar, and a day of Shotcrete Technical and Project Presentations to give you insights into the leading edge of shotcrete technology, both for today and the future. To round out the convention, we have a number of fun and exciting activities planned, taking advantage of the unique experiences that California's Napa Valley and the Silverado Resort and Spa lend to the destination.

Featured events:

- Full-day ASA Contractor Qualification Seminar;
- Full-day of Shotcrete Technology and Application Presentations;

- ASA Spring Committee Meetings (replacing meetings at The ACI Concrete Convention and Exposition – Spring 2018);
- Tabletop Exhibits;
- First ASA Golf Outing at one of Silverado's championship golf courses included in the PGA Tour;
- The ASA Annual Outstanding Shotcrete Projects Awards Banquet at nearby Inglenook Winery & Wine Caves (replacing the banquet at World of Concrete 2018); and
- Optional wine tours, spouse programs, and other resort offerings.

ASA SHOTCRETE INSPECTOR EDUCATION PROGRAM ROLLOUT

The Board has reviewed and approved the final version of the ASA Shotcrete Inspector full-day Education Seminar. We will be presenting the seminar to two state Department of Transportation (DOT) groups on a trial basis for feedback from the inspection community. The program was developed due to the strong growth of shotcrete construction and the resultant need for knowledgeable on-site inspectors. Contractors and specifiers are frequently challenged as building officials or inspectors may lack sufficient insight on acceptable placement procedures or shotcrete industry reference standards. Although an inspector may be thoroughly experienced in the inspection of form-and-pour concrete, it is necessary to have an understanding of the specific elements of shotcreting, the equipment used, terminology, and required procedures when using the shotcrete process.

Our program covers critical elements of shotcrete placement that on-site inspectors must know to properly evaluate and sign-off on acceptance documents, including an overview on materials, placement technique, finishing, curing, testing, equipment and safety as it relates to the building official or inspector. Upon completion of the course, the Inspectors should have:

- A fundamental understanding of the wet- and dry-mix shotcrete process;
- Current knowledge of ACI reference material and other industry standards pertaining to acceptable shotcrete placement;
- Industry-specific knowledge to determine if materials and methods used by the crew meet shotcrete project specifications; and

 Sufficient insight to recognize satisfactory application techniques, and actions which will lead to a poor-quality product.

We expect various types of individuals will want to attend this course, including Concrete Construction Inspectors; Transportation Construction Inspectors; ACI Concrete Field Testing Technicians—Grade I; ACI Special Inspectors; Engineers or Specifiers who desire or are required to possess additional education to properly inspect shotcrete operations on projects; and Building Officials who desire further knowledge of acceptable shotcrete placement methods.

In future education seminars where a fee is charged, we will include copies of ACI 506.2-13, "Specification for Shotcrete," and ACI 506R-16, "Guide to Shotcrete," and shotcrete-related ASTM specifications with the session registration fee. We should also note that ACI is working on an ACI Shotcrete Inspector certification that will use the completion of our ASA education session as a method for demonstrating experience in shotcrete inspection.

ASA CONTRACTOR QUALIFICATION PROGRAM

The Board has reviewed and approved a 1-day seminar that will be a prerequisite for shotcrete contractors seeking

qualification by ASA. The Contractor Qualification Committee is close to finishing a written exam that will be administered after taking the seminar to demonstrate the individual attendee's knowledge of shotcrete contracting.

Once the exam is completed, we will be conducting a regional session of two with member companies to gather feedback and refine the final product. We anticipate a public rollout by our 20th Anniversary event in March 2018.

ASA COMMITTEE MEETINGS IN ANAHEIM, CA, OCTOBER 14, 2017

Finally, a reminder that our ASA committees and Board will meet on the Saturday before The ACI Concrete Convention and Exposition – Fall 2017 at the Disneyland Hotel and Conference Center. Anyone interested in shotcrete is welcome to attend, though voting members of the committees must be either corporate or individual members of ASA. Check the Shotcrete Calendar on page 70 for the committees and their meeting times and rooms.



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Aiming for Extended Service Life with Migrating Corrosion Inhibitors

By Ray Schallom III, Jessi Meyer, and Julie Holmquist

orrosion of embedded steel reinforcement is a threat to all types of reinforced concrete, leading to cracking, spalling, and a shortened service life of the structure. While the pH of new concrete initially protects embedded steel reinforcement by creating a natural passive oxide layer, it inevitably gives way to the effects of carbonation, chloride exposure, and acid rain or other industrial pollutants. The corrosion process initiates, followed by deterioration that challenges the durability and safety of structures.

A variety of technologies have been developed to counteract this process, ranging from corrosion-inhibiting admixtures to cathodic protection (CP). Calcium nitrite (CNI), an older admixture technology, is effective against chloride-induced corrosion, but has disadvantages in that its dosage rate is variable depending on expected exposure to chlorides (the more chloride exposure, the higher the dosage rate). As dosage rates increase, so do CNI's adverse effects on the physical properties of concrete, such as dramatically increased shrinkage and accelerated setting time. CP technologies require reinforcement to be continuous and involve installation of many embedded galvanic anodes, or application of an impressed current, which must be continuously monitored.

MIGRATING CORROSION INHIBITOR TECHNOLOGY

Migrating corrosion inhibitors, which are based on organic amine alcohol and amine carboxylate technology, offer



Fig. 1: Illustration of amine alcohol inhibitor, where R1, 2, 3 is H or alkyl group OH tail end group

Fig. 2: Illustration of amine carboxylate inhibitor, where R1, 2, 3 is H or alkyl group OH tail end group many advantages for extending the service life of concrete structures. They have a set dosage rate, which is five to 30 times lower than that of CNI, and generally have no effect on the physical properties of concrete (strength, shrinkage, and freezing and thawing). Some versions can delay setting time, whereas others are normal set.

Migrating corrosion inhibitors are available in both liquid and powder formulations for ease of application, and are also available as topical treatments for existing structures. When added to the concrete mixture, they are dispersed through the mixing process but also have the ability to migrate through concrete pores by capillary action and vapor diffusion. They travel randomly from areas of high concentration to areas of low concentration, according to Fick's Second Law, until they come into contact with embedded reinforcement.

Migrating corrosion inhibitors are considered mixed corrosion inhibitors, meaning they provide protection to both anodic and cathodic areas. They are attracted to embedded metals and adsorb onto them. Figures 1 and 2 demonstrate the chemistry of amine alcohols and amine carboxylates on the metal surface. This chemistry allows migrating inhibitors to form a tenacious bond that protects the metal from interacting with corrosive elements at both the anode and cathode of a corrosion cell. This protective layer also keeps the pH at the reinforcing bar surface at an optimal level for inhibiting corrosion and reduces existing corrosion rates.¹

ADVANTAGES OF MIGRATING CORROSION INHIBITORS

Migrating corrosion inhibitor technology has many advantages in terms of effectiveness and user friendliness. As an admixture, migrating corrosion inhibitors can be readily added to shotcrete or other concrete mixtures at a relatively small dosage rate compared to other admixtures (1 to 1.5 pints/yd³ [0.6 to 1 L/m³] for liquids, 1 lb/yd³ [0.6 kg/m³] for powders). They do not negatively affect concrete properties, and they meet ASTM C1582/C1582M² requirements such as flexural strength, compressive strength, setting time, and freezing-and-thawing durability.³ Migrating corrosion inhibitors are nonhazardous and environmentally friendly and include bio-based options made from by-products of corn. The latest generation amine-carboxylate-based migrating corrosion-inhibiting admixtures have been certified to meet ANSI/NSF 61 requirements for safe use in structures containing potable water. Recent testing indicates that certain migrating corrosion inhibitor technologies are also compatible with CP systems, in some cases reducing the current requirement.⁴

CORROSION-INHIBITING PERFORMANCE

The use of migrating corrosion inhibitor admixtures can double or triple the time to corrosion initiation and, once corrosion starts, reduce corrosion rates by five to 15 times compared to a control.¹ Compared to other admixtures, such as CNI or amine esters, they do exceptionally well under modified ASTM G109 testing (refer to Fig. 3). This testing introduces cracks into the concrete test specimens, making it easier for corrosive elements to reach the surface of the reinforcing bar. In one example of this, corrosion rates for samples treated with a migrating corrosion inhibitor admixture stayed significantly lower than those of CNI and amine-ester treated concrete during 20 cycles of saltwater ponding.⁵

USES OF MIGRATING CORROSION INHIBITOR IN SHOTCRETE

Migrating corrosion inhibitor technology has more than 30 years of historical use in reinforced concrete, and more than 15 years of use with shotcrete applications. As far back as 2001, a repair project using migrating corrosion inhibitors won an ICRI Award of Excellence for the Transportation category. The project involved repairing the Crib Point Jetty in Western Port Bay, Victoria, Australia. The jetty had experienced substantial spalling, cracking, and degradation caused by corrosion in the harsh concrete environment. The degraded concrete and steel reinforcement was removed from any of the deteriorating concrete piers and beams, and new reinforcement was added as needed. The repair was completed by applying shotcrete repair mortar that contained migrating corrosion inhibitors to reduce further corrosion in the structure.⁶

Tunnels and Bridges

In the state of Pennsylvania, District 11 has used a migrating corrosion inhibitor in its wet- and dry-mix shotcrete for over 8 years. In patched areas, PENN DOT has included an anode system for extra protection. One of these projects was the repair of the Liberty Tunnel in Pittsburgh (refer to Fig. 4 and 5). Teams removed the surface layer of damaged concrete and then shotcreted the replacement concrete containing migrating corrosion inhibitors. This helps protect against the insipient ring anode effect, where the addition of new concrete can counter and productively encourage the spread of corrosion to adjacent concrete.

District 11 also used shotcrete with a migrating corrosion inhibiting admixture on some of the supports of the Rankin Bridge in Pittsburgh. The crew repaired damaged areas with shotcrete and applied a finish coat to the entire



Fig. 3: A normal set version (version used with shotcrete) of an amine carboxylate migrating corrosion inhibitor admixture (ACCI) showed significantly higher corrosion protection under modified ASTM G109 cracked beam testing, an accelerated but more intense version of ASTM G109 saltwater ponding Image courtesy of Cortec Corporation



Fig. 4: Liberty Tunnel before repair Photo by Dennis Bittner



Fig. 5: Liberty Tunnel finished section Photo by Dennis Bittner



Fig. 6: Rankin Bridge pier repairs Photo by Dennis Bittner



Fig. 7: Finished Rankin Bridge pier repair Photo by Dennis Bittner

piling structure (refer to Fig. 6 and 7). Work on both projects was completed by Mosites Construction Co., Pittsburgh, PA.

Amusement Park Volcano

Kings Dominion amusement park in Doswell, VA, has a volcano that was constructed over 40 years ago, using 0.375 in. (10 mm) reinforcement and plaster lath, with 2 in. (50 mm) thick low-velocity sand and cement. The structure held up quite well until the last ride was built in and around the 100 ft (30 m) high volcano shell. This left holes where the pipe supports holding the track for the ride were placed. Special rubber boots were installed around the pipes before the placing of the new high-strength, silica fume shot-crete. However, freezing-and-thawing conditions triggered condensation around the supports, causing some of the steel reinforcement to rust.

The areas marked for repair (refer to Fig. 8 through 10) require a 0.375 in. (10 mm) V-groove stay-in-place form, No. 3 (No. 10M) bar reinforcement spaced at 12 in. (300 mm)



Fig. 8: The Kings Dominion amusement park volcano was divided into eight work zones for budgeting Photo by Ray Schallom



Fig. 9: The 0.375 in. (9.5 mm) V-shape lath, the rubber boot around the pipe support, and reinforcement to be encased into the silica-fume shotcrete Photo by Ray Schallom

on center, and 2 in. (50 mm) thick high-strength, silica fume concrete mixture with a migrating corrosion inhibitor for corrosion control. Staining (for aesthetic purposes) and waterproofing are applied once the strength requirement is met. The entire work zone is covered and heated during repairs, which can only be conducted from October 31 to March 15 while the park is closed for the season. The scaffolding and protection is removed prior to the park's opening day.



Fig. 10: Volcano Zone 2 repair was quite extensive Photo by Ray Schallom

The project specification called for one or two migrating corrosion inhibitors to be added to the shotcrete, depending on whether a dry, bagged mix or a ready mixed product was used. When the winning contractor, Cemrock, chose the wet-mix process, its ready mix supplier chose a CNI-based corrosion inhibiting admixture that prevented the hard-ened shotcrete from reaching the specified strength. Once the ready mix producer removed the CNI from the design mixture and began adding an amine-carboxylate-based migrating corrosion inhibitor into the mixture at 1.5 pints/yd (0.62 L/m³), the strength requirement started to be met on every load.

In Fig. 11, the new lightly stained repaired zones and the old dark weathered zones yet to be repaired and stained are visible. Money budgeted annually includes the scaffolding erection and dismantling, the plastic protection, and the heating of the repaired areas as shown in Fig. 12. All work begins October 31 and must be cleaned up by March 15. This is an ongoing project until completed (Fig. 13).

JC Century Building

The JC Century Building in Binghamton, NY, is undergoing a mass renovation and repurposing to convert an old factory into an apartment complex. The architect has specified that the repairs to the structure must maintain the old construction appearance, such as exposed brick, arched concrete ceilings that look like they have been plastered, and new windows with the same look as the old factory windows. It was determined early on that hand-applying



Fig. 11: Arial view of the finished stained Kings Dominion amusement park mountain in Zone 2 and Zone 3 2016-2017 season photo by Chris Alburger



Fig. 12: Scaffold and the plastic protection over the mountain areas to be repaired Photo by Ray Schallom



Fig. 13: Volcano finished stained area in Zone 3 Photo by Jeff Reichart



Fig. 14: JC Century Building: typical ceiling before prep work began Photo by Rick Conrow

overhead concrete repair materials would be too costly, and be difficult to consistently assure good bond to the existing surface. The delaminated concrete surface in the ceiling was removed. The exposed surface was then sandblasted and high-pressure water blasted before reinforcing mesh was installed. The Shotcrete MS[®] wet-mix product was chosen



Fig. 15: Before picture of the arch ceilings Photo by Rick Conrow

supplemented by a liquid amine-carboxylate-based migrating corrosion inhibitor from Cortec. The thin repair was finished to look like textured plaster (refer to Fig. 14 through 16). The migrating corrosion inhibitor was chosen to give the existing steel additional corrosion protection given the thin layer application. The property is owned by the Regan





Fig. 16: Shows a completed section that needed to look like the original old structure Photo by Rick Conrow

Development Company and the shotcrete contractor was KHM INC. of Binghamton, NY.

CONCLUSIONS

Migrating corrosion inhibitor technology has been an important discovery in the protection of reinforced concrete from corrosion. It is compatible with both form-and-pour or shotcreted concrete, increasing the convenience of applying corrosion inhibitors to specialized structures or in special repair situations. The technology includes bio-based options and offers compatibility with CP and potable water structures. Migrating corrosion inhibitors have been used in a variety of shotcrete applications and have even shown advantages for achieving required concrete strength in contrast to alternative corrosion inhibitors. Most importantly, they protect reinforced shotcrete structures from corrosion at a very low dose without affecting important concrete properties such as strength and freezing-and-thawing durability.

References

1. Miksic, B.A., *Improving Durability of Infrastructure with Migratory Corrosion Inhibitors (MCI®) Handbook*, Cortec Corporation, Saint Paul, MN, 2014, pp. 7-8, 10.

2. ASTM C1582/C1582M, "Standard Specification for Admixtures to Inhibit Chloride-Induced Corrosion of Reinforcing Steel in Concrete," ASTM International, West Conshohocken, PA.

3. Schaefer, G., "Admixture to Inhibit Chloride-Induced Corrosion of Reinforcing Steel in Concrete (ASTM C1582) Concrete Properties Testing Final Report," *TCG # 09145*, Tourney Consulting Group, Kalamazoo, MI, Feb. 8, 2011.

4. Abed, K.; Nagi, M.; Meyer, J.; and Pynn, C., "Evaluation of Interactions between Cathodic Protection and Corrosion," Presentation at NACE Concrete Service Life Extension Conference, New York City, NY, June 27-29, 2017.

5. American Engineering Testing, Inc., "Report of Concrete Corrosion Inhibitor Testing," Aug. 13, 2003, 10 pp.

6. MBT Australia Pty Limited, "Repair of Crib Point Jetty," ICRI 2001 Project Award Winner, International Concrete Repair Institute, St. Paul, MN, https://icri. site-ym.com/?AOE01_CribPointJetty. (last accessed July 3, 2017)



Ray Schallom III is a shotcrete application specialist and President of RCS Consulting & Construction Co. Inc. He has 40 years of experience as a Project Manager, Owner, and Superintendent. Schallom works with state DOT departments on their shotcrete specifications and trains engineering company inspectors in the field of shot-

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Shotcrete Guide to Shotcrete Now Available

The American Concrete Institute announces a new ACI 506R-16, "Guide to Shotcrete," has been published and is now available. The guide serves as a companion document to the mandatory language in ACI 506.2, "Specification for Shotcrete." Additional industry-leading education and certification programs are available from the American Concrete Institute and American Shotcrete Association.

New Specification for Shotcrete Webinar.



A webinar explaining changes in ACI 506R and how it serves as a companion document to ACI 506.2 "Specification for Shotcrete," is available as an ACI On-Demand Course. More details available at www.ACIUniversity.com/webinars.



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Bridge and Highway Repairs Using Shotcrete and Cathodic Protection

By Dennis Bittner and Erik Bertrand

t was once believed that microsilica-enhanced shotcretes could not be used with cathodic protection. This belief centered on the argument that shotcrete was too dense and lacked the necessary permeability to be compatible with cathodic protection. The concern was that the density of the shotcrete inhibited proper flow of current, thus preventing the anodes from properly functioning. However, new techniques are being developed to allow the benefits of cathodic protection and shotcrete to work together.

To understand the issues with using low-permeability materials and cathodic protection together, it is helpful to understand how permeability is tested and what those results mean. Permeability is often tested using ASTM C1202, "Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration." This test method determines the electrical conductance of concrete, thus giving an indication of the concrete's resistance to penetration by chloride ions. Basically, electrical current is monitored as it passes through 2 in. (50 mm) slices of 4 in. (100 mm) concrete cores. The greater the density of the material being tested, the greater the material inhibits electrical current flow. This method of testing measures conductivity of the sample material in coulombs and provides a correlation with permeability. A highly conductive sample material is determined to be highly permeable and low conductivity implies a lower permeability. Microsilica-enhanced shotcretes have very low conductivity and thus very low permeability, with conductivity measures often below 500 coulombs. Historically, a cathodic protection system using anodes would require the surrounding cementitious material to have a significantly higher conductivity in the 1500 coulomb range.

Several techniques have been developed to overcome these conductivity issues, thus allowing the two systems to work together. First, it was determined that encapsulating the anode in a less dense, more conductive material, such as non-shrink grout prior to application of the shotcrete would minimize the adverse effects the shotcrete has on the anode. Non-shrink grout is used to "pancake" the anode, surrounding it with a material that does not interfere with the anode's ability to work correctly. Another technique developed was to redesign the anode shape so that it could



Cathodic protection is now offered in various shapes and sizes, some of which are more conducive to shotcrete application

be better positioned within the concrete repair to protect it from shotcrete material applied under high pressures. This redesigned shape also makes it possible to increase the number of anodes within the concrete repair.

Using these new techniques, there have been multiple projects where microsilica-enhanced shotcrete has been used with cathodic protection systems. All of the projects highlighted as follows were performed in Western Pennsylvania by Mosites Construction Company, based in Pittsburgh, PA.

NEW YORK AVENUE BRIDGE

This project involved the rehabilitation of a PENNDOT-owned 700 ft (210 m) long precast concrete I-beam ramp bridge carrying New York Avenue over Norfolk-Southern Railroad tracks and Harrison Street in Rochester, PA. The work included the rehabilitation of existing reinforced concrete piers using Quikrete Shotcrete MS with fibers, dry-process shotcrete placement, and incorporated cathodic protection (anodes) in the concrete repair patches. Vector Galvashield[®] anodes were encapsulated in non-shrink grout and shotcrete



Repairs have been completed and the piers are ready for installation of the superstructure and deck in Rochester, PA



Multiple bridge piers were repaired using shotcrete with cathodic protection

was then placed over the anodes. In total, 250 ft³ (7 m³) of repairs were made. This project originally mandated formand-pour concrete repairs, but Mosites Construction was able to show PENNDOT substantial savings by performing the concrete repairs with shotcrete and incorporating the cathodic protection as an additional means of corrosion protection. The pier repairs were part of a larger project lasting from September 2011 to December 2013.

CAMPBELLS RUN ROAD BRIDGE, SR 376

Repairs were performed to rehabilitate substantial deterioration to the concrete substructure of this PENNDOTowned 120 ft (37 m) long steel I-beam bridge carrying I-376 over Campbells Run Road in Pittsburgh, PA. The work was performed using Quikrete Shotcrete MS with fibers and dry-process shotcrete placement. In addition to the shotcrete, Vector Galvashield anodes encapsulated in non-shrink grout were used in the concrete repair patches. In total, 650 ft³ (17 m³) of repairs were placed between March 2011 and December 2011. Once again, the project originally mandated form-and-pour concrete repairs but Mosites Construction was able to show PENNDOT substantial savings by converting the repair to shotcrete with the added use of cathodic protection.

HOMEVILLE VIADUCT REHABILITATION

This project involved the rehabilitation of an Allegheny County Department of Public Works-owned 800 ft (240 m)



Material being pre-dampened and gunned onto a cap beam on a bridge in West Mifflin, PA

long combination steel I-beam and steel underdeck truss bridge carrying Homeville Road over Lower Bull Run Road,



Material being cut and finished to match the original shape and profile of the pier



Grant Avenue Extension, and Union Railroad Company tracks in West Mifflin, PA. The project took place from August 2015 to November 2016. Work included the repair of existing reinforced concrete abutments and piers using Quikrete Shotcrete MS with fibers and dry-process shotcrete. Euclid Sentinel anodes were installed in the repair areas. In total, there were 1500 ft³ (42 m³) of repairs. No nonshrink grout encapsulation of the anodes was necessary on this project.

In summary, with modern approaches, we can use shotcrete and cathodic protection together. Cathodic protection is a method of corrosion protection that is rapidly gaining popularity. At the same time, the shotcrete method is also experiencing rapid growth in popularity both in new construction and as a concrete repair method. Because of this parallel growth, opportunities to use the two systems together have increased and new, innovative techniques are being developed. Some of these techniques include the installation methods mentioned previously. Additionally, there are manufactured anodes on the market in shapes and sizes more conducive to shotcrete applications. These refined designs help the anode withstand the impact of the material and prevent voids from forming behind the anode. When combined, the end result is a high-quality concrete repair with the added benefit of increased corrosion protection. If you want to use both shotcrete and cathodic protection together, talk to the anode manufacturer as well as the shotcrete supplier. By working with both, you will be able to find the best way to successfully complete your project.



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Overcoming Existing Corrosion When Using Shotcrete for Repair

By Rachel Stiffler

or over 100 years, shotcrete has been used in a variety of new construction applications, but one of its major uses is in repair, rehabilitation, and repurposing. The shotcrete repair process is increasing in use, both for transportation and building applications. It is ideal for repairing both vertical and overhead surfaces at most thicknesses.

On many rehabilitation projects, there are challenges with corrosion of the existing reinforcing steel. Once the existing concrete has been removed, we can easily evaluate the condition of the reinforcement. The corrosion of the steel has usually been caused by penetration of chlorides into the concrete. When sufficient chloride reaches the reinforcement—typically 0.03% by weight of concrete in non-carbonated concrete—the natural protection of the steel created in the highly alkaline environment of the concrete becomes compromised and corrosion begins.

The iron oxide (rust), created from the expansion of the reinforcement, once corrosion begins, occupies a greater volume than the steel itself, thus causing cracking that can lead to delamination and spalling of the concrete.

When these concrete structures are repaired, the original concrete material remaining is contaminated with residual chloride. When the repair concrete is placed, there is an electrochemical incompatibility that occurs between the new and existing concrete. When this incompatibility is present, new corrosion sites will begin to appear.

The electrical potential of the reinforcing steel within the existing contaminated concrete becomes more electronega-

tive, shifting current to the repaired area. When this happens, concrete deterioration is noticeable in the parent concrete a short time after the repairs are completed.

This is commonly referred to as the "halo effect," "patch accelerated corrosion," or the "ring anode effect" (refer to Fig. 1). Galvanic zinc-based anodes are used to prevent this from occurring. These anodes can be tied onto the reinforcing steel around the perimeter of the patch areas, or on a grid pattern (refer to Fig. 2).

As the anode is connected directly to the cleaned reinforcing steel, the generated current protects the steel. This prevention or control of corrosion is effective within the area defined by the spacing of the anodes.

A good reference for anode installation is the American Concrete Institute's RAP-8 Bulletin, "Installation of Embedded Galvanic Anodes" (reprinted in this issue on page 37). It is available in PDF format as a free download from ACI (www.concrete.org). This guideline references installation guidelines and anode nomenclature. The nomenclature refers to a Type 1 anode as being attached and embedded inside the patch area while Type 2 anodes are placed into holes drilled into sound areas. Occasionally, the Type 2 anodes are used in a shotcrete application (refer to Fig. 3). This application is preferred when the concrete cannot be completely removed to expose all reinforcing steel, either for structural reasons or due to very little concrete cover. This is also a proactive approach of anode use when the concrete has not delaminated or spalled, but the testing shows



Fig.1: Example of the halo effect or ring anode effect



Fig.2: Anodes placed on a grid pattern

chloride penetration has occurred. By using both the Type 1 within the patch areas and the Type 2 in the parent concrete, you have provided global protection for your structure.

Anodes work by corroding preferentially to the reinforcing steel. The anode is electrically connected to the reinforcing steel and provides a protective current through that connection. To do that properly, the anode needs to be placed at a spacing that provides the needed amount of current necessary to adequately protect the steel.

The needed information for spacing requirements are reinforcing bar size, density, and steel distribution. Chloride content in the existing concrete is also very useful.

Once the needed information is considered, the spacing can be calculated using this formula:

Surface area of steel/surface area of concrete = steel density ratio

With the higher resistivity of shotcrete material, anode spacing is important. Shotcrete (both wet- and dry-mix) inherently has higher resistivity than most form-and-pour concrete due to higher cement contents, often using microsilica or fly ash supplemental cementitious materials and a lower water-cementitious materials ratio (*w/cm*). Thus, these shotcrete-specific mixture designs will slow the migration of chlorides along with increasing the resistivity of the mixture.

The normal recommendation is to have a resistivity of less than 5900 ohm-in. (15,000 ohm-cm). This allows sufficient protective current to flow from anode to steel. This number also relates to approximately 1500 coulombs using the Rapid Chloride Permeability testing (ASTM C1202). If the concrete mixture used will have a higher than 5900 ohm-in. (15,000 ohm-cm) resistivity, it is suggested to use a bridging or embedding mortar. The conductive bridge is then created with this mortar between the anode and the parent concrete. This also prevents the risk of shadowing or voids behind the anode, as shotcrete may have difficulty wrapping around the backside of the anode. You may use this bridging mortar even with a lower resistivity concrete to help prevent shadowing.

The decision for using a bridging mortar is based on several factors:

- What is resistivity of the parent concrete?
- Should more anodes be used to generate more current for a higher resistivity mixture?

- · How close can the anodes be placed to the patch edge?
- Can the anodes be tied on the steel well enough to not be damaged by the shotcrete application or to prevent shadowing?

Once these questions are reviewed and answered, the decision to use the bridging mortar can be made.

There are several anode sizes available today. So, once the steel density ratio is calculated, the decision can be made for proper anode size and zinc content use.

In summary, the use of embedded galvanic anodes in shotcrete repairs gives an additional level of protection from future corrosion. Use of shotcrete in conjunction with this type of cathodic protection is being used on a more regular basis, as more owners and specifiers realize the savings and long-term performance produced with this type of repair process.



Rachel Stiffler received her BS in biology and chemistry from California University of Pennsylvania, California, PA. She is currently the Business Development Manager for Vector Corrosion Technologies. Stiffler has been with Vector for almost 12 years and has 30-plus years of experience in the concrete industry. She is

responsible for business development for the northeastern United States, working closely with DOT agencies, structural and civil engineering firms, owners, and university groups introducing corrosion mitigation concepts for reinforced concrete structures. Stiffler's professional affiliations consist of being a cathodic protection tester certified by the National Association of Corrosion Engineers. She is a member of the International Concrete Repair Institute, greatly involved both locally in the Pittsburgh Chapter and the national organization. She is also involved with the American Concrete Institute, and currently most actively involved as a member of the executive committee of the International Bridge Conference, having been General Chairman in 2015.



Fig.3: Type 2 anodes are placed in series into drilled in holes in the existing concrete prior to shotcrete application



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What's Happening in There?

Part 1: Critical elements that dramatically affect shotcrete's hardened properties occur hidden from sight within the nozzle stream

By Oscar Duckworth



Can the skill of the nozzleman be a factor in diminishing or even eliminating rebound? The answer may surprise you

s this much rebound normal? Bet you've heard that comment before. How much rebound is normal? Rebound and its effects can be a hot topic for not only nozzlemen and crews but also engineers and inspectors, all whose goal is to produce a quality job.

Can the skill of the nozzleman diminish rebound? Rebound is aggregate that, due to impact at high velocity, ricochets off the receiving surface or other hard objects and falls onto lower surfaces. Its control during shotcrete placement will strongly influence both the amount of costly wasted material, and the quality and durability of the in-place work. Unfortunately, rebound is an unavoidable by-product of high-velocity shotcrete placement. Therefore, rebound can never be eliminated. Because rebound will always occur, obtaining a quality product is reliant on the nozzleman and shotcrete crew controlling it during placement.

There are two distinct steps to the control of rebound:

- 1. Use placement methods to diminish the formation of rebound; and
- 2. Prevent rebound from being trapped within the in-place material.

Concrete Mixtures + High-Velocity Impact = Separation

Specifications for typical form-and-pour concrete placement have prohibited plastic concrete materials from being dropped excessively for decades, and for good reason. Does concrete bruise easily? Probably not. However, because concrete is a mixture of many individual components, if materials exiting the delivery chute or placement equipment can free fall more than a few feet (meters), the mixture will gain significant velocity. Separation of the aggregates and other particles is likely to occur as the fastmoving material collides with the reinforcing steel or other surfaces at the bottom of the form. This classic problem is easily mitigated by using well-established placement methods. A pipe, belt, or hose depositing materials at or near the bottom of the form slows the materials' downward velocity; therefore, the potential for separation is eliminated.

Clearly, with shotcrete placement, rebound is a form of concrete separation caused by the concrete's velocity upon impact. Because shotcrete is placed with a high-velocity nozzle stream, the fast-moving, larger particles tend to bounce off all hard surfaces. This is the cause of rebound. Diminishing shotcrete's velocity to stop rebound is not practical because all of shotcrete's compaction and consolidation properties are derived from high-velocity impact.

WHY REBOUND MATTERS

Rebound is mainly larger aggregates with little or no encapsulating paste. It is porous and does not possess structural properties. Essentially, it is just a pile of rocks and sand. Rebound that does not fall clear of the concrete section can become unintentionally trapped by the deposition of additional shotcrete material (refer to Fig. 1). Trapped rebound results in loose, unconsolidated aggregate lenses within the in-place concrete section. Loose aggregates, rather than well-consolidated concrete encapsulating the embedded reinforcement, reduce the structural strength. If embedded areas of rebound are widespread, the concrete sections may become structurally deficient and unable to carry the design loads. Loose, entrapped rebound will also provide internal moisture paths that can reduce water tightness and accelerate corrosion of the embedded steel. Over time, with moisture flow through the trapped rebound, unsightly efflorescence deposits can build up on the surface. With poor nozzling techniques, trapped rebound can occur anywhere within shotcrete work, but corners, joints, and areas of congested steel reinforcement are especially susceptible.

Because rebound is continuously generated during shotcrete placement, rebound must be continuously controlled. Because the methods used by the placement crew to control rebound will strongly influence the structural integrity of the completed concrete section, it is the responsibility of the nozzleman and crew to use established techniques that both diminish the formation of rebound and continuously keep the receiving surfaces free of rebound during placement.

THE NOZZLEMAN'S ROLE IN DIMINISHING THE FORMATION OF REBOUND

The role of the nozzleman in preventing the detrimental effects of rebound cannot be overemphasized. It is the nozzleman's responsibility to use appropriate techniques and continuously maintain the correct slump for the project at hand. Nozzleman skill and the proper choice of slump during placement is one of the primary factors affecting the formation of rebound. Slump is a numerical value indirectly corresponding to the flow characteristics or workability of a mixture at a given moment. The nozzleman must constantly use visual indicators rather than a specific slump range to determine whether the flow characteristics of material are correct, or need to be adjusted. Although recognizing the appropriate workability for a given project through its slump value is important, it is not exact. With experience, the nozzleman should be able to more accurately maintain proper workability by visually monitoring the surface and the freshly applied materials behavior as it is applied. The nozzle stream should flow easily but not excessively around reinforcements, and produce a surface that displays a glossy and smooth outer layer, rather than a sandy or rocky surface.

A relatively smooth surface, glistening with paste, indicates that the mixture is sufficiently workable (refer to Fig. 2(a)). This surface is evidence that fast-moving aggregates within the nozzle stream have become deeply embedded within



Fig. 1: Test specimen displays loose aggregates that did not fall clear of the work and became trapped behind reinforcements



Fig. 2(a)—This freshly applied surface glistening with paste is evidence that the slump is ideal. Reinforcement bars are clean, without buildup. Fast-moving aggregates within the nozzle stream have become deeply embedded within the shotcrete surface, leaving a smooth, shiny paste layer



Fig. 2(b)—Buildup on reinforcement and a dull, sandy, or rocky surface is evidence that the material is likely too stiff. The mixture lacks fluidity and is sticking to the reinforcement. Aggregates are not embedding and have either bounced off or remain at the surface, leaving a dull, sandy, or rocky layer

the shotcrete surface, leaving a glistening, glossy paste layer. Buildup on reinforcement or a dull, sandy, or rocky surface is a red-flag indicator that the material is too stiff (refer to Fig. 2(b)). The mixture lacks fluidity and some of the

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aggregates are not embedding. Aggregates that have either bounced off or remain slightly embedded at the surface leave a dull, sandy, or rocky layer.

Rebound increases dramatically if aggregates cannot embed at impact. Do not increase the slump excessively; too high of slump will certainly create other placement problems. Nozzlemen must control rebound by using important visual indicators at the surface of the freshly applied material to continuously maintain a sufficiently workable mixture.

MIXTURE RHEOLOGY

Mixture rheology is a term used to define the physical properties of a concrete mixture in its fluid or plastic state. Mixture choices that affect rheology have a powerful effect on the rebound rate. Mixture choices such as the use of silica fume, fibers, or certain admixtures can be used to significantly reduce the rebound rate through the paste layer's ability to retain, rather than ricochet materials as impact occurs at the receiving surface.



Fig. 3—Correct and incorrect gunning positions from view from overhead (ACI CP-60(15), p. 58)



Fig. 4—Blow pipe operator continuously maintains a clean receiving surface by working ahead of nozzle stream

NOZZLE DISTANCE AND ANGLE

The nozzleman must maintain a position that orients the nozzle stream perpendicular to the work's receiving surface. Shooting at an angle other than perpendicular causes excessive rebound and should be avoided (refer to Fig. 3).

Use nozzle technique, distance, and angle to focus the nozzle stream primarily into a developing puddle of material at the receiving surface rather than directing the nozzle onto a hard-receiving surface. Shooting into a puddle of material dramatically reduces rebound.

Keep the nozzle close to the receiving surface, especially when working within congested reinforcement patterns. Nozzle velocity diminishes quickly as distance increases. Insufficient velocity cannot properly embed aggregates and will create excessive rebound. Use bench shooting techniques when working within congested reinforcement patterns and, when possible, direct the nozzle stream mainly through openings and around obstacles within the reinforcement pattern.

PREVENT REBOUND FROM BEING TRAPPED WITHIN THE IN-PLACE MATERIAL

Techniques used to control rebound created can substantially reduce the amount of rebound; however, they cannot eliminate it entirely—some rebound will always occur.

Because rebound is continuously generated during shotcrete placement, the continuous use of proper nozzle techniques, in conjunction with the proper use of a blow pipe when needed, are necessary requirements to prevent trapped rebound. The continuous use of a blow pipe or other suitable device is a required placement step in the current ACI 506.2-13, "Specification for Shotcrete":

"3.4.3.4 Shotcrete crew shall continuously remove accumulations of rebound and overspray using a compressed air blowpipe, or other suitable device, in advance of deposition of new shotcrete."

During placement, the blow pipe operator should work immediately ahead of the nozzle stream, continuously sweeping the receiving surface as material is being applied (refer to Fig. 4).

The blow pipe valve should be adjusted to supply enough air to easily displace rebound, but not displace freshly applied concrete materials. Rebound tends to accumulate in corners, ledges, joints, and behind reinforcement, where the nozzle stream cannot effectively embed the aggregates or blow them free of the work. The blow pipe operator must be especially vigilant in these areas to maintain a clean receiving surface. Placement should always begin in bottom corners or other areas that may trap rebound. Filling these areas first prevents accumulation of rebound. If possible, avoid aiming the stream directly toward, but rather on either side of reinforcement or other obstacles. Materials striking hard objects will rebound excessively. Use bench shooting techniques when working within congested reinforcement



Fig. 5(a)—Maintain a relatively sharp angle and completely cover reinforcements to encourage rebound to fall free of the work

patterns. Maintain a fairly sharp angle along the top of the bench to encourage rebound to fall

free rather than become trapped and fill around reinforcements completely to diminish potential accumulations behind bars (refer to Fig. 5(a) and (b)).

How to make a useful blow PIPE

Want to make a blow pipe? What could be easier? A fitting, a valve, and a few feet of pipe, and we have the perfect blow pipe. Or do we? An effective blow pipe must be capable of continuously keeping a receiving surface free of rebound as material is being applied. Although this task seems simple, the compressed air stream from a blow pipe can easily disrupt the nozzle stream's compaction and consolidation or disturb in-place material if the blow pipe air stream is too powerful. The blow pipe tip's shape plays a role in its usefulness. A blow pipe with an open tip can consume a LOT of air and thus a large portion of the air compressor's total output, potentially leaving insufficient air to accelerate concrete from the nozzle. Even with a relatively low air volume, an open tip will create a narrow, powerful stream that can displace or even blow a hole into freshly placed material during use. The design in Fig. 6 requires far



Fig. 5(b)—Close-up reveals what can occur when reinforcement is not properly covered by the nozzleman. Rebound will become trapped by the deposition of additional material if it is not blown free of the work. This is the likely cause of the flaws within the test specimen in Fig. 1

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CONTRACTOR'S CORNER



Fig. 6—This blow pipe is constructed from 0.75 in. (19 mm) steel pipe, approximately 3 ft (0.9 m) long. The tip has been shaped to a width of 0.25 in. (6 mm) with common tools to provide a wide fan pattern. It is efficient, durable, and requires very little air



Fig. 7—The nozzleman and blow pipe operator working side by side

less air flow. It creates a wide fan pattern that is powerful enough to clear rebound, but cannot easily displace material. A blow pipe 3 ft (0.9 m) in length sweeping a foot or two (0.3 to 0.6 m) from the receiving surface yields effective cleaning and excellent range of motion while giving the nozzleman sufficient working room for placing concrete.

An air compressor should be properly sized to adequately provide air flow to both the nozzle and blow pipe. If operation of the blow pipe causes a noticeable loss of air to the nozzle, the compressor is too small and must be upsized.

It is important to remember that the control of rebound is the responsibility of the nozzleman and crew (refer to Fig. 7). Because rebound is continuously generated during shotcrete placement, the continuous use of proper nozzle techniques, in conjunction with the proper use of a blow pipe when needed, are necessary requirements to a quality job.

NOZZLEMAN'S CHECKLIST

There are two distinct steps to the control of rebound. The nozzleman must use placement methods to diminish the formation of rebound and prevent rebound from being trapped within the in-place material, such as:

- Using visual cues to continuously maintain the correct slump for the project at hand;
- Considering recommended mixture design choices such as the use of silica fume, admixtures, or fibers to diminish the formation of rebound;
- Focusing the nozzle stream primarily into the developing puddle of material rather than directing the nozzle onto a hard receiving surface;
- Positioning the nozzle stream perpendicular to the receiving surface—shooting from an angle causes excessive rebound;
- Starting in corners or other areas that may trap rebound;
- Directing the blow pipe operator to work immediately ahead of the nozzle stream by continuously sweeping the receiving surface as material is being applied; and
- Using a blow pipe that uses a fan pattern that is powerful enough to clear rebound, but cannot easily displace material.

Safety Tip

The blow pipe is a dangerous tool. A highpowered compressed air stream can cause serious injuries. Never direct the stream towards someone. Exercise caution when handling a blow pipe.



ACI Certified Nozzleman **Oscar Duckworth** is an ASA and American Concrete Institute (ACI) member with over 25,000 hours of nozzle time. He has worked as a nozzleman on over 2500 projects. Duckworth is currently an ACI Examiner for the wet- and dry-mix processes. He serves on the ASA Board of Direction and as Chair of ASA's

Education Committee. He continues to work as a shotcrete consultant and certified nozzleman.

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Q. GOIN' UNDERGROUND

Underground at Mines

By Michael Mooney

COLORADOSCHOOLOFMINES.

n 2011, realizing a need to identify a unifying program dedicated to underground construction and tunneling education across campus, Colorado School of Mines established the Center for Underground Construction and Tunneling, or generally referred to as "Underground at Mines." Core faculty members from civil engineering, geological engineering, and mining engineering work together to provide Mines students with an interdisciplinary curriculum and provide the industry with focused research projects relevant to current underground challenges and development.

Over the last 6 years, additional departments on campus have joined the efforts, including mechanical engineering, computer science, and geophysics. The core faculty has grown from three to eight, ensuring students involved in Center research and courses are receiving an allencompassing education.

Underground at Colorado School of Mines operates with two primary goals: preparing leaders through educational

programs and advancing knowledge through research and development.

Underground at Mines educates both undergraduate and graduate students. Undergraduates can enroll in any number of underground-related courses, participate in independent study research, attend the biweekly industry lunch-and-learn series, and attend field trips to underground projects.

Graduate students (both masters and doctorate levels) can pursue degree programs in civil, geological, mining, geophysics, and more, or enroll in the newly developed Underground Construction and Tunnel Engineering (UCTE) masters or doctoral program. The UCTE graduate degree program—the only such program in North America—is an interdisciplinary blend of civil, geological, and mining engineering that reflects the modern-day practice of underground engineering. The program attracts the best and brightest from around the world.

Educational efforts span beyond the classroom, with field trips, conference trips, and internships for students on project sites. For example, in March 2017, a group of 17 graduate and



Fig. 1: Graduate student looking at the ground-freezing techniques used in the cross-passage construction on the SR99 tunnel in Seattle


Fig. 2: Students and faculty attending March 2017 field trip to Seattle in a field of precast segmental liners

undergraduate students traveled to Seattle, WA, to visit three underground projects: the 57.4 ft (17.5 m) diameter Alaskan Way Viaduct replacement tunnel, the Sound Transit Northlink extension transit tunnel and stations, and the Sound Transit Eastlink tunnel in Belleview. This was the fourth field trip by Colorado School of Mines in recent years.

In a deeper effort to prepare future industry leaders, students involved with the Center attend industry conferences to cultivate an awareness of industry trends, technical challenges, and research needs. Conferences also provide important opportunities for networking with top industry experts. Nine graduate students from Mines were recently awarded scholarships to attend the Rapid Excavation and Tunneling Conference held in San Diego, CA, in June 2017, where they participated in sessions and met potential employers and collaborators.

Internships are an integral part of the underground tunneling construction and curriculum. On-the-job training provides students with the depth of knowledge necessary to enter the workforce immediately upon graduation. The Center provides recruiters with a focused group of budding tunnel experts ready for hire. Mines students involved with the Center, either through the degree program or research, are regularly placed in internships—and ultimately full-time positions—with companies throughout the underground industry.



Fig. 3: Shotcrete application instruction at Shotcrete short course in September 2016

GOIN' UNDERGROUND

Colorado School of Mines is at the forefront of advancing knowledge in underground construction. Through the Center, faculty and students work together on projects ranging from "blue sky" ideas to very applied. Student internships and longstanding professional relationships with industry partners ensure Mines has a finger on the pulse of the current challenges facing tunnel engineers, project managers, owners, and consultants. The university's dedicated underground construction and tunneling community is focused on solving current research topics, including sensing, control and automation of tunnel boring machines, advancing performance modeling of underground equipment, abrasivity and wear, imaging ahead of the face, shotcrete materials, soil conditioning, and many more. A complete list of projects can be found at underground. mines.edu.

Colorado School of Mines has recently expanded its reach in underground construction and tunneling research with the addition of a U.S. Department of Transportationfunded University Transportation Center (UTC) for Underground Transportation Infrastructure. The newly established UTC pursues research in rehabilitation and renewal of aging infrastructure with several projects related to aging lining, shotcrete behavior, and advances in shotcrete materials and construction methods.

In addition, Colorado School of Mines provides continuing education for industry professionals to expand on its mission to advance knowledge. Mines offered four short courses in 2016: Shotcrete; Geotechnical & Structural Instrumentation, Monitoring, and Information Engineering; Underground Grouting and Ground Improvement; and Tunneling Fundamentals, Practice and Innovation. These courses attracted hundreds of attendees from all levels of employment and provided professionals with opportunities to network and discuss research with Mines faculty and students. All net revenue generated from these professional short courses are fed back into tunneling education, providing Mines students with funding for field trips, lab equipment, guest-lecture seminars, and internships.

This September, Mines will hold their annual short course in Tunneling Fundamentals, Practice and Innovation. In 2016, this course drew over 120 participants and more than 20 speakers, representing a broad perspective on the tunneling industry from young and seasoned professionals alike. Colorado School of Mines is well-positioned for recognition as home to the most advanced tunneling research in the world. 2018 short course dates will be announced later this year. More information can be found at **underground.mines.edu**.

There are many ways for companies to get involved with Underground at Colorado School of Mines. Please contact the school if interested in sponsoring research, attending short courses, hosting interns, or presenting at a lunch and learn (www.mines.edu).



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ACI RAP Bulletin 8

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FIELD GUIDE TO CONCRETE REPAIR APPLICATION PROCEDURES

Installation of Embedded Galvanic Anodes



ACI RAP Bulletin 8

(Reapproved 2010)

Field Guide to Concrete Repair Application Procedures

Installation of Embedded Galvanic Anodes

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ACI Repair Application Procedure 8.

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Introduction

In the last 20 years, there has been an increase in the need for concrete rehabilitation. In many structures, exposure to deicing chemicals and marine-sourced chloride is a significant cause of corrosion, playing a more detrimental role than originally anticipated. Corrosion of reinforcing steel within concrete is recognized as a significant problem facing present-day owners and engineers.

The most common procedure for repairing deteriorated concrete involves the removal of the damaged material and replacement with new concrete or mortar. While this addresses the immediate serviceability requirements, it does not always satisfy long-term durability needs. Differences in pH, porosity, and chloride content are a few of the factors that may result in corrosion activity. As a result, "chip and patch-style" repairs may fail prematurely in chlorideexposed structures.

Repair of corrosion-related deterioration in concrete structures offers unique challenges. In particular, the "ringanode" effect, also called the "halo" effect (Fig. 1), is a phenomenon that is frequently overlooked but is a common cause of premature patch failure or increased repair volume. Generally stated, the ring-anode effect describes the increase in corrosion activity adjacent to a repair area. The ring-anode effect is caused by the electrochemical incompatibility between reinforcing steel within a patch and the steel embedded within the surrounding concrete.

Galvanic technology—Zinc anodes have been developed to provide galvanic corrosion protection to steel in concrete. These methods are used to combat the underlying corrosion rather than simply repairing the physical damage. By supplying a small electrical current to the reinforcing steel, one can slow down corrosion of the steel. Galvanic systems are desirable because they create their protective current internally through a natural reaction wherein the anode corrodes to galvanically protect the reinforcing steel.

Embedded galvanic anodes-Embedded galvanic anodes are installed by burying them within the concrete. Type 1 embeddable galvanic anodes are available to be included in standard concrete repair (Fig. 2) or along a joint between new and existing concrete. Type 2 embeddable galvanic anodes are designed to be installed in sound concrete (Fig. 3). Anodes are activated such that they continue to provide current over time. Anodes are available that use one of two methods of activation: alkali-activated anodes (A), and halide-activated anodes (H). Each method of activation has its own benefits and limitations. When Type 1 anodes are included in a concrete repair, they are typically installed at the perimeter of a repair area to be as close as possible to the area of concern. When a suitable concrete or mortar is placed around the anode, it begins to sacrificially protect the adjacent reinforcement.

What is the purpose of this repair?

Embedded galvanic anodes reduce the corrosion activity of the reinforcing steel in the vicinity of the installed anode. Anodes are installed in areas of the concrete where there is a high likelihood of corrosion occurring or recurring. Type 1 anodes are installed to provide improved protection of rein-



Fig. 1—"Ring-anode" corrosion.



Fig. 2—Chloride-accelerated corrosion.



Fig. 3—Chloride-accelerated corrosion.

forcing steel in chloride-contaminated or carbonated concrete surrounding a patch repair. Type 2 anodes are used in sound chloride-contaminated or carbonated concrete to prevent the onset of delamination or spalling of the concrete.

When do I use this method?

Embedded galvanic anodes are attached to reinforcing steel within the patch cavity to protect the steel in concrete adjacent to the patch. For repairs in either chloride-contaminated or carbonated concrete, embedded galvanic anodes can be incorporated in the repair to minimize corrosion of the reinforcing steel adjacent to the repair. Embedded galvanic anodes can also be attached to reinforcement at the interface of new and existing chloride-contaminated concrete. Examples of uses include bridge deck widening, replacement of deck joint nosings, or concrete pile jacketing.



Fig. 4—Deteriorated concrete removed.

During concrete condition inspections, areas of potentially active corrosion of the reinforcing steel are often discovered in mechanically sound concrete. Embedded galvanic anodes can be installed in these areas to delay corrosion damage to the concrete. These anodes can be installed on a grid pattern over a large area to provide protection for reinforcing steel in concrete that is found to be or is suspected to be contaminated.

How do I prepare the surface?

Complete surface preparation as required for the application of the repair concrete or mortar. Limit the use of bonding agents to those with low resistivity, such as slurries containing portland cement or portland cement-sand mixtures. Avoid insulating materials such as epoxy bonding agents.

How do I select the right material?

Embedded galvanic anodes should be used only in conjunction with cementitious or cementitious-polymer repair materials, which have a low resistivity. Resistivity of repair materials or concrete for use with embedded galvanic anodes should be less than 15,000 ohm-cm. High-resistivity materials such as epoxies or highly polymer modified repair mortars greatly reduce the available galvanic current or prevent the anodes from functioning properly. If a low-resistivity material is not suitable for the full repair, anodes can be embedded in individual pockets of low-resistivity material. These pockets should completely encapsulate the anode and completely fill the space between the anode and the concrete substrate.

What equipment do I need?

The equipment needed to install Type 1 embedded galvanic anodes in standard repairs entails only basic hand tools and a DC ohm meter capable of reading 0 to 200 ohms. To install Type 2 embedded galvanic anodes in sound concrete, the equipment required includes a reinforcing bar locator, percussion drill or core drill, basic hand tools, and DC ohm meter.

What are the safety considerations?

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Fig. 5—Checking continuity of reinforcing steel.

make any representations with regard to health and safety issues and the use of this document. The user must determine the applicability of all regulatory limitations before applying the document and must comply with all applicable laws and regulations including, but not limited to, United States Occupational Safety and Health Administration (OSHA) health and safety standards.

Preconstruction meeting

Prior to proceeding with the repair, a preconstruction meeting is recommended. The meeting should include representatives from all participating parties (owner, engineer, contractor, materials manufacturer, etc.), and specifically address the parameters, means, methods, and materials necessary to achieve the repair objectives.

Repair procedure

Anode spacing in either repair type is often determined by the engineer, and differs for each situation. Spacing of the anodes is mainly a function of steel density and the corrosiveness of the environment. Structures with heavy reinforcement or structures in highly corrosive environments often require closer spacing for the anodes to function effectively.

Type 1 embedded anodes installed in standard repairs— As in standard patch repairs, all deteriorated concrete should be removed from around and behind the reinforcing steel inside the repair area in accordance with good concrete repair practice (Fig. 4). Sufficient clearance between the anode and the substrate concrete should be provided (minimum of 3/4 in. [19 mm] or 1/4 in. [6 mm] larger than the nominal maximum size of the coarse aggregate used in the repair material, whichever is greater). The exposed reinforcing bar in the repair area should be thoroughly cleaned and at least the visible surfaces should be cleaned to a bright metal surface to facilitate good electrical connections where the anodes are attached. Prior to installation, electrical continuity of the reinforcing bar within the repair area should be confirmed with the use of a DC ohm meter (Fig. 5).

Anode spacing is as specified by the engineer, with the anodes placed along the perimeter of the repair area. Each anode should then be securely connected to the reinforcing



Fig. 6-Tying tool and Type 1A anode.



Fig. 7—Tying a Type 1A anode.



Fig. 8—Confirming connection to reinforcing steel.

steel (Fig. 6 and 7). If less than 1 in. (25 mm) of cover exists, the anode should be placed beneath the bar (away from the surface of the concrete). Once installed, the electrical connection between the anode and the reinforcing steel should be confirmed (Fig. 8). The resistance of the electrical connection should be less than 1 ohm. Finally, the patch cavity is filled with a compatible repair material, using



Fig. 9—Locating reinforcing steel.



Fig. 10—Coring hole for anode.



Fig. 11-Secondary hole with reinforcing steel connection.

normal patching procedures and taking care to completely encase the anode.

Type 2 embedded anodes installed in sound concrete— Reinforcing steel in the area of the desired installation should be located and marked on the concrete surface (Fig. 9). Based on the location of the reinforcing steel, the anode location should be marked, and a hole of appropriate size should be drilled to accommodate the anode (Fig. 10). A location for connection of the anode to the reinforcing steel should then



Fig. 12—Confirming connection to reinforcing steel.

be marked, drilled if necessary, and a connection made (Fig. 11), either within the original hole or in a secondary hole. Continuity of the reinforcing steel in the location of installation should be verified with a DC ohm meter.

All holes should be cleaned of debris and dust. The anode should be securely connected to the reinforcing steel, and the contact should be confirmed using the DC ohm meter (Fig. 12). Connection resistance should be less than 1 ohm. Any connections between dissimilar metals (such as copper wires to steel) should be sealed with silicone or a two-part epoxy to prevent localized corrosion. The drilled hole(s) can then be filled using the appropriate repair material (Fig. 13).

How do I check the repair?

Embedded galvanic anodes, when normally installed, allow for very few direct measurements other than those for corrosion potentials. If more-detailed performance data are desired, anodes can be installed to allow monitoring of the current and voltage output of the anodes. With a switch



Fig. 13—Type 2A anode placed in hole with patching material.

installed in the circuit, corrosion potential or corrosion potential decay measurements can also be taken, if appropriate, to determine the level of polarization of the steel.

Sources for additional information

ACI Committee 222, 2001, "Protection of Metals in Concrete Against Corrosion (222R-01)," American Concrete Institute, Farmington Hills, MI, 41 pp.

ACI Committee 546, 2004, "Concrete Repair Guide (ACI 546R-04)," American Concrete Institute, Farmington Hills, MI, 53 pp.

Bertolini et al., 1998, "Cathodic Protection and Cathodic Prevention in Concrete: Principles and Applications," *Journal of Applied Electrochemistry*, V. 28, pp. 1321-1331.

Glass, G.; Taylor, J.; Roberts, A.; and Davison, N., 2003, "The Protective Effects of Electrochemical Treatment in Reinforced Concrete," *NACE Paper* No. 03291, Corrosion 2003.

Glass, G.K.; Hassenein, A.M.; and Buenfeld, N.R.; *Corrosion Science*, V. 43, No. 6, 2001, pp. 1111-1131.

Hausman, D. A., 1967, "Steel Corrosion in Concrete," *Material Protection*, pp. 19-23.

International Concrete Repair Institute, 2008, "Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion," *ICRI Technical Guideline* No. 310.1R-2008, 12 pp.

ACI RAP Bulletins

ACI Committee E706, Concrete Repair Education, has produced 14 documents on Repair Application Procedures (RAP) that cover a wide variety concrete repair topics. These documents are available for free as downloadable PDFs. Visit www.concrete.org/publications/educationpublications.aspx for a complete list of the free ACI RAP documents v. Also, ACI University offers a Certificate Program that encourages concrete professionals to gain indepth knowledge about particular topics in concrete materials, design, or construction by following a defined online course of study. One of the online Certificate Program visit www.concrete.org/education/aciuniversity/certificateprogram.aspx.





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Forming and Substrates in Pool Shotcrete

any factors lead to success in building strong, durable, and watertight pools. But what is success in constructing a pool shell? Structural integrity, proper shape, watertightness, and durability are key to success. Structural integrity requires meeting or exceeding the design strength for expected loading conditions with the desired thickness and shape. Providing the desired shape requires a sound, well-defined surface to accept the impact of the shotcrete placement. Thus, formwork or a prepared substrate is key to constructing a pool shell with the required structural section, desired shape, and aesthetics.

Strength, watertightness, and long-term durability are essential to performance of all concrete swimming pools and other recreational water structures. Achieving these properties requires high-quality concrete materials, proper shotcrete equipment, and quality shotcrete placement. The receiving surface, whether erected formwork or a prepared subgrade, must meet certain performance criteria and local building codes. A solid, rigid, nonvibrating surface must withstand the high compaction energy produced by shotcrete placement, allowing maximum compaction for a watertight concrete pool shell and full encapsulation of embedded reinforcing bars.

Reinforcing steel rests against, and is often attached to, the formwork or substrate. Thus, rigidity of the formwork is important for supporting the reinforcing steel and preventing excessive vibration. This is important to both durability and strength of the shotcreted shell. Reinforced concrete is a system, where the interaction of steel and concrete provide a combined compressive and flexural resistance to those respective forces. For the reinforcing steel to be effective, it must be fully encased by the concrete. A rigid form and well-secured reinforcing steel help facilitate proper encasement.

Forming for shotcreted pool shells is one-sided, and falls into two general categories: "Against Soil" or "Installed Formwork."

"AGAINST SOIL" CONSIDERATIONS

• The floors of most pools rest directly on the existing soil of the project. It is a basic but fundamental requirement

that all organic materials that may decompose and reduce or expand in volume be removed with the remaining soil left in an undisturbed or properly compacted condition.

- Many times, a layer of crushed stone is applied on top of the subgrade soils to provide a well-draining, stable, workable surface, as well as a clean, dense surface for the shotcrete. The crushed stone also serves as a drainage layer beneath the pool shell. An additional benefit of the crushed stone layer is it can be used to fill in voids or remove unevenness in the excavation process, which enables the shotcrete floor to meet the designed thickness as recommended in ACI 506R, "Guide to Shotcrete."
- In addition to being a "form" for the floor, the soil has structural significance. The soil must provide support in two directions: horizontal and vertical (that is, floors and walls). In most cases, the soil the pool shell rests on must support the combined weight of the shotcreted pool shell along with the weight of the contained water. These are very high loads and require competent soils to provide adequate support. Consider the soil loads for a pool with a 6 in. (150 mm) thick floor that goes from 3 ft (1 m) water depth to 10 ft (3 m) in depth. The vertical loads on the soil under the floor range from a low of 250 lb/ft² to a maximum of 675 lb/ft² (1200 to 3300 kg/m²).
- The supporting soil subgrade should be evaluated by a geotechnical engineer for various properties when establishing its suitability for any project. These may include: type(s) of soil, variations in the soil composition, presence of groundwater, rock, expansive soils, sloping grades, slope stability, bearing capacity, and potential for differential settlement or sinkholes. The structural engineer will use the bearing capacity of the soil in the structural design of the pool.
- When using the natural subgrade as a form, the soil must be compacted and stable before shotcreting. The geotechnical engineer should provide recommendations on methods needed to compact and test the soil for proper levels of compaction in the subgrade soils. During freezing weather, a frozen subgrade or one covered with frost must not be shotcreted upon.

american shotcrete association

Position Statement #6 ASA Pool and Recreational Shotcrete Committee

Properly stabilized soil or rock can be used as the vertical surfaces to be shotcreted on for the walls of the pool. This process can be quite effective, as it requires less time and materials spent excavating and forming, with little backfill. Loose, soft, or fractured soil or rock should be removed to give the shotcrete a stable, rigid receiving surface. Large voids in the soil can often be filled in with structural foam, or alternatively, formed so the shotcrete section is held to the designed thickness and in the desired shape.

"INSTALLED" FORMWORK CONSIDERATIONS

- Man-made materials are commonly used for the onesided forming of the walls. Forming may be required because the soil may be too rough, leaving large voids or undulating surfaces, or is unstable after excavation. The pool structure may need to have all or a portion of the pool built above the existing site grade, as is often the case in sloping sites or sites with very high groundwater conditions. On occasion, the pool may have been excavated without the shotcrete contractor being on site or even being consulted, and due to excessive excavation necessitate forms being built later.
- If a forming material can conform to the desired shape, be durable, relatively rigid, and not be detrimental to the shotcrete process, it can be used to create a form surface. Rough-cut lumber, framing lumber, tempered hardboard, thin plywood, structural foam, and stay-inplace forms are common pool forming materials. Often, more than one material is used to create custom shapes or to add stability.
- Forms must be constructed in a way that provides a rigid, stable, nonvibrating surface to receive high-velocity, high-impact shotcrete placement. With shotcrete typically being delivered at 60 to 80 mph (95 to 130 kph), the need for form rigidity is essential. If formed surfaces are weak or loose, the shotcrete crew may incorrectly reduce the force of shotcrete's impact by reducing the volume of compressed air being delivered. In doing this, the reduced velocity of the shotcrete reduces the compaction, reduces the ability to fully encase the reinforcement, reduces the concrete's strength, and increases the concrete shell's permeability. Often sloping walls, bottoms of skimmers, and other areas require that forms be strong enough to carry both the impact and weight of the wet shotcrete.
- Stay-in-place forms are often comprised of a thick-gauge welded wire covered with a heavy-duty fiberglass or water-resistant paper. This type of stay-in-place form is

very useful for creating single- or double-curved profiles. However, if misused, it can create problems. An example of inappropriate use would be hanging the stay-in-place form from a wood form being used for the pool beam at the top of the pool wall, or attaching the stay-in-place forming material to the reinforcing bar cage with tie wire, but having no other support. During shooting, the impact and weight of the shotcrete pulls on the reinforcing bars and the wood forms. This can lead to many problems, and even catastrophic failure during the shoot. This type of stay-in-place form should be supported with an appropriate number and spacing of stakes, ribbing or other suitable bracing materials.

Sometimes soil or formwork may have extended exposure to weather and on occasion over the winter. Delayed shoots resulting from complexity or size of a pool, or because of coordination of other work on a project, may expose the soil or formwork for weeks and months prior to shotcrete placement. Other potentials for delay are pre-shotcrete placement inspection schedules and building department requirements. Under these circumstances, the exposed soil or formwork is exposed to the weather and potentially to swelling, shrinkage, cracking, or movement. In circumstances where longer-than-anticipated exposures occur, repairs must be made to restore the integrity of the soil subgrade or formwork prior to scheduling the shoot.

In summary, whether using natural soil or installed formwork for pool construction, the shotcrete contractor must verify the receiving surface is stable, rigid, and nonvibrating; define and maintain the desired thickness and shape; and fully support any attached reinforcement during shotcreting. Full attention to the details of providing a proper surface for shotcrete placement will help to give the Owner a pool that is structurally sound, aesthetically pleasing, watertight, and will give decades of low-maintenance service.

Contributing authors: Jamie Scott, Bill Drakeley, and Charles Hanskat

Position Statements

ASA has produced position statements on the best practices for proper shotcrete placement. To date, six position statements from our Pool & Recreational Shotcrete Committee and one from our Board of Direction have been issued. These statements have also been published in *Shotcrete* magazine.

a. | SHOTCRETE COR∩ER

Shotcrete—The Blindside Waterproofing Solution

By Ross King

The large cities of the world are growing and being rebuilt like never before. This city rebuilding and densification is increasing below-grade construction complexity and challenges due to smaller sites, close proximity to adjacent buildings, and traffic congestion. One of the most recent and rapidly growing solutions to deal with this boom in urban basement construction is the use of structural shotcrete. A particularly efficient and economical use is in place of traditional form-and-pour concrete construction for one-sided walls built at the building perimeter against excavation shoring tight to property lines, also known as blindside wall construction. The performance demands for blindside waterproofing increase as the uses of these below-grade structures change. More buildings situated downtown are using the below-grade areas not just for parking, but for finished, occupied spaces that are far more sensitive to water intrusion (refer to Fig. 1). Add to this the boom in urban condominium construction and a resident lawyer on every condominium council, and water leaks can become very costly.

A new challenge in below-grade construction is rising in cities such as Toronto and Seattle, where the city is prohibiting groundwater discharge from basement drainage systems, or imposing an expensive metered charge



Fig. 1: Downtown high-rise hospital, below-grade blindside walls, with shoring rakers and densely reinforced high-strength pilasters supporting 20 floors

on lift pumps to discharge into the city sewer mains. This will become more common as cities grow because existing storm or combined storm/sanitary sewers are not designed for the increasing density and are becoming overloaded and nearly impossible to upgrade.

The solution is to "bathtub" waterproof the below-grade structure, meaning not just the blindside walls but also the basement floor. This bathtub, or essentially a concrete tank, resisting the outside groundwater with no hydrostatic drainage relief, increases the need for more competent blindside wall waterproofing.

I see using structural shotcrete in combination with a proper blindside waterproofing system as a solution over traditional form-and-pour to address these new challenges by creating watertight and dry, below-grade concrete structures in our growing cities.

There is a wealth of information available on blindside waterproofing for both form-and-pour and structural shotcrete. Unfortunately, much of this information is written based on a long history of using form-and-pour and with a lack of knowledge of the structural shotcrete process. As a result, the information on the finished product typically relates to traditional form-and-pour. Also, most information and articles have been written from the waterproofing side, with at times the obvious lack of knowledge of concrete construction methods regardless of form-and-pour or structural shotcrete methods.

The goal of this article is to address and clarify the similarities and differences of both these methods of placing concrete in reinforced concrete structures while focusing on blindside walls below-grade to dispel the myths and show the advantages of using structural shotcrete in building construction.

To compare and show the advantages of structural shotcrete, the following points need to be addressed:

- Shotcrete is concrete;
- · Form-and-pour versus structural shotcrete;
- Site conditions and building dynamics; and
- Types of blindside waterproofing.

SHOTCRETE IS CONCRETE

Many times, the structural shotcrete process is referred to as a product, as though we are substituting an alternative concrete mixture for ready mixed concrete. Builders and consultants need to realize that the concrete mixture used in wet-mix shotcreting is very similar. Whether for a small-diameter line pump or in a heavily reinforced, high-strength core wall, both require reduced aggregate size and a higher cement content. The only difference is that when they use these mixtures in form-and-pour placements, they need to have higher slumps, as compared to shotcrete placement that needs a lower slump (with the benefit of a lower watercementitious materials ratio [*w/cm*]) depending on the stack rate, reinforcement density, and wall thickness.

Given that shotcrete is concrete, the next typical question is, "What are the differences in construction joints, details, and sequencing?" The answer is, "none." Construction joints, control joints, and placing sequences are not altered and use the same construction details as traditional form-and-pour.

Structural shotcrete experiences drying shrinkage as it matures and gains strength, the same as form-and-pour. This rate of concrete material shrinkage varies based on many factors. The major influences are aggregate size, *w/cm*, and curing. There are several ways to design for this shrinkage, including admixtures, reinforcement, and control joints. In the end, concrete cracks in different ways, sizes, and spacing, and at times induced by the overall structure settlement.

So, comparing the slight difference between concrete mixtures placed by form-and-pour and structural shotcrete to see whether the cracking occurs at 12 ft (3.7 m) on center or 14 ft (4.3 m) on center doesn't really matter when comparing blindside waterproofing options. Stopping water flowing from any crack regardless of spacing is the goal, not by what method the concrete was placed.

When making critical blindside waterproofing choices, it is important for the waterproofing and building construction industries to address concrete crack control by making sure that control joints are properly detailed and spaced with adequate reinforcement.

Another factor I see that is rarely taken into consideration when choosing a blindside waterproofing system is linear shrinkage of the overall structure below grade. Proof of this often-overlooked movement is that buildings over a certain length commonly have delay strips or gaps designed into the structure to allow for contraction caused by shrinkage and are only filled in 28 days later. Common sense says that this shrinkage occurs in both horizontal directions regardless of the length, and pulls inward toward the center point of the structure, not just one way from the delay strip. This inward shrinkage, mostly restrained by the floor slabs, decreases the confining pressure against the excavation shoring substrate, which in turn can create issues for blindside waterproofing systems requiring confining pressure to work.

STRUCTURAL SHOTCRETE VERSUS FORM-AND-POUR

I have found when introducing the relatively new shotcrete process for placing concrete in blindside walls that the builders, engineers, and especially the waterproofing industry really don't fully understand how the process works, nor the finished product. Because of this lack of overall knowledge and myths about the shotcrete process, and at times even the process of concrete placement for form-and-pour, incorrect statements and decisions are made when considering blindside waterproofing.

The number-one factor and myth to dispel is that it's all just about the nozzlemen. Over my 40 years of experience in the form-and-pour industry, it's also been all about the vibrator man. The skill and necessity of these designated skilled persons is the same for either placement method, and the first major step to achieving high-quality cast-in-place concrete blindside walls. Proper compaction is essential.

SHOTCRETE CORNER

The next most important step required for quality blindside walls is using a placement-specific mixture design with properly spaced reinforcement, maintaining required reinforcing bar clearance from formwork and to the finished surface. The formwork must also be constructed to create proper access for concrete placement and consolidation.

The only way to achieve all these steps to quality is by using a qualified concrete contractor who uses properly trained people, the correct placement equipment, and plans ahead with the on-site team to make sure the concrete is placed correctly.

Everything stated in the previous three paragraphs applies completely to both form-and-pour and structural shotcrete placement. The needs for both processes are the same, and the quality of concrete placement with blindside waterproofing depends on the experience of the concrete contractor, whether it is shotcrete or form-and-pour. The opportunity and risk to place poor-quality concrete is equal between both methods (refer to Fig. 2(a) and (b)). The ability to achieve the required concrete quality for blindside waterproofing is also equal with both placement methods.

Just as there are similarities, there are also differences between both placement methods:

• Form-and-pour subjects the waterproofing to puncturing or splitting open seams from internal vibration. The formwork industry slang for this is "vibrator burn," which commonly occurs when a vibrator head snakes between the exterior reinforcing bar curtain and the form plywood, gouging out multiple layers of veneer from the plywood this also happens to the blindside waterproofing on the outside of the wall 50% of the time!

- Most blindside form-and-pour is not placed using an elephant trunk or tremie drop pipe; instead, the concrete is dropped full height. This creates two major issues:
 - 1. Impact energy commonly dislodges the waterproofing attachments, and the horizontal impact force from the "big blob" effect can tear open seams, especially at deviations in the shoring substrate. Additionally, segregation of aggregate and paste from dropping concrete through reinforcing bar (pinball effect) occurs on form-and-pour projects always! This commonly creates unconsolidated pockets of gravel at the bottom of wall joint to the floor slab, a critical location when it comes to blindside waterproofing and a watertight below-grade structure. Properly placed structural shotcrete employs the use of a blow pipe along this initial bottom of the wall pass, which basically eliminates the common form-and-pour rock pockets. Many cores and saw-cut testing of floor-wall joints have proven the superior performance of this method; and
 - 2. Walls over 8 ft (2.4 m) tall are poured at a rate of usually 4 ft (1.2 m) high per hour to control form pressure, meaning the taller a wall, the more time to complete the pour. This delayed pour process creates a dried cement paste buildup on the blindside waterproofing, which can affect certain waterproofing systems' bonding performance. I have been recently surprised to hear from major waterproofing suppliers, consultants, and installation contractors that they were unaware of this phenomenon! Properly installed structural shotcrete does not create this paste buildup issue. During lift placement and at the top of the wall,



Fig. 2(a) and (b): Honeycomb and voids in form-and-pour (left) and dense sharp-edged structural shotcrete (right)

the shotcrete process uses a blow pipe to continuously clean the top of wall and the waterproofing as placement progresses. Using the blow pipe is much easier when shotcreting because there is no formwork protruding above the pour line. This would also make cleaning off the waterproofing membrane virtually impossible when using form-and-pour.

- Another urban shotcrete myth is that cold joints are created from multiple lift placements. Refer to a previous *Shotcrete* magazine article, "Shotcrete Placed in Multiple Layers does NOT Create Cold Joints," by Charles Hanskat (www.shotcrete.org/media/Archive/2014Spr_Technical Tip.pdf), which dispels this myth and explains how proper shotcrete lifts are achieved. Form-and-pour is also placed in lifts but the risk of a cold joint is certainly greater and happens when concrete placement is delayed by pump or crane malfunctions, or just simply a late concrete truck, which happens often in a busy city. Once the vibrator cannot penetrate the previously placed lift of cast concrete, a cold joint occurs. This is a blind-side waterproofing issue that does not happen with properly placed structural shotcrete.
- Liquid head pressure within formwork can reach 600 to 800 lb/ft² (2900 to 3900 kg/m²), exerting extremely high lateral pressure on the waterproof membrane, and forcing it against uneven shoring substrates and the sharp anchor points. This often damages the waterproofing. Structural shotcrete exerts only 15 to 25 lb/ft² (73 to 120 kg/m²), helping the waterproofing to bridge irregularities and not warping the smoothing materials added behind the waterproofing in extreme conditions.
- One-sided forms require form tie anchorage to resist form pressure created by each placement lift (refer to Fig. 3). Many projects don't use "A-frame" one-sided forms due to availability, cost, height, shoring raker/strut projections, or complex shapes. The only alternative is to install numerous formwork tie anchor points attached to the shoring substrate, creating many penetrations in the waterproofing. This requires a lot of attention to detail for successful performance, and many opportunities for the penetration to leak. The structural shotcrete process requires far less anchorage to the substrate. Shotcrete placement is comparable to safely restrained reinforcing bar curtains used with "A-frame" formwork. These reinforcing bar anchorage points are at much greater spacing than form tie anchorage. Having a greatly reduced number of penetrations in the waterproofing substantially reduces the chances of leakage in the system.

SITE CONDITIONS AND BUILDING DYNAMICS

Many different site conditions can affect the performance between the cast-in-place concrete blindside walls and the waterproofing system, depending on



Fig. 3: Form-and-pour requires far more form tie anchor penetrations in the blindside waterproofing than reinforcing bar stabilization for shotcrete

which type of waterproofing is used. The following should be taken into consideration when selecting a blindside waterproofing system:

- Shoring subsidence, especially with wood lagging, where the hand-packed fill material settles behind the lagging or is washed out by groundwater flowing down the backside of the lagging, carrying the fines away, and creating a loss of density, resulting in movement that decreases the confining pressure between the concrete wall and the shoring substructure. This can be an issue for some types of waterproofing that rely on confining pressure.
- Differential settlement can occur between the building and the shoring system, caused by the building compressing the ground beneath and the anchored shoring system staying in place. This shearing movement can negatively affect the blindside waterproofing if not planned for.
- Substrate smoothness is always a factor and can affect the performance of any blindside waterproofing, except for integral waterproofing admixtures.

BLINDSIDE WATERPROOFING TYPES

A brief and simple explanation of blindside waterproofing can be broken down into five types of membranes, either sheet- or liquid-applied:

- 1. **Unbonded hydrophilic** sheet membranes, such as bentonite, swell when exposed to water and permanently rely on the confining pressure between the exterior concrete wall face and the shoring substrate.
- 2. **Mechanically bonded** systems rely on a fabric or hairlike structure to bond with the concrete wall during initial set. This in turn is attached to various waterproofing materials, including bentonite sheeting.

SHOTCRETE CORNER

- 3. **Chemically bonded** waterproofing relies on an adhesive activated by heat and minimal contact pressure. This type of system does not rely on confining pressure and stops water from traveling laterally along the wall face to a crack, creating a leak.
- 4. **Integral crystalline** waterproofing admixtures are added to ready mixed concrete. Once the concrete has cured, cracking occurs and leads to water infiltration; the crystalline waterproofing grows internally to fill in non-moving cracks and voids to seal off the passageways for potential water leaks.
- 5. Post-groutable fabric membrane is a newly developed waterproofing system that takes full advantage of the unique properties offered by the structural shotcrete process. A fabric with an attached woven geo-like grid is attached to the shoring substrate. After the reinforcing bar is installed, grout tubes are connected to the fabric grid and project slightly past the final wall face. Later, these tubes are used to inject grout to fill the curtain wall fabric to completely seal the blindside of the basement wall. This injection grouting is done after much of the concrete shrinkage has occurred, with an elastomeric, hydrophilic adhesive, two-part grout.

SHOTCRETE THE BLINDSIDE SOLUTION

The use of structural shotcrete for blindside walls is rapidly expanding and is becoming a common solution on tight urban sites, with fast-track schedules that require a watertight below-grade structure. Once all the players of these projects fully understand the similarities and differences of form-and-pour and structural shotcrete, and get past the misconceptions, they can benefit from these advantages to create a better blindside waterproofing assembly:

- Speeds up the concrete placement schedule because little or no formwork is needed, thus freeing up the workforce and crane time, and requiring less on-site formwork storage.
- Steel trowel final finish on the exposed surfaces, requiring far less touchup than form-and-pour.
- The ability to place concrete for blindside walls around obstructions such as shoring struts and rakers while still addressing tall, complex wall configurations.
- The unique ability to shoot around properly spaced in-place control joint inducers, which helps to meet ACI requirements to reduce wall thickness by 20 to 25% at control joints (refer to Fig. 4).
- Shotcrete delivers concrete to the bottom of the wall without the segregation of concrete dropping through the reinforcement and with no formwork in the way, enabling complete consolidation at the bottom of the wall and creating a better construction joint for the blindside waterproofing.
- Shotcrete can achieve better concrete consolidation in walls with dense reinforcement because greater access is available with no formwork in the way, making it easier to create a denser surface for the blindside waterproofing integrity.
- With much lower concrete pressure and no impact dropping concrete from the top of a form, shotcrete inherently has far less risk of damaging the waterproofing system.



Fig. 4: In-place crack control inducer (two pipes for thicker walls) is only possible with structural shotcrete. Concrete placement in form-and pour would wash pipes away

- Shotcrete is placed in short, visible lifts, with overspray blown off the blindside waterproofing continuously until the end of placement. There is no additional risk for both mechanical and chemically bonded waterproofing degradation due to a buildup of dry concrete paste, which typically happens in form-and-pour.
- Shotcrete reinforcing bar stabilization requires far fewer anchorage penetrations than most one-sided formwork systems, therefore requiring less detailing, and reduces the risk of leakage.
- Structural shotcrete now creates the opportunity to use a post-grouted hydrophilic curtain wall fabric, which accommodates shrinkage cracking, and other irregularities that can occur in any concrete placement (refer to Fig. 5). This system cannot be used with form-and-pour because the fabric grid would be crushed by the form pressure, vibration would force cement paste into the fabric, and the injection tubes would be knocked off by the concrete drop placement and vibration. Also, no concrete contractor would approve several holes drilled through expensive formwork, let alone trying to fish the pipes through the holes in the form while closing the form panel.

CONCLUSIONS

My opinion, after many years of experience in the form-andpour industry and more recently in the rapidly growing structural shotcrete sector, is that structural shotcrete is THE solution to improving blindside waterproofing. We need to toss aside all the silly misconceptions and incorrect details that have been presented for blindside waterproofing projects and objectively consider the total performance of the completed concrete walls when using shotcrete placement.



Fig. 5: Large highway tunnel project in Seattle, WA, with over 750,000 ft² (69,677.28 m²) of structural shotcrete, completely done with a post-injected hydrophilic membrane/textile composite system for blindside waterproofing



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O. SUSTAINABILITY

Durability of Shotcrete-Corrosion Protection

By Jonathan E. Dongell

n a prior *Shotcrete* magazine article, Spring 2015, "Durability and Exposure Conditions of Cementitious Materials – Deterioration Mechanisms,"¹ the author discussed durability as it relates to the placement environment. This article is a continuation of that topic with a basic overview of good shotcrete practices and materials and how each contributes to durability. An example of reinforcement corrosion protection is offered to show the complexities involved in creating durable concrete.

PROPER APPLICATION (EQUIPMENT)

Shotcrete requires "high" exit velocity (or shot concrete force) to create a lineal stream of material without deviation until contacting a solid form, existing substrate, or previously shot material. High velocity creates the impact force necessary for enhanced surface bonding (adhesion); mixture component bonding (cohesion); and anticipated compressive strength (compaction) to be achieved. Assuming adequate proportioning and constancy of material being shot, there is direct correlation between the material exit velocity (nozzle velocity) and the compressive strength. While a typical concrete placement relies on internal or external vibration for consolidation, shotcrete consolidation is primarily achieved through impact velocity. Of course, the use of proper equipment (pump, hoses, air compressor, nozzle, and so on) to facilitate an adequate flow of material with homogenous and uniform mixing and densification of the material is critical.2-4

QUALIFIED PERSONNEL (APPLICATOR)

In the most basic of terms, the nozzleman is responsible to ensure that the necessary in-place shotcrete characteristics for durability are maintained throughout the shotcrete placement. The qualifications of the nozzleman and the shooting practices employed must match the expertise level needed for the project. Thus, the experience and craftsmanship of the nozzleman provide the necessary workmanship for sound, durable shotcrete.

Shooting techniques consistent with sound industry practice ensure excellent compaction and consolidation, which lessens the potential for irregular trapped air pockets (or "vugs") much larger than air-entrainment size within the shotcrete and around reinforcement.^{2,4,5}

DURABILITY BY PRESCRIPTION (QUALIFYING THE MATERIALS)

As with any concrete, it is important to use only sound, proven materials (cement, aggregate, sand, pozzolan, polymers, additives, and water) for shotcrete. Each of these materials has at least one ASTM standard that qualifies its use for shotcrete placement of concrete. Proper proportioning of these materials is critical to the shotcrete application. Proper wet- and dry-mix aggregate gradations and mixture designs are addressed in ACI 506R-16, "Guide to Shotcrete."⁶

DURABILITY BY PERFORMANCE (QUALIFYING THE APPLICATION)

The most commonly used acceptance and performance testing criterion for shotcrete is compressive strength testing (ASTM C1604) in conjunction with testing that quantifies the shotcrete's overall interconnectivity.^{7,6} Knowing the shotcrete's overall density (as correlated by compressive strength testing) and its overall resistance to water/ moisture ingress (as relayed by permeability, absorption, or diffusion testing) directly relates to the shotcreted concrete's ability to resist most deterioration mechanisms. This in turn also provides a means to forecast shotcrete's durability.^{2,7,8}

Several test methods have been developed and used to indicate the "apparent" interconnectivity of shotcreted concrete. Such testing includes: rapid chloride permeability (RCP); rapid migration (RM); surface resistivity (SR); boiled water absorption (BWA); and bulk diffusion (BD).^{7,9} Each of these test methods have been used to quantify or qualify the potential durability of a cementitious material by determining its ability to resist the ingress and movement of ions though the material. The more commonly used test method is the ASTM C1202 RCP Test Method. While the ASTM C1202 RCP Test Method actually measures electrical conductivity and not permeability, it serves as a rapid indicator that many Agencies use to indirectly correlate somewhat closely to long-term bulk diffusion.⁷

Other performance test methods exist for shotcrete for specific uses, placement conditions, or environments, such as bond strength, shrinkage, freezing and thawing, alkalisilica reaction resistance, and sulfate resistance.

QUALITY OF SHOTCRETE

As shown previously, it is somewhat straightforward to design and fabricate a good shotcrete pumping system and equipment to produce durable shotcrete. It is also somewhat straightforward to design and proportion shotcrete materials to be durable. However, qualifying the nozzleman's consistency of workmanship throughout a shoot remains elusive. Currently, the combination of compression testing and the ASTM C1202 RCP Test Method (or similar testing to establish shotcrete's apparent interconnectivity) are used as a rapid method of qualifying a shotcrete, and by default the nozzleman's workmanship. Knowing the overall density and interconnectivity of shotcrete reveals the rate of moisture/ water ingress that facilitates most deterioration mechanisms. Ultimately, each of the aforementioned aspects of shotcreting determine shotcrete durability.

METAL REINFORCEMENT PASSIVATION

When steel is manufactured from natural iron sources, the iron is in a somewhat low energy state. An addition of energy is transferred to the iron during the melting, refining, and shaping processes during the fabrication of steel. The bound energy of pure iron (or corrosion potential) within reinforcement is higher, for example, than the iron compounds within the cement binder. This energy allows steel to be molded or stamped into various shapes and to be malleable and ductile, yet retain its shape. However, it is thermodynamically unstable for most placement conditions. Furthermore, this induced energy is not consistent across the surface of the steel. This increased energy, and the uneven energy fluctuations, would be quickly shortcircuited without some type of passivation layer added to the surface of the steel during fabrication. Without a passivation coating, the resulting instability would create an energy release, allowing an electrochemical corrosion reaction to proceed. As a result, all steel reinforcement for use in construction in the United States has a passivation coating (usually an electroplated coat) applied during the fabrication of the steel.

Passivation: A condition whereby metal is in a nonreactive or "dormant" state.

For metal reinforcement embedded in shotcrete, the highly alkaline environment of the cementitious binder quickly forms an iron oxide layer through a reaction with the higher energy iron at the surface of the steel. This passivation layer protects the remainder of the higher-energy iron within the steel from entering reaction (refer to Fig. 1).

In other words, within a few days of being embedded in the hardened cement paste, some of the outer-surface iron reacts to form a stable layer of iron oxide, creating an additional passivation layer necessary to prevent further reaction or corrosion. This new iron oxide passivation layer is stable against the highly alkaline environment of the cement on one side, and against the higher-energy iron within the steel on the other side; therefore, it serves as an "insulator" against further corrosion. A demonstration of the reaction creating an iron oxide passivation layer can be seen in Fig. 2 and 3. It is a very thin layer, yet a highly protective formation on the surface of the metal.

METAL REINFORCEMENT CORROSION

If the electro-plated passivation coating applied during fabrication of the steel, as well as the iron oxide passivation layer which formed after embedment in cement are compromised, then a short circuit can be created between two exposed areas of differing energy levels. If an electrochemical cell (or chemical "bridge") can be established, a corrosion reaction will proceed.



Fig. 1: Passivation (iron oxide) layer



Fig. 2: Metal plate having one end that was ground down (shiny section) to expose virgin steel



Fig. 3: Same metal plate after being halfway submersed in a high-alkaline (high-pH) water for 24 hours showing the formation of an iron oxide passivation layer (grayish-black)

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In an electrochemical cell (chemical bridge), one area of the steel becomes the "anode" and another area becomes the "cathode," and the pore water is the electrolyte.

The positively charged ferrous ions at the anode pass into the pore solution, and the negatively charged free electrons pass through the steel to the cathode. They are then absorbed by the pore solution, combining with water and oxygen to form hydroxyl ions (OH⁻). Hydroxyl ions combine with iron (II, III) ions (ferrous, ferric) to form hydrated iron (II/ III) oxide - $Fe(OH)_3$, or "rust" (nomenclature for rust written for understanding convenience).

CHEMICAL CAUSES OF METAL REINFORCEMENT CORROSION

There are many chemicals and environments that can facilitate corrosion.¹⁰ Two of the most common deterioration mechanisms involve carbonation and chloride ingress.

Carbonation

Carbonation of the cement binder occurs due to carbon dioxide (CO_2) in the atmosphere, or contact with bicarbonate ions (HCO_3^{-}) in a water-contact environment. Over



Fig. 4: Macro void space (air pocket) around reinforcement and bar termination bent upward



Fig. 5: Structural crack created pathway allowing chemical bridge to initiate corrosion

time, the compound calcium hydroxide $Ca(OH)_2$, which comprises between 15 and 22% of a fully hydrated cement, can carbonate to form calcium carbonate (CaCO₃). Because $Ca(OH)_2$ is 11.2 pH and $CaCO_3$ is 9.0 pH, this chemical reaction causes the pH of the overall cement binder to drop, starting from the outer surface and progressing inwards.

As CO_2 or HCO_3^- penetrates the cement binder system, the predominant hydroxide (OH⁻) alkalinity species within the pore solution reacts to form the carbonate ion (CO₃). This reaction forms a CaCO₃ precipitate (or solid solution) and pure water. This in turn reduces the oxygen content and lowers the pH of the pore solution, causing the loss of the iron oxide passivation layer and facilitating the electrochemical reaction that deteriorates the steel to rust.

Chlorides

Chlorides present a double threat for corrosion. Chlorides are an excellent electrolyte or conductor. Once a short circuit or chemical bridge is created, chlorides increase the corrosion reaction rate. Chlorides also concentrate at the corrosion pitting sites and form ferric chloride (FeCl₂) "rust." Ferric chloride enters a secondary reaction FeCl₂ + $2H_2O = Fe(OH)_2 + 2HCI$, which further lowers the pH of the pore solution at the corrosion pitting sites, and accelerates localized corrosion.¹¹ This double threat makes the prevention or significant slowing of chloride ingress a priority for many environments, to achieve the anticipated service life of the structure.

CORROSION PROTECTION

To achieve corrosion protection of the embedded metal reinforcement, as well as the anticipated service life of the shotcrete structure, each of the aforementioned aspects for a proper shotcrete installation are critical.^{*} This also includes sound engineering and design practices, specifying the necessary metal reinforcement and its proper installation, as well as the adequate embedment or "coverage"



Fig. 6: Insufficient coverage over reinforcement. Reinforcement bowed outward



Fig. 7: Complete corrosion of reinforcement grid due to inadequate coverage. Corrosion reaction creates internal stress and delamination of cover material

of shotcrete based on the structure's in-service use and placement environment.

Quality shotcrete and good design practices are the key to corrosion protection and overall durability by ensuring that inadequacies (Fig. 4 through 8), such as thin concrete cover, poor compaction, high water-cementitious materials ratios (*w/cm*), low cement content, and poor curing conditions are avoided.

References

1. Dongell, J. E., "Durability and Exposure Conditions of Cementitious Materials – Deterioration Mechanisms," *Shotcrete*, V. 17, No. 2, Spring 2015, pp. 8-10.

2. Morgan, D. R., "Freeze-Thaw Durability of Shotcrete," *Shotcrete*, V. 5, No. 2, Spring 2003, pp. 30-37.

3. Glassgold, I. L., "An Evaluation of Shotcrete Durability," *Concrete International*, V. 11, No. 8, Aug. 1989, pp. 78-85.

4. Hubacek, A., and Hela, R., "Study of Durability of Sprayed Concrete," *Recent Researches in Business Administration, Product Design, and Marketing, World Scientific and Engineering Academy and Society*, 2013, pp. 71-75.

5. Reading, T. A., "Durability of Shotcrete," *Concrete International*, V. 3, No. 1, Jan. 1981, pp. 27-33.

6. ACI Committee 506, "Guide to Shotcrete (ACI 506R-16)," American Concrete Institute, Farmington Hills, MI, 2016, 52 pp.

7. Hamilton III, H. R.; Boyd, A. J.; and Vivas, E., "Permeability of Concrete – Comparison of Conductivity and Diffusion Methods," University of Florida, Department of Civil and Coastal Engineering, Project 00026899, though grant from Florida Department of Transportation – Research Management Center, available through National Technical Information Services, Springfield, VA, 22161, June 2007.

8. Obla, K.; Lobo, C.; and Lemay, L., "Specifying Concrete for Durability," NRMCA Concrete InFocus, Winter 2006, pp. 42-50.

9. Bolduc, L.-S., and Jolin, M., "Shotcrete Boiled Water Absorption," *Shotcrete*, V. 12, No. 1, Winter 2010, pp. 12-17.

10. Verbeck, G. J., "Mechanisms of Corrosion of Concrete," *Corrosion of Materials in Concrete*, SP-49, American Concrete Institute, Farmington Hills, MI, 1975, pp. 21-38.

11. Ma, F.-Y., "Corrosion Effects of Chlorides on Metals," *Pitting Corrosion*, Mar. 2012, pp. 141-145, 150.



Fig. 8: Rust bleeding through a plaster finish of a swimming pool due to reinforcement corrosion



Jonathan E. Dongell is Director of Research & Development, Pebble Technologies, Scottsdale, AZ. Dongell has worked in concrete construction and with cementitious materials spanning over 30 years. His roles have included technician, superintendent, manager, contractor, and President. He was Past President,

Whitestone Cement Company, Scottsdale, AZ (1998-2005) and Universal White Cement Co, Inc., Glendale, AZ (1992-1998). He is a member and past Chair of ACI Committee 524, Plastering, and is a member of ACI Committees 201, Durability of Concrete; 225, Hydraulic Cements; 232, Fly Ash in Concrete; 308, Curing Concrete; 350, Environmental Engineering Concrete Structures; and 555, Concrete with Recycled Materials. Dongell also serves on the ACI Concrete Research Council (CRC) and the ASA Pool & Recreational Shotcrete Committee. He is a voting member of ASTM International main committees and several subcommittees, including C4.01, Cement, Lime, Gypsum, and C4.02, Concrete and Aggregates. Dongell is the author of several books, including The Durability of Cementitious Materials in a Water Contact Environment. He is an inventor and holds three patents on cementitious materials. Dongell is a designated expert witness in the fields of cement, concrete, stucco/plaster, and water chemistry. He was the recipient of the Del Bloem Distinguished Service Award in 2008.

*The intent of this article is to promote proper shotcrete workmanship and materials practices. While there are many products that have been shown to lessen corrosion and extend the service life (such as pozzolan, slag, densifiers, sacrificial anodes, epoxycoated reinforcement, and many others) these were not within the scope of this article.



KING SHOTCRETE EQUIPMENT INC. ENTERS U.S. MARKET

King Shotcrete Equipment Inc. (KSE) has set up shop in Allentown, PA. With office and warehouse space at 964 Postal Road, Unit 200,



KSE is positioned to service the U.S. and international mining, tunneling, refractory, concrete construction, and concrete rehabilitation markets.

With industry-leading shotcrete equipment and technical support, KSE is proud to distribute the shotcrete industry's leading brands, including Aliva, Fiori, Meyco, Putzmeister, Reed, and Terramin. KSE is projected to be the most comprehensive distributor of all major shotcrete equipment manufacturers in the marketplace.

The King Shotcrete Equipment business model is built on the concept of superior customer service, with the understanding that downtime is something its customers cannot afford. KSE will stock a wide range of wet- and dry-process shotcrete equipment, including all spare parts and related accessories required to keep its customers productive and on the job.

Its highly knowledgeable staff has over 50 years of combined experience in the shotcrete equipment and materials sector. As part of the King Shotcrete Solutions brand, KSE will support your complete shotcrete operation. To learn more, browse the equipment brands offered at **www.**



KingShotcrete-Equip.com/US or call Bridger Patrick Bridger, General Manager, at (610) 443-1800.

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PUTZMEISTER ADDS JAY LEE AS SENIOR VICE PRESIDENT OF SALES AND SERVICE

Putzmeister

Putzmeister America, Inc., has hired Jay Lee as Senior Vice President of Sales and Service. Lee will work closely with the company's sales and service teams to define future strategies, which will ensure Putzmeister continues to provide the highest level of products and services in the industry.

Lee brings to Putzmeister nearly 30 years of management experience, including leading teams of up to 800 employees. Throughout his career, he has held several positions related to the strategic development of sales and service organizations, including two decades in leadership roles at billion-dollar global manufacturing companies.

"We are extremely pleased to have added Jay to our senior leadership team," said Peter Mendel, Putzmeister's President and CEO. "His extensive experience in process optimization, vision and strategy, product innovation, and client service will not only serve as a huge asset to our organization but will also prove beneficial to our customers."

Lee received his bachelor's degree in engineering analysis with an emphasis in computer engineering and his master's degree in business administration from Clemson University, Clemson, SC. He will be based out of Putzmeister's Sturtevant, WI, headquarters and can be reached at leej@putzam.com.



Lee

NRMCA PROMOTES BUILD WITH STRENGTH CAMPAIGN

Since the inception of the Softwoods Lumber Board in 2012, the wood industry



has invested at least \$33 million to promote wood applications. As the residential building and nonresidential building sectors represent approximately three quarters of all potential for concrete, it is vital that the concrete industry unite to combat this encroachment into traditional concrete markets. The wood industry has been successful in wrestling share away from concrete over the last decade in the mid-rise market.

To protect concrete markets, National Ready Mixed Concrete Association (NRMCA) has launched "Build with Strength," a multi-million-dollar coordinated industry campaign to better educate the design/build and code communities about the benefits of concrete construction in the low- to mid-rise sector and in general. The program is based on a significant research investment made by NRMCA to better understand the motivations behind the use of certain construction materials, including concrete. The research showed that a great majority of the design/build community was favorable to concrete construction because of attributes such as strength, durability, and ease of use. However, certain misconceptions about cost and environmental impact often led decision-makers to choose less safe building materials such as wood and wood products.

The campaign relies on an unprecedented communications strategy that includes a Build with Strength branded website, video content, a multi-city media tour, rapid response capabilities, advertising, social media properties, and stakeholder engagement opportunities. Additionally, the campaign is designed to drive industry and project decision-makers to resources such as webinars and live seminars for technical support and design assistance while also building an advocacy network that will support concrete's position in building codes, standards, and rating systems at the state and local level.

"With Build with Strength we will re-energize the concrete industry and better position concrete products in the construction marketplace," said Ted Chandler, NRMCA Chairman and President of Chandler Concrete Co., Inc. "This initiative will serve as a united voice reminding people inside and outside the industry that no product is as safe, strong, or durable as ready mixed concrete."

For more information on the NRMCA coalition initiative. visit BuildWithStrength.com.

CARL BAUR BRINGS EXPERTISE AND **NEW OPPORTUNITIES TO MINOVA**

Carl Baur has joined the Minova Team as the Technical Sales & Services Lead for the refractories and construction division in North America.

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Baur brings with him over 24 years in shotcrete and refractories industry experience and is an established expert in the shotcrete community. He has extensive experience in the cement, lime, and alumi-

num markets, and has worked in concrete and refractories shotcreting, both wet and dry processes, for most of his career. Decades of installation and management experience equip Baur with professional and practical experience to effectively and successfully lead their teams.

Given his expertise, Baur is often requested by clients for training classes, specification guidance, and project estimation opportunities. In addition, clients frequently refer to Baur for professional guidance in determining the best and most efficient manner to solve their complex shotcrete project problems. Most recently, Baur was a consultant at the Oroville Dam project site after the flooding and near failure of the spillway caused excessive damage to the spillway and surrounding infrastructure last February.

Since joining Minova, Baur has helped establish a comprehensive shotcrete services and sales team in Millstadt, IL. With the addition of this facility, MINOVA now has a rapid response team in place that affords us them the ability to provide technical field services, as well as the capability to fill specialty pump and shotcrete orders outside of their standard customer service teams. This centralized U.S. location further enables Minova to consolidate and manage all their existing pumps and shotcrete resources while affording them a centralized location where they can stock third-party parts and supplies, such as Reed pump parts, as well as standard cementitious shotcrete and Tekcrete products.

Baur is an incredible addition to the Minova team. With his experience and solid reputation, they now have a proven leader that provides direct access to markets that would have taken years to develop.

About Minova

Started more than 135 years

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ago, Minova is a global manufacturer and supplier of chemical and mechanical earth control products, adhesives, and support equipment. With manufacturing plants on five continents and operations in more than 25 countries, Minova is an industry-leading provider of ground support solutions for the underground mining, construction, tunneling, and civil engineering industries. Minova is wholly owned by Orica Limited.

Media and industry inquiries regarding Minova should be directed to James Burris at (801) 673-7589 or james.burris@ minovaglobal.com.

INTERESTED IN SEEING YOUR INDUSTRY NEWS IN THIS COLUMN?

Visit www.shotcrete.org/pages/products-services/ shotcrete-magazine-authors.htm, contact ASA via e-mail at info@shotcrete.org, or call (248) 848-3780 for more details.



Baur

Q. ASSOCIATION NEWS

RUSS RINGLER, FOUNDING MEMBER OF ASA, PASSES AWAY MAY 22

Russell Harold Ringler of Marshall, VA, passed away on May 22, 2017. He was born on August 25, 1946, in Martinez, CA, to the late Harold L. and Rose E. Ringler. Ringler worked in the shotcrete industry for over 50 years, owning and operating several companies, including TopGun Commercial Gunite of Virginia. His true passion was



being out in the field with a shotcrete nozzle Ringler

in his hands. As one of the founding members of the American Shotcrete Association, he enthusiastically shared his knowledge and lent his active support to better our industry. He was honored in 2014 with an ASA Outstanding Project of the Year Award for an innovative and creative shotcrete project that exemplified shotcrete's efficiency, creativity, and pleasing aesthetics.

Ray Schallom III, another long-time member of ASA, remembers Ringler: "Russ worked with Chris Zynda, shotcreting for Chris's dad before moving East. Russ would



www.LRutt.com

always tell stories back when he was an 18-year-old with money earned doing shotcrete work. When he moved to Virginia, he applied what he had learned on the West Coast to his East Coast work. That knowledge carried him up to his passing. He was a great friend and colleague. He will be missed along with Chris Zynda."

ASA Board member Dennis Bittner related: "Russ loved the shotcrete industry and was one of my favorite people in the construction business. He would always help anyone who asked. One of the nicest, most genuine people in the business."

Ringler took great personal pride in making sure his family, friends, and coworkers always knew he was there for them to help in any way, or just to have some fun and share a good story or two. Ringler also loved sporting clays and traveled the country with friends to enjoy the sport. Ringler is survived by his wife Lori Ringler; his siblings Judy Berthiume, Vickie Ringler, and Dale Ringler; and a host of nieces and nephews.

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NITSCHKE TO LEAD NATM TUNNELING AT WSP USA

Axel Nitschke, PE, PhD, has been named a Tunnel Practice Leader and will be based in the Washington, DC, office of WSP USA, formerly WSP | Parsons Brinckerhoff. In his new position, Nitschke will be a member of the firm's geotechnical and tunnel technical excellence center and will work on tunnel projects and lead the firm's practice on the New Austrian Tunneling Method (NATM).



Nitschke

Nitschke has more than 20 years of experience in tunneling, including design, management, quality assurance/ quality control, safety, and construction. During his career, he has gained particular experience in conventional tunneling and NATM (also referred to as the sequential excavation method), as well as tunneling with tunnel boring machines. Prior to joining WSP, he worked on numerous tunneling and mining projects across Europe and the Americas as project manager, designer, construction manager, risk manager, contract manager, and consultant. Noteworthy NATM projects in the United States include the Beacon Hill station tunnel in Seattle, WA; the Dulles Corridor Metrorail Project (Phase I) in Virginia; the Devil's Slide tunnel in San Mateo County on the California coast; and the Caldecott Tunnel fourth bore project in Oakland, CA.

"Axel brings critical expertise to WSP with his extensive NATM and tunnel design and construction experience. His skills, combined with our existing expert staff and global experience, will allow our team to continue to serve our clients and solve their underground and tunnel engineering challenges," said Frank Pepe, Vice President and Director of the firm's geotechnical and tunneling technical excellence center. A licensed professional engineer in Virginia; California; Maryland; Washington; Washington, DC; and New Jersey, Nitschke received PhD and MSc degrees in civil engineering from Ruhr University Bochum in Germany. He is a member of the Board of Directors and Chair of the Underground Committee of the American Shotcrete Association. He is also a member of the American Concrete Institute and serves on ACI Committee 506, Shotcrete, and ACI Subcommittee 506-B, Shotcrete-Fiber-Reinforced; and is a member of the American Society of Civil Engineers and the Underground Construction Association of the Society for Mining, Metallurgy, and Exploration.

PCA EDUCATION FOUNDATION PROFESSORS' WORKSHOP

The PCA Education Foundation will be hosting the 2017 Professors' Workshop, July 24-28, 2017, in Skokie, IL, at the PCA Campus.



ASA Executive Director Charles Hanskat will be presenting a session on shotcrete at the workshop. The Professors' Workshop is designed to provide faculty in engineering, architecture, and construction management programs the tools to teach the latest developments in concrete design, construction, and materials. The weeklong session includes networking opportunities to exchange ideas with professors from many universities, demonstrations by software vendors, and free resource materials.

ASA EXHIBITING AT RAILWAY

To further our outreach efforts into the railroad marketplace, ASA will be exhibiting at the Railway Interchange 2017, show



September 17-20, 2017 in Indianapolis, IN, with the primary goal of bringing rail industry professionals together in a way that informs, inspires, and promotes the global rail marketplace. Railway Interchange is the largest combined railway exhibition and technical conference in North America. Attended by nearly 10,000 industry professionals from around the globe, this massive event is held every 2 years in major U.S. cities and includes impressive outdoor railyard yard exhibits on alternating years.

The Railway Interchange exhibition showcases the latest

NEED A SHOTCRETE CONTRACTOR OR CONSULTANT FOR A SPECIFIC PROJECT?



SUBMIT YOUR PROJECT FOR A BID REQUEST

The American Shotcrete Association has created a free online tool to allow owners and specifiers the opportunity to distribute their bid request to all ASA Corporate Members in one easy form!

Submit your project for a bid request from ASA's outstanding Corporate Members today by visiting:

www.Shotcrete.org/ProjectBidRequest

american shotcrete association



ASSOCIATION NEWS

technology, services, and research by members of the Railway Supply Institute (RSI), the Railway Engineering-Maintenance Suppliers Association (REMSA), and Railway Systems Suppliers, Inc. (RSSI).

Railway Interchange also features technical presentations and discussions by the American Railway Engineering and Maintenance-of-Way Association (AREMA) and the Coordinated Mechanical Associations (CMA). You can find more information at railwayinterchange.org. Visit the ASA Booth, #4943!

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ASA EXHIBITING AT THE 2017 INTERNATIONAL POOL | SPA | PATIO EXPO

ASA will once again be exhibiting at INTERNATIONAL the International Pool | Spa | Patio Expo (PSP), October 29 through November 3, 2017, in Orlando, FL.



ASA Past President Bill Drakeley and Executive Director Charles Hanskat will be conducting a full-day ASA Nozzleman Education Class at the show.

The PSP Expo is North America's largest industry event covering all segments of pool, spa, and outdoor living. More than 525 manufacturers will be on display, covering 138,000 square feet of exhibits. You can take part in world-class and unmatched education programs targeted to the pool industry. There will also be numerous networking events with opportunities to mingle with industry peers.

This 2017 event will be held in at the Orange County Convention Center. With the Orlando International Airport being the third-largest origin and destination airport in the United States, the location makes it convenient for international attendees traveling from over 80 countries. And with the industry thriving in the region, the PSP Expo is a pivotal platform for manufacturers looking to expand their foothold in the Southeast while meeting qualified buyers from across



the country and the globe. You can find full information at www.poolspapatio.com. Visit the ASA Booth, #1162!

WANT TO PROMOTE YOUR COMPANY TO OUR 17.000 READERS?

Advertising in Shotcrete magazine is the most affordable and effective way to reach the shotcrete industry. Each issue of Shotcrete magazine reaches a growing number of over 17,000 readers that include current and potential designers, specifiers, and purchasers of shotcrete in well over 100 countries. Your advertisement in Shotcrete will



reach the companies and people that you need to grow your business. Shotcrete's cost for advertising is competitive, with an average savings of 25% or more compared to other leading trade association magazines. These rates certainly provide you with the most "bang" for your advertising dollars!

For more information including ad rates and deadlines, please download the 2017 Media Kit (shotcrete.org/media/ pdf/ASAMediaKit.pdf). Our streamlined rate charts make choosing the right advertising option for your company easy.

Special Fall issue: ASA 20th Anniversary Edition-be sure to submit an ad in this special issue celebrating the advancement of shotcrete in the industry!

STRATEGIC DEVELOPMENT COUNCIL **TECHNOLOGY FORUM 42**

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ACI's Strategic Development Council (SDC) will be hosting their 42nd Technology Forum on September 6 and 7, 2017, at the Hyatt Regency

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aciFoundation

in Reston, VA. This semi-annual technical conference brings leaders in the concrete industry, government, and academia together to collaborate on industry-critical issues and accelerate new technology acceptance. The forum provides a platform for examining and incrementally addressing challenges facing the concrete industry.

An important facet of SDC's efforts over the last 2 years has been working with ASCC on a strategic plan for the concrete construction industry. This initiative "Concrete 2029" has used the SDC as a venue for gathering members from all segments of concrete construction together to help shape a plan that is relevant and useful to our industry. As in several previous forums, there will be a Concrete 2029 workshop following the main SDC Forum.

The SDC Technology Forum 42 will include technology showcases, SDC activity updates, research trends, and a tour of the FHWA's Turner-Fairbank Highway Research Center.

More information on the SDC Forum and the Concrete 2029 Workshop is available at www.concretesdc.org.

NEW!

shotcrete brochures





Ground Support







Pools, Water Features and Skateparks



Repair and Rehabilitation

Streamlined and targeted to specific markets, ASA has developed a series of affordable four-page promotional brochures to help you promote shotcrete! All brochures include basic introduction to shotcrete information and have market-specific images.

Brochures are sold in bundles of 25.

Per bundle: ASA Members: \$8.00

Nonmembers: \$15.00

MARKET SEGMENT	EXAMPLES INCLUDED	ORDER CODE
Architectural	Free-formed and curved structural sections, simulated rock	SBA
Ground Support	Tunnel linings, subway stations, soil nails, retaining walls, channels	SBGS
New Structures	Foundations, domes, tanks, channels, retaining walls, luge/bobsled runs	SBNS
Pools, Water Features, and Skateparks	Pools, skateparks, landscaping water features	SBPWS
Repair and Rehabilitation	Seismic retrofit, bridges, parking garages, historic restoration, dams	SBRR
Sampler Pack	Five (5) copies of each market segment	SB5

Visit the ASA website to order!

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american shotcrete association



D. | ∩EW PRODUCTS & PROCESSES

PUTZMEISTER INTRODUCES NEW TIER 4 FINAL THOM-KATT® LINE

Putzmeister

Putzmeister America, Inc., introduced its new line of Tier 4 Final Thom-Katt[®] Trailer Pumps at World of Concrete in January 2017. The new pumps, including the Thom-Katt TK 50, TK 60 HP, and TK 70 models, feature Tier 4 Final compliant Cummins engines to meet the latest government emissions regulations.

In addition to the new engines, the Tier 4 Final Thom-Katt offers a redesigned body, including a new hood, tanks, and cooler location. Other key features, including active display of pump information; angled hopper for ease-of-use and cleaning; and wide, high-strength trailer for maximum stability, will remain unchanged.

"The addition of these Tier 4 Final Thom-Katts to our current offerings provides our customers with more options as the industry transitions to meet government regulations," said Drew Krivsky, Putzmeister's Engineering Product Manager – Trailer Pump, Mortar & Shotcrete Products. "With the change in engine came a redesign in pump body layout, but the proven reliability and performance of our trailer pumps remains the same."

Putzmeister will continue to offer its existing Thom-Katt line for the next year, in addition to the Tier 4 Final compliant pumps, to help customers make the transition to the new engine requirements.

The new Thom-Katt models are available for immediate order. For more information, call (800) 884-7210.



KING SHOTCRETE OFFERS NEW TERRABLAST WATER ATOMIZER

King Shotcrete Equipment is pleased to carry a new piece of equipment from the Terramin brand. The Terrablast Water Atomizer positivity contributes



Grab your camera

Working on an interesting shotcrete project?

Proud of the work you shoot?

TAKE A PICTURE!

Take several! From beginning to end, photos add a lot to the story. If you have high-quality/print-resolution photos to support the work you do, you could enter your project for ASA's Outstanding Shotcrete Project Awards Program. **So start taking pictures today!**

2017 Awards Program NOW open!

Program Deadline: Monday, October 2, 2017 | 5 pm EDT



american shotcrete association

QSQ

www.shotcrete.org/ASAOutstandingProjects

to dust particle emission, in support of OSHA's ruling to protect workers from exposure to respirable crystalline silica, starting in September 2017. For more information about this piece, visit **www.kingshotcrete-equip.com** or e-mail kingshotcrete@kpmindustries.com.

The Terrablast Water Atomizer works by combining compressed air and water to create small water droplets that travel with the mine ventilation system, capturing airborne dust particles and causing them to fall with the water droplet.

The air and water are adjusted until the optimum water atomization occurs. Terrablast Water Atomizers are set up in

Specifications

Model	Single blast (AM082)
Material	Black PE housing (FRAS)
Nozzle size	8 mm (0.31 in.)
Dimensions	510 mm (20 in.) length x 200 mm (8 in.) diameter
Weight	3.2 kg (7 lb)

locations where dust is commonly emitted, allowing for dust control at its source.

When the water mist is directed at a surface, it leaves the substrate saturated in water, which allows for proper curing when methods such as burlap curing are not possible. As such, the Terrablast Water Atomizer can be used in the curing of concrete or shotcrete or in applications where water curing is difficult, such as under bridge decks or in overhead applications.







Q. | SAFETY SHOOTER

Footwear

By Andrea Scott

sk any shoe lover about shoes and you will often get a lengthy answer about their favorite pair, when they got them, how much they paid, and the name of the designer that made them. But while some can easily go on at great length about the variety of shoes in their collections, construction workers have different needs—color and style are not the most important concerns. Members of the shotcrete crew are on their feet all day. They need a great pair of well-fitting boots to wear daily that are comfortable, protective, and don't make their back ache.

To achieve this, care should be taken when selecting work boots. Purchase a pair that are comfortable and



One of many hazards safety boots can protect you from



Examples of burns from cement seeping into boots

durable and satisfy the requirements of the job, OSHA, and the employer.

For a work boot to be OSHA-approved, it must abide by ASTM and ANSI standards.

Because foot-related injuries make up 25% of all disabling workplace injuries, well-fitting, well-made work boots are imperative for the safety of construction workers. OSHA requires that "the employer shall ensure that each affected employee uses protective footwear when working in areas where there is a danger of foot injuries due to falling or rolling objects, objects piercing the sole, or electrical hazards."

As part of the most basic safety equipment, a crew member's personal protective equipment (PPE) should include quality footwear. With uneven terrain on the jobsite, as well as climbing up and down scaffolding, work boots make up the solid base required to provide traction and protect against a twisted ankle or fall. Athletic shoes are never an option. There are many brands of appropriate work boots available, and they all fit differently. Personal preference and needs will determine the best pair for each worker. Bear in mind that cost doesn't always correlate to quality and durability.

At a minimum, crew members need to have boots that provide plenty of ankle support for stability, arch support for comfort, and a nonskid sole to prevent slipping. The option of a steel toe or sole will be a matter of personal preference, but may be required by the employer. While on site, employees work in an environment with exposure to wet concrete, mud, and concrete dust; therefore, care must be taken to select boots that are best suited for the jobsite. They should be constructed of materials that will not degrade or easily become saturated. Boots that become saturated with cement-laden moisture create a highly alkaline environment in contact with the skin that can lead to cement burns. Wearing rubber boots over the leather work boots can be helpful, but will make moving around more difficult and can increase the tripping hazard. Pant cuffs should be taped over the boots or taped and tucked in, so that cement burns don't occur where cement-laden materials fall into the top of the boot and expose the skin to high alkalinity. The start of cement burns is generally not felt immediately, so precautions must be taken BEFORE being exposed to concrete materials to prevent damage to the skin. Working in wet conditions such as rain or even just in high humidity can lead to cement burns if concrete dust settles on the skin.

Some key features to look for when selecting your footwear are:

STEEL TOES

These contain protective reinforcement made of steel and are the original safety-toe work boots. Their benefits include the best puncture protection from sharp and falling objects and their affordability. Composite toes are a more recent development, and contain no metal. Instead, they're crafted from materials such as plastic, carbon fiber, and rubber. Their benefits are better electrical resistance and temperature regulation in addition to being significantly lighter in weight. Composites may be better for colder climates and to reduce leg fatigue. Steel toe or composite toe are both acceptable; choosing one instead of the other will come down to personal preference. Steel soles can help to protect your feet from accidental puncture wounds commonly caused by sharp objects (ever see nails sticking up from lumber on a jobsite?) that you may step on.

SLIP RESISTANCE

Slips, trips, and falls are responsible for some of the most common workplace injuries. Slip resistance offers a simple yet effective way to maintain everyday safety. Design, tread pattern, and material used in the outsole will affect gripping ability. Check to see that outsole materials are resistant to the environment you'll be exposed to on the project. Some materials are more resistant to oils or chemicals than others.

CONSTRUCTION AND FIT

The amount of use provided by a pair of boots will depend on how well constructed they are and how well they fit. There should be sufficient ankle support for stability. The shoe must grip the heel firmly to prevent chafing and slipping, with the forepart allowing free movement of the toes. The boots should have a low, wide-based heel. When purchasing shoes, have both your feet measured. Most people have different sized feet, so purchase shoes that fit the larger foot. Also, purchase footwear late in the afternoon when feet are at their largest, and while wearing the same kind of socks you will wear daily to prevent blisters. Don't buy footwear that is too tight, expecting it to break in, but do allow a few days of wearing your boots for short periods before wearing them for a full day's work. Shock-absorbing insoles and orthotics can also be helpful for preventing calluses and ingrown toenails. They can also delay the onset of foot fatigue from working on hard surfaces, which has been proven to be a contributing factor of accidents. Having more than one pair of work boots will allow them to dry fully each day and help them last longer. Boots should also be cleaned regularly and replaced when they start to show signs of excessive wear.

Taking all these factors into account should help extend the useful life of your work boots and get the most value from your investment. Selecting the right boot is an important choice for your workplace productivity and safety. Your feet will thank you when you make the right choice!



STEEL TOE



WATERPROOF



Examples of safety boots



Andrea Scott is the Director of Safety and Quality Control for Hydro-Arch, Henderson, NV. She has over 20 years of experience in the construction industry with a background in special inspection of reinforced concrete, reinforced masonry, structural steel and welding, and nondestructive testing. She is a member of ASA, Chair of

the ASA Safety Committee, and a former member of the ASA Board of Direction. Scott is also a longtime ACI member, and member and Past President of the Las Vegas Chapter – ACI.

O. SHOTCRETE FAQs

As a service to our readers, each issue of *Shotcrete* will include selected questions and provide answers by the American Shotcrete Association (ASA). Questions can be submitted to info@shotcrete.org. Selected FAQs can also be found on the ASA website, http://shotcrete.org/pages/products-services/technical-questions.htm.

Question: We want to know if it's possible to apply a 1 in. (25 mm) lift of shotcrete to a berm (2:1 slope). The berm will be treated with emulsion (oil and water) prior to the shotcrete. We are only looking for long-term erosion control. Will the emulsion be required or will it cause a bonding problem with the soil?

Answer: Shotcrete is a placement method for concrete. If the berm is composed of granular materials, one wouldn't expect the shotcrete to actually bond to the soil. Rather, placing a thin shotcrete layer would create a uniform, relatively impermeable layer of concrete to prevent water from penetrating through and washing out the soil underneath. The emulsion may help to stabilize the soil to help withstand the pressure of shotcreting directly against the berm, but many similar soil stabilization projects will shotcrete directly onto the natural soils.

Also, when considering using the emulsion, be aware that some oils may contain ingredients (like sulfur) that can attack the concrete over time. You should consult with an engineer or concrete materials specialist to ascertain whether the specific oil you want to use will have a longterm effect on the shotcreted layer.

Question: I have a contractor requiring cast 4 x 8 in. (100 x 200 mm) cylinders instead of test panels. Is there a written procedure for casting cylinders for shotcrete?

Answer: Shotcrete compressive strength should be tested using cores from test panels. Shotcrete cannot be shot into closed cylinder forms and be representative of the in-place

shotcrete. ASTM C1140-11 and C1604-05(2012) provides the panel configuration and compression testing requirements.

However, if using the wet-mix process for shotcreting and one wants to verify the compressive strength, air content, or temperature of ready mixed concrete materials as delivered, rather than as shotcreted in place, samples can be taken from the truck before pumping. These cylinders would follow ASTM C31-15 for making and curing concrete test specimens.

Question: We are looking for the application of shotcrete on tidal waters. We are located on Lower Puget Sound in Washington state and need examples where this has been used and is holding up under the moving tides.

Answer: Shotcrete is a placement method for high-quality concrete. Here's a link to an article of a rehabilitation of a concrete-supported lighthouse in the St. Lawrence Seaway (Pointe de la Prairie Lighthouse) that provides a lot of detail on an installation like yours, including saltwater exposure in a tidal zone. Additionally, this project also has regular freezing-and-thawing exposure (www.shotcrete.org/media/Archive/2014Sum_Sustainability.pdf).

Another project with tidal zone exposure involved repair of bridge pier pile caps on the East Coast of Florida. The article details the project parameters and testing conducted to verify the quality of the shotcrete placement (**www. shotcrete.org/media/Archive/2012Win_White.pdf**).

Question: I am currently working on a construction project that involves a soil nail retaining wall along a major highway



with architectural stone face using shotcrete. We have already installed the soil nails and a 4 in. (100 mm) thick shotcrete wall reinforced with welded wire mesh. The shotcrete was continuously wet cured for 7 days and due to cold weather, we are waiting until spring to shotcrete an additional 8 in. (200 mm) thick wall face and 5 in. (125 mm) nominal depth architectural stone facing. The shotcrete is wet-mix process with fibers, silica fume, 0.375 in. (9 mm) aggregates, and fines, and the architectural facing is being sculpted by hand. Since shotcreting the 4 in. (100 mm) wall face 2 months ago, there has been a lot of cracking and efflorescence appearing.

To avoid shrinkage cracking when installing the additional 13 in. (330 mm) of shotcrete, we are thinking of adding a shrinkage-reducing admixture (SRA) or even a product that is supposed to eliminate efflorescence. Do you have any recommendations regarding admixtures or any other products that might help reduce shrinkage cracking?

Answer: SRAs have been used in shotcrete, and should help reduce long-term shrinkage potential. You may also try reducing the cement content and thus the paste portion of the mixture. Because you've added silica fume, you probably are getting good strengths, and may find a lower cement content doesn't reduce the concrete strength too much. Also, reducing a very high cement content may reduce the potential for autogenous shrinkage of the paste. You mentioned 7 days of wet curing; that is good. Is it possible the cracks were initiated at an early age as a result of plastic shrinkage cracking? We know silica fume is a very "thirsty" supplemental cementitious material, so combined with evaporation at the surface, there may have been a potential to initiate some very thin cracks at an early age. The cracks may then be exasperated by drying shrinkage. To help reduce early-age plastic shrinkage cracking, the contractor may find fogging the surface immediately after finishing helpful.

Question: Can we find an appropriate and easy way to evaluate the shrinkage performance of shotcrete?

Answer: Shotcrete is a placement method for concrete. So, standard concrete tests for shrinkage are applicable. You will find an article from *Shotcrete* magazine, "Shotcrete Testing—Who, Why, When, and How," helpful (www.shotcrete. org/media/Archive/2011Sum_Hanskat.pdf). The specific section on drying shrinkage tests says:

"Drying shrinkage of the shotcrete can be tested using general provisions of ASTM C157. Because the shotcrete is shot into a large panel and not into the relatively small mold specified by ASTM for the shrinkage test beam, it is recommended that a beam approximately 11.25 in. (285 mm) in length be sawed from a test panel. As most shotcrete uses coarse aggregate less than 1 in. (25 mm), a 3 in. (75 mm) thick panel with a 3 in. (75 mm) wide cut should approximate the ASTM requirements. The A/E should specify in the contract documents drying shrinkage limits that are appropriate for the design of the structure."

Question: I am an architect and we have a client that is planning to do some major landscaping to his yard. He would like to consider shotcrete to create stone-type walls and outcroppings. Can you advise us on this? Would this be an appropriate application? Should he also just consider having a landscape company install boulders in lieu of a shotcrete-type landscape?

Answer: Shotcrete placement for a concrete wall gives the owner the advantages of concrete durability and the appearance of rock. Shotcrete has been used extensively for creating false rock faces for zoos, water parks, highways, and retaining walls. However, because shotcrete placement and carving to look like natural rock requires quite a bit of labor, the costs to do so may be more extensive than simply placing boulders.



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Q. SHOTCRETE CALENDAR

SEPTEMBER 17-20, 2017	Railway Interchange 2017 Visit ASA Booth #4943 Indiana Convention Center Indianapolis, IN railwayinterchange.org
SEPTEMBER 18-21, 2017	Tunneling Fundamentals, Practice and Innovations Colorado School of Mines Golden, CO underground.mines.edu/tunneling
OCTOBER 2, 2017	2017 Outstanding Shotcrete Project Awards Program Entry Deadline www.shotcrete.org
OCTOBER 11-13, 2017	First International Conference on Underground Mining Technology Radisson Hotel Sudbury Sudbury, ON, Canada www.umt2017.com
OCTOBER 14, 2017	ASA Fall 2017 Committee Meetings [*] Disneyland Hotel Anaheim, CA www.shotcrete.org

*Schedule of ASA Fall Committee Meetings, October 14, 2017

Times	Magic Kingdom Ballroom 1	Magic Kingdom Ballroom 2
8:00 am-9:00 am	Education	Underground
9:00 am-10:00 am	Membership	Pool & Recreational
10:00 am–10:30 am	Break	
10:30 am–11:30 am	Marketing	Safety
11:30 am-12:00 pm	Publications	—
12:00 pm–1:00 pm	Lunch	_
1:00 pm–2:00 pm	Contractors Qualification	_
2:00 pm–2:30 pm	Break	-
2:30 pm–5:00 pm	Board of Direction	_

ASA Shotcrete Nozzleman Education 9:00 am to 4:00 pm at International Pool Spa Patio Expo Orange County Convention Center (North Halls A&B) Orlando, FL explore.poolspapatio.com/Attendee/Schedule/SessionDetails/40142	
NOVEMBER 1-3, 2017 International Pool Spa Patio Expo Visit ASA Booth #1162 Orange County Convention Center (North Halls A&B) Orlando, FL www.poolspapatio.com	
NOVEMBER 15-17, 2017 International Concrete Repair Institute Fall Convention Hyatt Regency Hotel New Orleans, LA www.icri.org	
DECEMBER 3-6, 2017 ASTM International Committee C09, Concrete and Concrete Aggregates Sheraton New Orleans New Orleans, LA www.astm.org	
DECEMBER 3-8, 2017	American Exploration & Mining Association Annual Meeting & Exhibit Nugget Casino Resort Sparks (Reno), NV www.miningamerica.org
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JANUARY 11-12, 2018	Shotcrete 2018 Alpbach Conference Centre Tyrol, Austria www.spritzbeton-tagung.com
JANUARY 22, 2018	ASA Meetings at World of Concrete Las Vegas Convention Center Las Vegas, NV www.shotcrete.org
JANUARY 23-26, 2018	World of Concrete 2018 Visit ASA Booth #S10839 Las Vegas Convention Center Las Vegas, NV www.worldofconcrete.com
JANUARY 23-25, 2018	The Pool & Spa Show 2018 Atlantic City Convention Center Atlantic City, NJ www.nespapool.org
MARCH 11-13, 2018	ASA 20th Anniversary Event: 1st ASA Shotcrete Convention Save the Dates! Silverado Resort and Spa Napa, CA www.shotcrete.org
MARCH 25-29, 2018	The ACI Concrete Convention and Exposition Theme: "Concrete Elevated" Grand America & Little America Salt Lake City, UT www.concrete.org
JUNE 11-14, 2018	International Bridge Conference Gaylord National Resort & Country Club, National Harbor, MD www.eswp.com/bridge
WANT MORE INFORMATION?	See a full list with active links to each event: visit www.shotcrete.org and click on the Calendar link under the News & Events tab.



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Q. CORPORATE MEMBER PROFILE



SpecChem is a Kansas City-based manufacturer supplying concrete distributors with high-quality, industry-leading concrete construction materials. SpecChem offers a full line of liquid chemical technologies, including form release agents, paving and curing compounds, finishing aids, cures and hardeners, bond breakers, sealers, bonding agents and surface retarders, and an array of cleaning and stripping products.

Additionally, SpecChem has a line of epoxy products that include adhesive bonding agents, epoxy sealers and coatings, and high-strength epoxy mortars and grouts.

Finally, SpecChem's comprehensive line of cementitious grouts, repair mortars, underlayments and overlayments, and specialty concrete accessories round out an exhaustive lineup designed to provide quality, innovation, and value to distributors, specifiers, and contractors.

THE COMPANY

SpecChem has built, maintained, and continues to grow a strong team of industry professionals focused on building solid, long-term relationships, increasing distributor profitability, continually evolving and developing new products, and providing premium, best-in-class customer service.

With over 300 years of collective industry experience and expertise, SpecChem is well positioned to grow their leadership role in an industry poised for growth.

INDUSTRY LEADERSHIP

SpecChem takes their commitment to being an industry leader very seriously. SpecChem serves five key concrete markets—commercial, industrial, highway, infrastructure, and repair/restoration. They participate in nearly every industry trade group—organizations such as the American Shotcrete Association—involved with these key market segments.

Investing in research and development is also a key differentiator helping to establish SpecChem as a best-inclass manufacturer. Ongoing updates to their laboratory and quality control facilities, combined with some of the most knowledgeable and experienced minds in the industry, help ensure SpecChem is more than just serving their customers—they're fostering innovation in the industry.

Another area where SpecChem provides exceptional value to the industry comes in the form of their training programs. They annually host 2- to 3-day programs in their 7600 ft² (710 m²) training facility, where distributors from across the country and internationally enjoy interactive, hands-on product, application, and industry information in an exciting and engaging environment.

SpecChem also hosts numerous ad-hoc product and application demos year-round for distributors, contractors, and trade associations in this facility, as well as product demonstrations, jobsite visits, and lunch and learns all over



Fig. 1: SpecChem offers a full line of high-quality, industry-leading concrete construction materials



Fig. 2: Centrally headquartered in Kansas City, MO, SpecChem maintains five state-of-the-art manufacturing plants strategically located to serve all major markets



Fig. 3: Shotcrete application on the 18,000-bag Pickwick Condo project in Kansas City.

the country, designed to educate distributors, contractors, and the specification community.

Reducing environmental impact is yet another area where SpecChem strives to be an industry leader. With a focus on offering low volatile organic compound, environmentally friendly products—products that meet and exceed standards and specifications for sustainability and offer LEED credits that drive to make better, more innovative, concrete products using less material and energy is always at the forefront.

NATIONWIDE DISTRIBUTION, SALES, AND SUPPORT

SpecChem maintains five state-of-the-art manufacturing plants strategically located to serve all major markets, ensuring cost-effective and on-time shipping to every major market in the continental United States.

With regional sales offices and a national sales force serving every major market, they've built a nationwide distribution model that allows them to provide best-in-class products, top-rated customer service and support, and—by leveraging location-based raw materials advantages—some of the most competitive pricing on the market.

SPECSHOT PLUS

One of the most exciting new products last year for SpecChem was their SpecShot Plus, a high-performance shotcrete repair product formulated for extremely low rebound, reducing waste, and minimizing material cost, making it the ideal choice for concrete restoration where a shotcrete application is preferred.

Their single-component, fiber-reinforced microsilica



Fig. 4: The Pickwick Building parking garage, featuring SpecShot Plus

shotcrete found immediate success in a major parking structure restoration project—the Pickwick Building, a high-end condo project with street-level retail, located in downtown Kansas City, MO.

SpecChem worked with consultant Oscar Duckworth and with contractor Mo/Kan Concrete's certified shotcrete nozzleman on the 18,000-bag project—that's 20 full truckloads of shotcrete materials.

YOUR CONCRETE SOLUTION

From commercial and industrial concrete applications to repair and restoration projects; from DOT and infrastructure projects to decorative sealers for residential applications, SpecChem has concrete covered.

SpecChem will gladly answer any questions you have regarding your concrete needs and will put you in touch with a local sales manager in your area. With nationwide distribution and a dedicated sales and support team, along with a comprehensive suite of innovative, best-in-class products, SpecChem is truly the number-one solution to your concrete needs.

SpecChem LLC

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Chris Marston

Airplaco Monrovia, CA

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All ASA members and subscribers have access to the electronic version of *Shotcrete* magazine. A link to this e-magazine is sent as an item in the "What's in the Mix" e-newsletter. To ensure that you receive access to every issue of the electronic version of the magazine, send your e-mail information to info@shotcrete.org. At a time when more and more companies are demanding effective use of their dollars, more and more companies in the shotcrete industry are realizing the benefits of becoming an ASA Corporate Member

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- EDUCATE the construction world on the advantages of the shotcrete process through Onsite Learning Seminars to engineers and specifiers
- PROMOTE the benefits of shotcrete at national trade shows
- COORDINATE proper specification of shotcrete in private and public specifications and national codes and standards
- ENGAGE DOT and other Public Authority officials with a variety of ASA resources and outreach efforts
- Take advantage of TARGETED MARKETING in national and regional organizations and publications
- ENABLE owners and specifiers to embrace shotcrete with a portfolio of tools designed to give them an understanding of and confidence in the shotcrete process

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For more information on ASA membership, visit www.Shotcrete.org/Membership



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