Shotcrete MAGAZINE

A quarterly publication of the American Shotcrete Association

Volume 15, Number 2 ◆ Spring 2013

www.shotcrete.org

Repair & Rehabilitation

AMERICAN SHOTCRETE ASSOCIATION


"KING IS THE NOZZLEMAN'S CHOICE.
OUR JOB IS TOUGH ENOUGH. WITH KING ON OUR TEAM, THERE ARE NO SURPRISES. JUST QUALITY AND CONSISTENCY."
- Marc Evans, ACI Certified Nozzleman
Damian Farmer, ACI Certified Finisher
Ram Construction Services, Livonia, MI.
RAM

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Volume 15, Number 2
Spring 2013

Features

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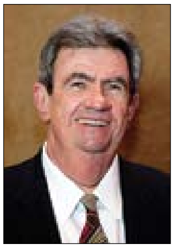
On the cover: Shotcrete placement for the Michigan Avenue Bridge Project, Chicago, IL, from the article "How Carl Akeley Saved Christmas," page 10. Photo courtesy of Cathy Burkert, American Concrete Restorations

Certification and the Law of Unintended Consequences

By Michael P. Cotter



As incoming President, I would like to thank my peers for electing me and thank the sponsors who made the 2012 Outstanding Project Awards Banquet in Las Vegas, NV, a rousing success. I would also like to welcome the new Board of Direction and our new Executive Director Mark Campo, and give a special thank-you to Alice McComas for all her dedication and hard work. My thanks to the Committee Chairs for their extensive efforts, especially Patrick Bridger and Joe Hutter, for all the years of work they put into ASA. I'm honored to follow in their footsteps and look forward to working with the new Executive Committee and Board of Direction.

The next order of business is to admit that we at ASA were wrong! We apologize to the industry for the following statement that was on our website: "The American Concrete Institute (ACI) established the shotcrete nozzleman certification program to establish a basic skill level of shotcrete nozzling. A design engineer or specifier can require the use of ACI nozzleman certification in their specifications. **This gives the specifier assurance that the nozzleman has demonstrated the knowledge and ability to properly place shotcrete.**"

The nozzleman certification means nothing more than, on a given day, in a perfect environment, a person shot a 30 x 30 x 4 in. (762 x 762 x 102 mm) panel under ideal conditions. To say that this gives the specifier assurance that the nozzleman has demonstrated the knowledge and ability to properly place shotcrete is a false and misleading statement.

The first action of the 2013 Executive Committee was to change the text on the website to: "The American Concrete Institute (ACI) established the shotcrete nozzleman certification program to establish a basic skill level for shotcrete placement. A design engineer or specifier should always require an experienced and qualified contractor for support, which includes experienced crew members and the proper equipment including material selection for the specific project. **This gives the specifier assurance that the entire shotcrete team (qualified contractor, ACI certified nozzleman and experienced crew) have proven their knowledge and ability to consistently place quality shotcrete.**"

ASA is an association of contractors, material suppliers, equipment suppliers, and engineers who are committed to quality installation of shotcrete in various applications. I believe that ASA should support and embrace a statement that quality shotcrete should be done by quality, committed contractors. The certification of nozzlemen by no means guarantees a quality shotcrete job.

ASA is actively working on solutions in the form of ASA-qualified contractors, nozzlemen in training, and inspector training programs. I ask that more members get involved—let your voice be heard! I do not believe it was ever ACI's or ASA's vision that certification of a nozzleman would or should replace an experienced contractor and crew while helping educate an experienced nozzleman to further his/her trade. This program seems to be suffering from the "Law of the Unintended Consequences."

Our goal is to get accurate information into specifications, which will help ensure consistently placed quality shotcrete.

May everyone have a safe and successful season. I look forward to working with all of you this next year as President of ASA.

Reference

"Unintended consequences," Wikipedia, USA, 2013, http://en.wikipedia.org/wiki/Unintended_consequences. (last accessed Mar. 25, 2013)

"Unintended consequences" can be roughly grouped into three types:

- A positive, unexpected benefit (usually referred to as luck, serendipity, or a windfall);
- A negative, unexpected detriment occurring in addition to the desired effect of the policy (for example, while irrigation schemes provide people with water for agriculture, they can increase waterborne diseases that have devastating health effects, such as schistosomiasis); or
- A perverse effect contrary to what was originally intended (when an intended solution makes a problem worse).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ASA Pool & Recreational Shotcrete Committee

By William T. Drakeley Jr.

In 2011, the Pool & Recreational Shotcrete Committee of ASA identified a "current state of affairs" in the pool shotcrete industry. Much effort has been put in since then to make pool building using the shotcrete process more of a researched and accepted practice. The ASA Pool & Recreational Shotcrete Committee is currently devoting its energies to making shotcrete in the pool industry more recognized as a credible form of concrete placement with work product examples and technical writings. The committee's efforts to raise the bar in shotcrete education include:

1. The Committee continually restates an older and not-so-well-known compressive standard of concrete in water exposure conditions. This standard and building code is represented in ACI 318 and a previous table in Section 4 (Table 4.2.2), which states that concrete designed to have a low permeability when exposed to water (yes, that indeed is a pool) shall have a minimum compressive value of 4000 psi (28 MPa) and maximum water-cementitious material ratio (*w/cm*) of 0.50. This forgotten knowledge has been given new life in the pool and spa industry and is currently replacing the substandard and incorrect lingering values of anything less than this minimum benchmark.
2. There has been an increased awareness at many of the industry shows of shotcrete nozzleman certification. ASA makes a concerted effort to offer the ASA education session (normally provided on the first day of a certification session) to major pool shows across the country. This exposure allows people seeking certification to receive the mandated classroom review and preparation for the written exam. This class also benefits owners, the foreman, and others involved with the shotcrete process to become more proficient at recognizing what makes a job successful and not so successful.
3. With approval from the ASA Board of Direction, the Pool & Recreational Shotcrete Committee has established the technical writing of Position Papers that take certain topics or aspects of shotcrete and explain their correct merits and procedures. These Position Papers are designed to be used directly by the pool industry as a reference library. To date, ASA has published two Position Papers that are foundational for the pool industry:
   - Proper Compressive Values; and
   - Terminology and Definitions.

   A third Position Paper will be released later this year on Sustainability. The committee is currently working on Position Papers regarding watertightness of shotcrete, sound forming for pool shotcrete, and the issue of control joints. We encourage all our members to participate in writing topics. This is a great way to set records straight; throw out inaccurate procedures or guidelines; and get all builders, specifiers, and engineers on the same page.
4. Reaching out to pool industry groups or associations is critical in this next phase of contact from the ASA Pool & Recreational Shotcrete Committee. Current discourse in the pool industry does not necessarily support proper shotcrete applications as endorsed by the American Concrete Institute (ACI) and ASA. Correcting these inaccuracies seems to be the biggest obstacle so far. Despite the committee's efforts to educate and inform, minor resistance to change still exists.

Table 4.2.2: Requirements for Special Exposure Conditions

Exposure condition	Maximum water-cementitious material ratio*, by weight, normal-weight concrete	Minimum f_c', normalweight and lightweight concrete, psi*
Concrete intended to have low permeability when exposed to water	0.50	4000
Concrete exposed to freezing and thawing in a moist condition or to deicing chemicals	0.45	4500
For corrosion protection of reinforcement in concrete exposed to chlorides from deicing chemicals, salt, salt water, brackish water, seawater, or spray from these sources	0.40	5000

*When Table 4.2.2 is considered, the lowest applicable maximum water-cementitious material ratio and highest applicable minimum f_c' shall be used (ACI 318).

(This is evident in the new International Swimming Pool and Spa Code Book [ISPSC], where ACI shotcrete references are misrepresented.)

We have had, however, great success with the following groups supporting and promoting the ASA and ACI positions: New England Spa and Pool Association (NESPA); Genesis 3 Design Group; National Plasters Association (NPA); and industry shows such as the Region 1 Atlantic City Show, World of Concrete, and the International Pool and Spa Show.

To continue moving forward, our efforts must not subside. Let's face it—there are still far too many pool structural failures in this country that could have been avoided. Proper education in the entire process is key. Some veterans who don't follow proper placement techniques justify their actions with statements such as: "I've been doing it this way for 30 years and never had a problem." To this I counter from an old proverb "…you don't know what you don't know." Pool shotcrete is still wrongly considered by most to be the bottom of the placement ladder. Slowly but surely we will bring credibility to our profession by recognizing shotcrete fundamentals. Hopefully, in the not-so-distant future, we will all be on the same page and will have raised the credibility bar in the pool building industry.

ASA Pool & Recreational Shotcrete Committee

William T. Drakeley Jr., Chair | Drakeley Industries
Jonathan Dongell | Pebble Technologies
Oscar Duckworth | Valley Concrete Services
Roberto Guardia | Shannon & Wilson
Mason Guarino | South Shore Gunite Pool & Spa Inc.
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James Scott | Group Works LLC
Marcus H. von der Hofen | Coastal Gunite
Jerry Werner | Aquron Corporation Division
Lihe (John) Zhang | LZhang Consulting & Testing Ltd.

Introducing ASA's All-New Website

By Mark A. Campo, ASA Executive Director

I'd like to take this opportunity to introduce ASA's all-new, completely redesigned website, **www.shotcrete.org**. In addition to retaining all of the useful information from the previous website, the new site brings additional functionality in a more modern layout that is clear, concise, and easier to navigate for both first-time visitors and frequent users alike.

Upon visiting the site, you'll immediately notice the updated content, including clear, high-resolution images and expandable menus designed to provide access to a wide variety of information, yet hide the information when you don't need it.

Some additional website features include the ability to integrate with ASA's social media outlets in real-time; menus that show customized, specific information relevant to the selected page; and more prominent advertising for our *Shotcrete* magazine advertisers, as a series of larger company logos perpetually scroll along the bottom of every page.

Overall, the entire site is organized into five category tabs across the top of the page, thoughtfully designed to address why you have visited ASA's website. (Hovering on any of these items will also bring up a menu of sub-items that you can access even more quickly.) Did you visit the site to learn more about shotcrete and why to use it? Simply click on Why Shotcrete? Looking for membership information or benefits? Click ASA Membership. Overall, it's a simpler, more streamlined approach to help you find the shotcrete information you need.

Why Shotcrete?

Perhaps the most notable addition to the ASA website is the new Why Shotcrete? page, which can be accessed directly at **www.whyshotcrete.org**. Intended to be ASA's front-line marketing tool to promote the use of shotcrete in all beneficial applications, this page highlights the features and benefits of shotcrete that make it the preferred placement method for numerous applications. Please link to us (**www.whyshotcrete.org**) from your own website as a tool to help your clients understand the shotcrete process more fully.

Whether you're a designer or specifier researching the best construction method for your project or a contractor new to shotcrete who wants to learn more about the process and its versatility, this page provides an overview of the substantial time and cost savings, sustainability benefits, and real-world examples of when and where to use shotcrete. Also, be sure to check out the video content—another all-new feature on ASA's website—which showcases the versatility of shotcrete and demonstrates its uses in a variety of applications.

Products/Services & Information

Hover your pointer over Products/Services & Information to access a wide variety of resources, including ASA's online bookstore, catalog of services, buyers guide, technical Q&A, and full archive of *Shotcrete* magazine. The ASA online store is where you'll receive your member discount on shotcrete compilations, nozzleman education resources, and more.

The ASA Buyers Guide is another powerful tool to help you get in touch with our Corporate Members and find the services or products you might need for your shotcrete project. Plus, take advantage of our free tool that allows owners and specifiers to Submit (their) Projects for a Bid Request from ASA's Corporate Members.

A dedicated *Shotcrete* magazine page in this section of the website also allows you to look up past issues, perform searches on content in archived articles, and learn how advertising in *Shotcrete* magazine can provide the exposure you need to reach your customers more effectively.

News & Events

The News & Events section is a great way to catch up on the latest happenings in the shotcrete industry. This area houses ASA's calendar of shotcrete-related events and meetings, news and press releases, and recent issues of our What's in the Mix? e-newsletter. To stay informed about the latest products, services, and events, sign up for the newsletter to be delivered directly to your inbox up to twice a month.

Education/Certification

Educational and certification programs continue to be a large part of ASA's day-to-day operations, and you now have easy access to information on these offerings directly from ASA's main page. In this section of the website, you'll find procedures on how to request and host an ASA certification session, how to schedule an in-house ASA informational presentation for your design and engineering firm, and even how to register to participate in ASA's graduate scholarship program.

ASA Membership

Not surprisingly, this is where you will learn all about ASA and the numerous benefits enjoyed by its members. You can even apply for membership or update your membership/contact information directly online.

New ASA committee pages—accessible to ASA committee members only—are also featured in this section. They provide a unified location for the coordination of committee work, notices, balloting, and other committee business.

How do you start using the new website? First-time users will need to use the one-time registration code "ASA2012," along with their membership or customer number. This will allow you to receive a User ID and choose a password. Once registered, you can then sign in and take advantage of all the latest informative, time-saving features located at **www.shotcrete.org.**

Don't know your membership number? Contact us at info@shotcrete.org or (248) 848-3780.

ANNOUNCING THE 2013-2014 American Shotcrete Association Graduate Scholarship PROGRAM

The purpose of the **ASA Graduate Scholarship Program** is to attract, identify, and assist outstanding graduate students pursuing careers within the field of concrete with a significant interest in the shotcrete process.

Two $3000 (USD) awards are available for the 2013-2014 academic year. One scholarship will be awarded to a graduate student within the United States and the second scholarship will be awarded to a graduate student in Canada.

All applications and required documents must be received by **5:00 p.m. EDT** on **Friday, November 1, 2013**.

Obtain an application and requirements at: **www.shotcrete.org/ASAscholarships**.

AMERICAN SHOTCRETE ASSOCIATION

ASA welcomes all students to take advantage of the outstanding benefits of a **free Student Membership** with both ASA and the American Concrete Institute (ACI).

You can find more information and sign up as an ASA Student Member at: **www.shotcrete.org/membership**

You can find more information and sign up as an ACI Student Member at: **www.concrete.org/students/stu.htm**

How Carl Akeley Saved Christmas

By Cathy Burkert

For more than 50 years, the trees along Chicago's North Michigan Avenue have been illuminated to signal the official kick-off of the holiday season and encourage everyone to join in the spirit and enjoy a host of festive experiences along Chicago's Magnificent Mile.

The centerpiece of the day-long festival is the evening parade, and the lights on Michigan Avenue are illuminated block-by-block as the procession passes. More than one million spectators line the parade route each year to see the lighted floats, marching bands, balloons, and performing artists. The 1.2 mile (1.9 km) parade route travels under millions of twinkling lights along Michigan Avenue from Oak Street to Wacker Drive.[1]

However, on October 1, 2012, just 6 weeks before the day of the festival and parade, the Chicago Department of Transportation (CDOT) wanted to begin a necessary rehabilitation of the deteriorated viaduct and retaining walls along the northbound entrance ramp to Lake Shore Drive at Michigan Avenue and Oak Street, exactly where the route of the parade begins. As explained by the city:

"This repair project is necessary due to the deteriorated condition of the concrete of the viaduct deck and retaining walls of the ramp, which has not seen any significant rehabilitation since its original construction in 1963," said CDOT Commissioner Gabe Klein. "We want to complete this repair work immediately before another winter cycle of freezing and thawing, as well as additional damage that could come from the use of road salt."

During the 6-week rehabilitation project, the on-ramp will be closed to traffic until mid-November. Northbound vehicles will be rerouted along Inner Lake Shore Drive for 1 mile (1.6 km) to LaSalle Drive, where they can proceed north on Lake Shore Drive. Adjustments to traffic signals and the deployment of traffic control aides will help move vehicles along the detour route.

The $1.78 million project will include the repair of the underside and topside of the on-ramp viaduct, repairing the concrete retaining walls, and miscellaneous electrical and lighting repairs."[2]

Fig. 1: Shoring towers at 8.5 ft (3 m) apart made for tight access between the exposed deteriorated concrete

American Concrete Restorations (ACR), a Chicago-based shotcrete contractor, was awarded the project due to its vast knowledge, experience, and reputation to perform efficiently. ACR accepted the challenge of a rigorous 4-week schedule to complete the overhead repairs. However, many more challenges were in store. The entire bottom of the deck, approximately 4000 ft^2 (372 m^2), was to be repaired; but due to the extent of deterioration, CDOT required temporary shoring be installed—spaced every 8.5 ft (3 m)—to support the loads from the traffic above. This restricted mobility for equipment and materials. The shotcrete contractor, needing access to the 15 ft (5 m) tall underside, required special equipment to gain access between the 8.5 ft (3 m) spaced shoring towers.

The shoring tower arrangement was so restricting that the turning radius of standard manlifts was too large to maneuver between the towers. ACR called five different equipment rental companies with no luck. Finally, one company was found that rented manlifts that would work, but only had two in inventory. They were delivered to the job site the next day and, with fingers crossed, successfully made the tight-radius turn and fit between the towers (Fig. 1).

Additionally, due to the congestion of shoring towers and workers from other trades, all equipment needed to be staged outside the viaduct. The shotcrete pump, compressors, and water tanks were stored at each end of the bridge and the hoses were lined along the inside of the wall. The center of the viaduct was to be left open to construction traffic, as seen in Fig. 2.

And that was only the first challenge! CDOT required the repairs be performed sequentially, so that no more than four sections of load-bearing shoring could be in place at a time. This required ACR to chip and prepare the surface and place shotcrete in four phases. Considering the short time frame to complete the project, ACR proposed moving the shoring towers when the in-place shotcrete reached 75% of its design strength to accelerate the job. In addition, ACR recommended using epoxy-set "L-shaped" dowel bars to support the reinforcing steel rather than the specified expansion anchors. ACR documented the success of the proposed changes from successful use on past projects where time was of the essence. CDOT agreed to the proposed changes. They also allowed the shotcrete to be tested for compressive strength from 72 to 96 hours after placement instead of the specified 14 days. This allowed earlier resetting of the shoring as soon as 75% of the design strength was confirmed.

ACR mobilized in mid-October and began the removal of the first segment of overhead repairs, averaging 6 in. (150 mm) in depth (Fig. 3). The repair areas needed to be cleaned and wire mesh needed to be installed prior to shotcrete placement. Special attention was given to the saw-cut edges because saw cutting leaves a polished surface that must be heavily blasted to ensure proper bonding. All existing reinforcing bars exposed by the concrete removal were coated with zinc-rich primer. The freshly sandblasted surface was prewetted to a saturated surface-dry (SSD) condition. Due to the depth of the repairs, the areas needed to be shot in two lifts and the surface of the first lift was power-washed prior to placing the second lift. The prepackaged, pre-blended Illinois Department of Transportation (IDOT)-approved shotcrete material typically reached 75% of the design strength in 3 to 4 days. Once complete, the repair areas were sounded by ACR to assure that all the shotcrete was fully bonded to the substrate. After sounding was complete, the ironworkers moved the shoring towers and ACR was able to proceed with the next section of removals, followed by the surface preparation and mesh installation.

As late fall approached Chicago, the temperature became the next challenge. Work in the cold temperatures causes equipment delays and inefficient production. Additionally, the CDOT specification for shooting shotcrete required that environmental conditions be a minimum ambient temperature of 45°F (7°C), a 50°F (10°C) material temperature, and a 40°F (4°C) substrate temperature. The experienced shotcrete contractor brought in large heaters to raise the ambient and surface temperatures. Heated water was used in the shotcrete mixture to keep it in compliance.

Fig. 2: Viaduct center left open for construction traffic

In addition to the shotcrete operation, other trades were in close proximity performing their work, including but not limited to crack injection, lighting, and formed concrete repairs. Because everyone was aware of the expedited schedule, it was important that the entire construction team work together to get the project done. As the project was located in downtown Chicago, near several large hotels, there were city noise ordinances that had to be accommodated with the workday schedules. The noise restriction only allowed 12 hours of construction work per day. Along with the project time constraints and noise ordinances, the project was abandoned for a few days due to 20 ft (6 m) waves flooding the underpass from a tremendous storm on Lake Michigan, just 200 ft (60 m) away from the project. All the contractors pulled together as a team and regular communication between the trades was a key element in making this project successful.

In the four different phases of shotcrete, over 300,000 lb (136,000 kg) of material was applied. The shotcrete process, performed by the qualified shotcrete contractor, was given high praise for the completion of the project on schedule, even with

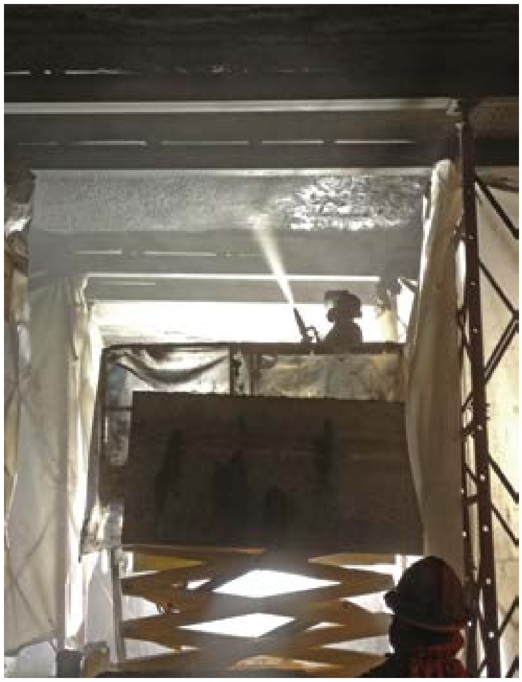

Fig. 3: Nozzleman shooting on the scissor lift between the temporary shoring

all the challenges. While ACR used American Concrete Institute (ACI) certified nozzlemen, the entire shotcrete team—including the pump tender, the finisher, and the grounds man, all of whom have many years of experience in the shotcrete operation—made the project a success. This experience and qualification of the individuals made the shotcrete process a successful and efficient team effort.

While some DOT specifications have not yet adapted to shotcrete, the CDOT's innovative specification wisely requires shotcrete for all overhead repairs. Shotcrete repairs on overhead applications are far more cost-effective and structurally efficient than formed concrete. Using shotcrete readily allows visual confirmation of the full encapsulation of the reinforcing bar and complete compaction of the shotcrete in place, whereas casting concrete into a closed, blind form often results in large voids. Workers using ready mixed concrete in a "form-and-pour" approach would have only had a little time to work with the concrete after it was transported from the concrete batch plant to the site through downtown Chicago traffic. Shotcrete also has enhanced safety benefits in the tight quarters of a project. The air and water hoses for shotcrete offer considerably less risk than raising and roughly handling lumber overhead in the large underside area of the bridge deck.

Furthermore, sustainability continues to grow as a driving force in the decision-making of owners and specifiers regarding construction materials and placement strategies. Shotcrete offers many significant sustainability advantages. Because shotcrete is simply a method of placing concrete, it offers all of the sustainability benefits of concrete as a building material in addition to a long list of advantages that are unique to the shotcrete method of placement.[3]

In conclusion, the project was successfully completed while reporting zero accidents. All construction on the project was completed while over 200,000 vehicles a day traveled on the bridge above. Carl Akeley, a taxidermist by trade, would be proud that 101 years after his patent of the "cement gun," developed in Chicago at the Field Museum of Natural History, Chicago still benefits from his innovation. The shotcrete solution resulted in a durable and cost-effective repair that will significantly extend the life of the original concrete structure. CDOT was impressed that the project stayed on schedule. All the contractors involved contributed to the success and the Festival of Lights parade went on as planned!

References

1. "Magnificent Mile Lights Festival," The Buckingham, Chicago, IL, 2012, http://thebuckinghamchicago.com/event/magnificent-mile-lights-festival. (last accessed March 20, 2013)

2. "Rehabilitation of Lake Shore Drive On-Ramp at Michigan Avenue and Oak Street to Begin October 1st," City of Chicago, Chicago, IL, 2012, http://www.cityofchicago.org/city/en/depts/cdot/provdrs/bridge/news/2012/sep/rehabilitation_oflakeshoredriveon-rampatmichiganavenueandoakstre.html. (last accessed March 20, 2013)

3. "Sustainability," American Shotcrete Association, Farmington Hills, MI, 2013, http://www.shotcrete.org/pages/why-shotcrete/sustainability.htm. (last accessed March 20, 2013)

Related Links

History of Shotcrete
en.wikipedia.org/wiki/Shotcrete#History

American Concrete Restorations
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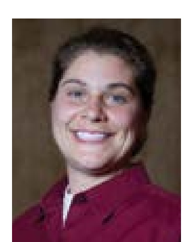

***Cathy Burkert** received her bachelor's degree in business management and thereafter started working at American Concrete Restorations, a Chicago-based shotcrete contractor. She joined the laborers' apprenticeship program to learn the intricate details of the trade. After 2 years in the program, she began running her own shotcrete crews and shortly after earned the title of Field Office Coordinator. In March 2009, Burkert became the first female ACI Certified Nozzleman for the wet-mix, vertical, and overhead processes. She has been involved with two award-winning ASA infrastructure projects: the Abraham Lincoln Memorial Bridge in 2008 and the Dan Ryan Expressway in 2009.*


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Fort McHenry Tunnel Miscellaneous Structural Repairs

By John Becker

At the time of its construction, the widest underwater tunnel in the world, the Fort McHenry Tunnel in Baltimore, MD, was opened to traffic in 1985. It houses Interstate Route 95 as it travels under the Baltimore Harbor and is operated and maintained by the Maryland Transportation Authority. In 2011, Coastal Gunite Construction Company was given the task of repairing spalled and delaminated concrete areas of the two southbound bores on the underside of the road deck and other areas in the fresh air duct that runs beneath the roadway (Fig. 1 and 2).

Minimizing exposure of the ventilation fans to dust was a prime concern during the execution of these repairs. The bulk of the concrete was removed using hydrodemolition by Rampart Hydro Services with a rig specially designed to maneuver and work in the small space of the duct. The repair areas ranged in depth from 1 to 6 in. (25 to 150 mm) depending on the extent of the deterioration and corrosion present. The hydrodemolition process also roughened the existing concrete surface sufficiently such that no additional roughening was required.

As another way to minimize dust, the damaged concrete of the structure was replaced by Coastal Gunite using the wet-mix shotcrete method. The shotcrete needed to maintain a minimum of 2 in. (50 mm) cover over the reinforcing steel, necessitating that it be built out past the surface of the existing concrete sections in most places. It was given a fine brush finish. Because of the inconsistent and limited access times for construction, a preblended, dry material bag mixture provided by US Concrete Products was batched on site. Batching on site also allowed Coastal Gunite to accurately optimize the water-cement ratio (*w/c*) for the placement needs.

Because of the high volume of material and short working time available, the debris generated from the hydrodemolition and shotcrete activities had to be handled and removed using small equipment and a great deal of labor through the few available manholes (Fig. 3 and 4). Wastewater generated by the hydrodemolition and shotcrete activities had to be collected and properly treated to prevent negative environmental impact.

The Maryland Transportation Authority provided traffic control for the project. All work was done at night and required the closing of one bore of the tunnel at a time. Because the tunnel is such a vital traffic artery, the entire repair

Fig. 1: Mobile shotcrete equipment in tunnel (work is underneath road deck)

Fig. 2: Underside of road deck prior to rehabilitation activities


Fig. 3: Hydrodemolition robot in action removing overhead concrete


Fig. 4: Areas after hydrodemolition and hand chipping behind reinforcing steel ready for shotcrete


Fig. 5: Placing overhead wet-mix shotcrete

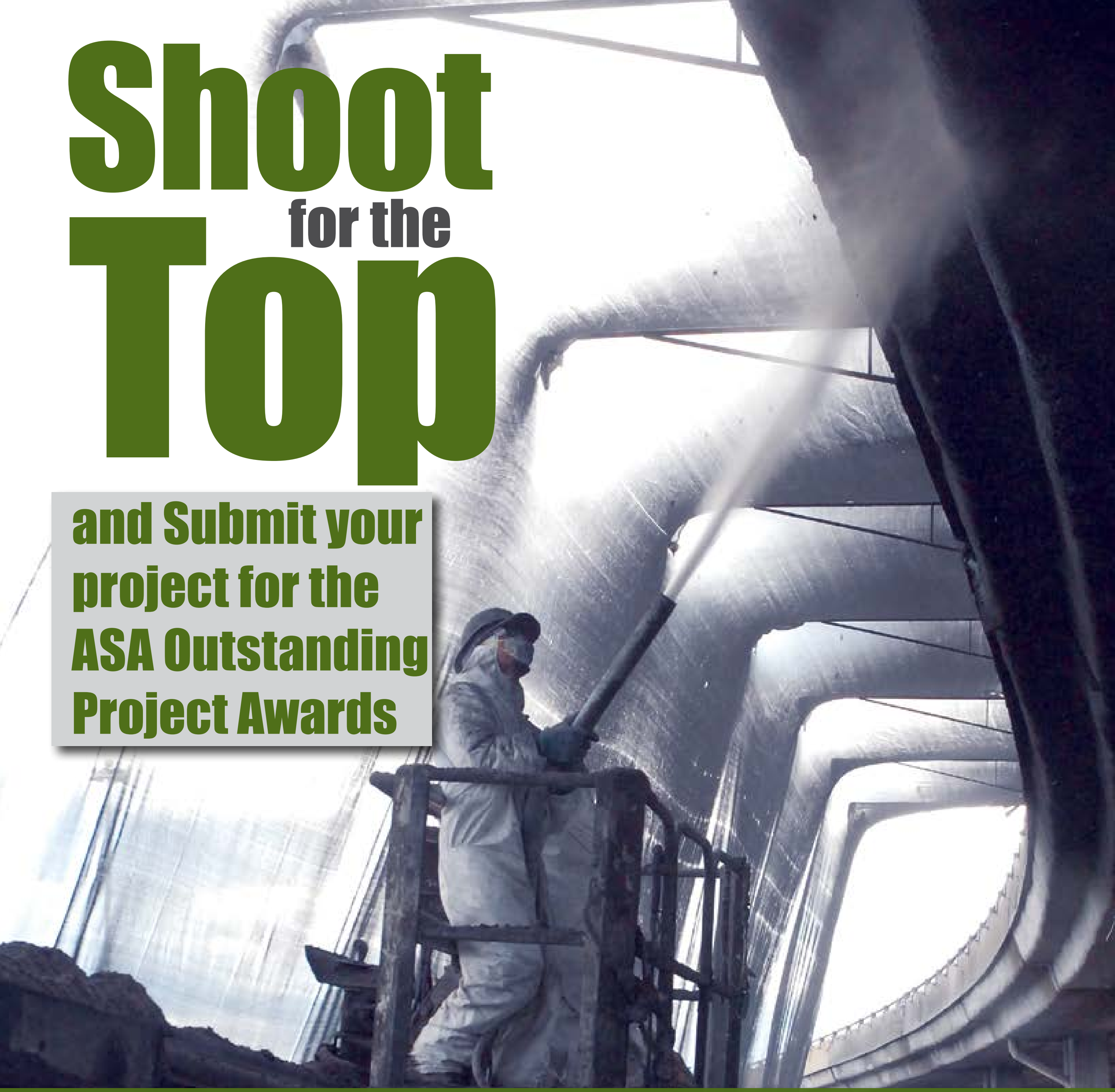

Fig. 6: Completed ceiling and wall rehabilitation

operation had to be designed so that, if necessary, the job site could be vacated and the bore reopened within 30 minutes. To accommodate this requirement, all necessary equipment and materials mobilized in the roadway were mounted to and used from trailers or vehicles, enabling them to be removed quickly. All equipment left in the air duct had to be fully secured as well. Liquid accelerator was used in the shotcrete mixture to guarantee that the repair material would reach initial set before traffic resumed in the bore.

An unanticipated difficulty arose, as it was found that the water piping and electrical utilities encased in the concrete walls on both sides of the fresh air duct were heavily corroded. Removal of the deteriorated and corroded materials without causing further damage to the equipment while it was in use required delicate use of hand tools. Much of the replacement reinforcing steel used on the project went into these areas, as total corrosion of the existing reinforcement was common (Fig. 5 and 6).

The extent of necessary repairs significantly increased from the initial estimates the contract for the project was based on, requiring substantial additional work in some areas. Thus, the decision was made to exhaust the original funding designated for the project and leave the work unfinished. Ultimately, after we completed the first phase, two additional phases were added to complete the project. The third phase has not yet been completed. By placing the 23,600 ft^3 (668 m^3) of concrete using the wet-mix shotcrete method, the repairs were completed much faster and more efficiently than possible with other methods. This construction efficiency and flexibility convinced the Maryland Transportation Authority that shotcrete was the method of choice for the rest of the needed repairs in the tunnel.

John Becker *is an ACI Certified Nozzleman who, for the last 5 years, has worked in many capacities—most recently as Project Manager—for Coastal Gunite Construction Company based in Cambridge, MD. In addition to the Fort McHenry Tunnel, he has been involved with many shotcrete projects large and small, including the $15 million Bonner Bridge Rehabilitation Project in Nags Head, NC, and the $5 million Old Mill Creek Sewer Rehabilitation Project in St. Louis, MO.*



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Soudan Mine Shaft Rehabilitation

By Shane McFadden

The Soudan Mine is a historic taconite and iron ore mine in Northeastern Minnesota. First built in 1882, the Soudan Mine was one of Minnesota's only and deepest underground mines. Mining continued at the facility until the US Steel Corporation closed the facility in 1962, when production became too costly to sustain the operation. Over 80 years of mining production, more than 50 miles (80 km) of underground drifts, adits, levels, and raises were constructed, with the deepest being Level 27 at 2341 ft (714 m) below the surface—689 ft (210 m) below sea level. The mine was donated to the state of Minnesota in 1965 and is now operated as a state park by the Minnesota Department of Natural Resources (MnDNR). In the early 2000s, the National Science Foundation funded the construction of a major research laboratory on Level 27 to conduct physics and other scientific experiments. With the addition of the lab facility, the site serves the dual purpose of public recreation and education along with the advancement of cutting-edge science.

Access to the mine is through the main shaft and hoist system (Shaft 8). The hoist system is a dual-cage assembly, meaning that there are two cages attached to the hoist cables at all times. As one cage is lowered into the shaft, the other cage is concurrently raised. Along with personnel, equipment, and material conveyance, the shaft is the main conduit for all of the utilities to the underground portions of the mine, including the supply of air, power, and water, and the removal of groundwater. The shaft is split into three bays: two cage bays and one utility chase bay (refer to Fig. 1).

When the mine was first developed, modern drilling and mining techniques did not exist, making blasting rock very difficult and labor-intensive. Therefore, it was desirable to have the shaft closely follow the ore body to minimize the need to construct drift tunnels. In the case of the Soudan Mine, the shaft follows the edge of the main ore body, which lies at a steep angle (78 degrees) (refer to Fig. 2). Therefore, the shaft cages are hoisted vertically but are also supported horizontally by rails installed off the footwall of the shaft. The rails ride on structural steel sets that are spaced approximately every 4 ft (1.2 m) along the shaft. For the cages to ride smoothly along the length of the 0.44 mile (0.71 km) deep shaft, the rails and the corresponding supporting steel sets needed to be properly aligned. To accomplish this, the sets were supported against the irregular shaft walls with rough timbers harvested from the surrounding forests (refer to Fig. 1, 3, and 4). Approximately every 300 vertical ft (90 m) in the shaft, a concrete collar was placed tight to the rock to provide additional structural support to the shaft system.

In March of 2011, the supporting timbers of the shaft caught fire approximately 100 ft (30 m) above Level 27. This fire consumed the shaft and caused extensive damage from Level 27 up the shaft approximately 350 ft (110 m), including the burning of the shaft support timbers, pump and water supply lines, communications, power supply, warping of many of the structural steel supports, and destabilized portions of the surrounding shaft geology.

The MnDNR chose to execute the repairs to the shaft on an emergency fast-track design-build contract and selected the team of Engineering & Construction Innovations, Inc. (ECI); Engineering Partners International, LLC (EPI); and CNA Consulting Engineers, LLC (CNA). After defining the lower and upper limits of the damage to the shaft, the team's first task was to temporarily stabilize the shaft, re-establish the shaft utilities, and assess specific damage to the steel structure and the impact to the shaft geology. At that point, the repair options were evaluated. The following performance criteria were established:

- All shaft structural steel support timber materials needed to be removed;
- The shaft structural steel support structure needed to be positively braced to the rock;
- The rock surface needed to be stabilized; and
- The shaft needed to be protected from future rock falls or spalls.

Many repair methods were evaluated that met the design criteria. After thorough evaluation of the repair method options, the team determined

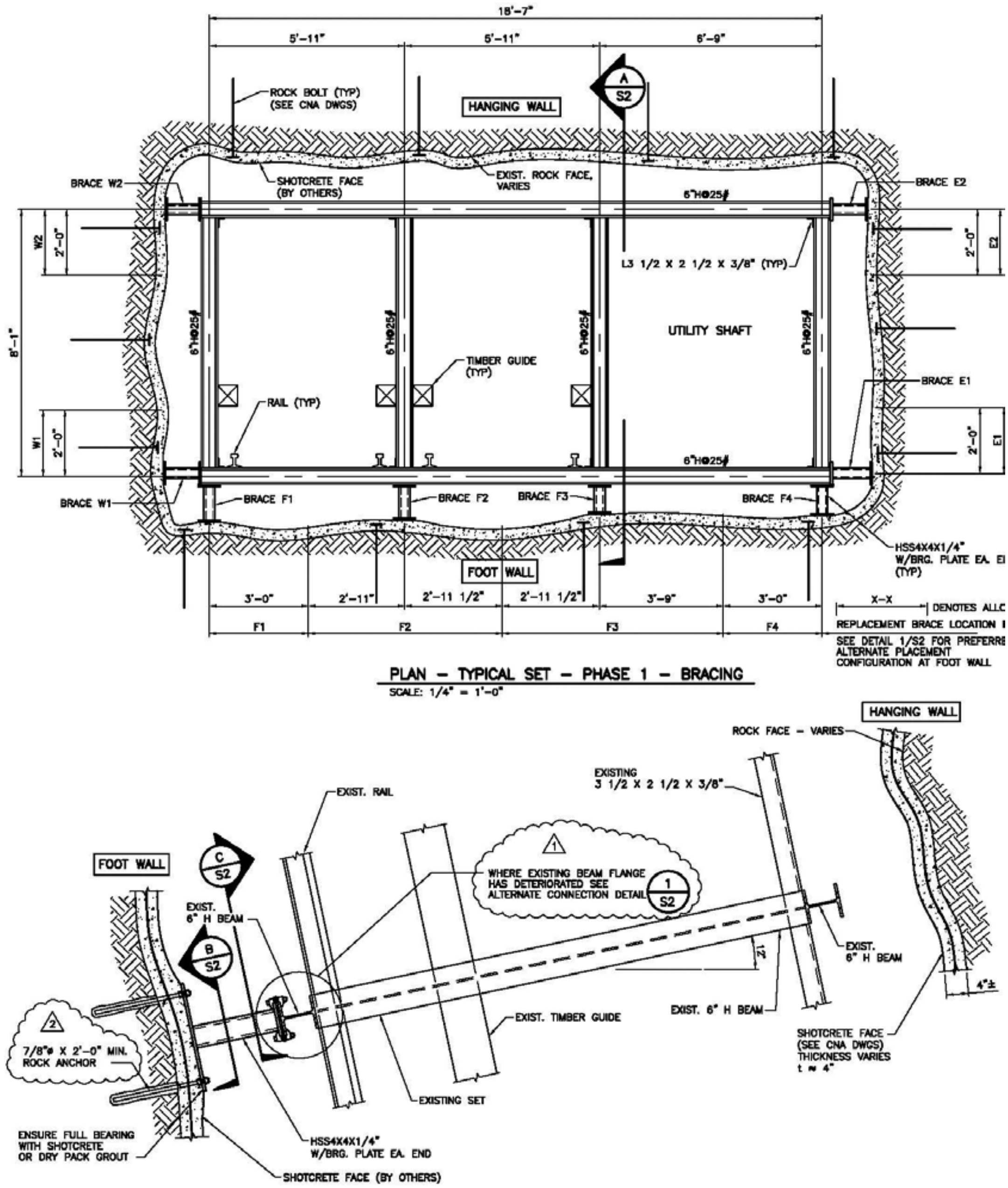


Fig. 1: Plan and profile section of the shaft repair (Note: 1 in. = 25.4 mm; 1 ft = 0.328 m)

that an upgraded structural steel support system with a reinforced shotcrete shaft lining was the most time- and cost-effective option.

One challenge to placing shotcrete on this project was that dust had to be minimized due to the proximity of sensitive laboratory equipment. Conveyance of bulk prepackaged shotcrete material to the repair area was difficult because of the available sizes of the shaft cages, and establishing an underground mixing plant at the available levels was impossible without extensive mining. Because of the physical constraints underground, ECI selected to establish on-site batching operations at the surface and pump the shotcrete from the surface down the shaft approximately 2300 ft (700 m) to the placement areas. To pump the required distance, a high-slump, self-consolidating mixture was designed with accelerator introduced at the nozzle. The product was to be pumped through a 2 in. (51 mm) line. A surface and procedure test was conducted, including full-mixture testing and the production of test panels. Once the shotcrete mixture and placement techniques were worked out, 2 in. (51 mm) slickline was installed in the shaft to the work area.

After the shaft and steel support structure was temporarily stabilized, the final repair was executed in stages from the upper limit of the damage to Level 27. The average stage length was 8 to 10 ft (2.4 to 3 m) and included removing the steel sheeting between the support sets,

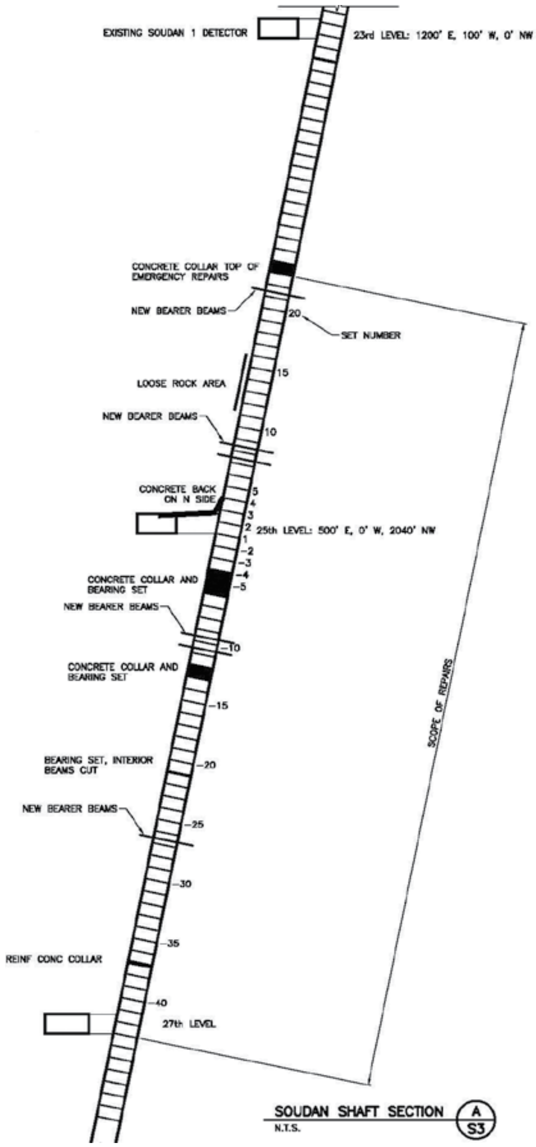


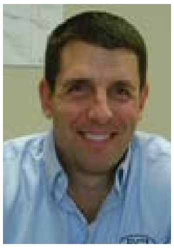
Fig. 2: Elevation view of the shaft repair area

Fig. 3: Application of shotcrete on shaft wall

Fig. 4: Bottom of shaft

removing all support timbers and loose or delaminated rock, installing new steel support columns, installing rock-bolts and reinforcing bar, and applying a minimum of 4 in. (102 mm) of shotcrete. Executing the work in this procedure ensured that personnel were always working under a safe, stabilized, and shielded environment. Shotcreting operations commenced in September 2011 and were completed in February 2012; the entire project was completed in May 2012. Approximately 500 yd^3 (280 m^3) of shotcrete was placed on this project.

This project was very difficult and risky for many reasons, including working at height, risk of falling objects, confined space, limited working room, obstructed access, and restrictive physical parameters. Shotcreting with the unique mixture design and engineered delivery system enabled the project team to deliver the project in a timely and cost-effective manner.



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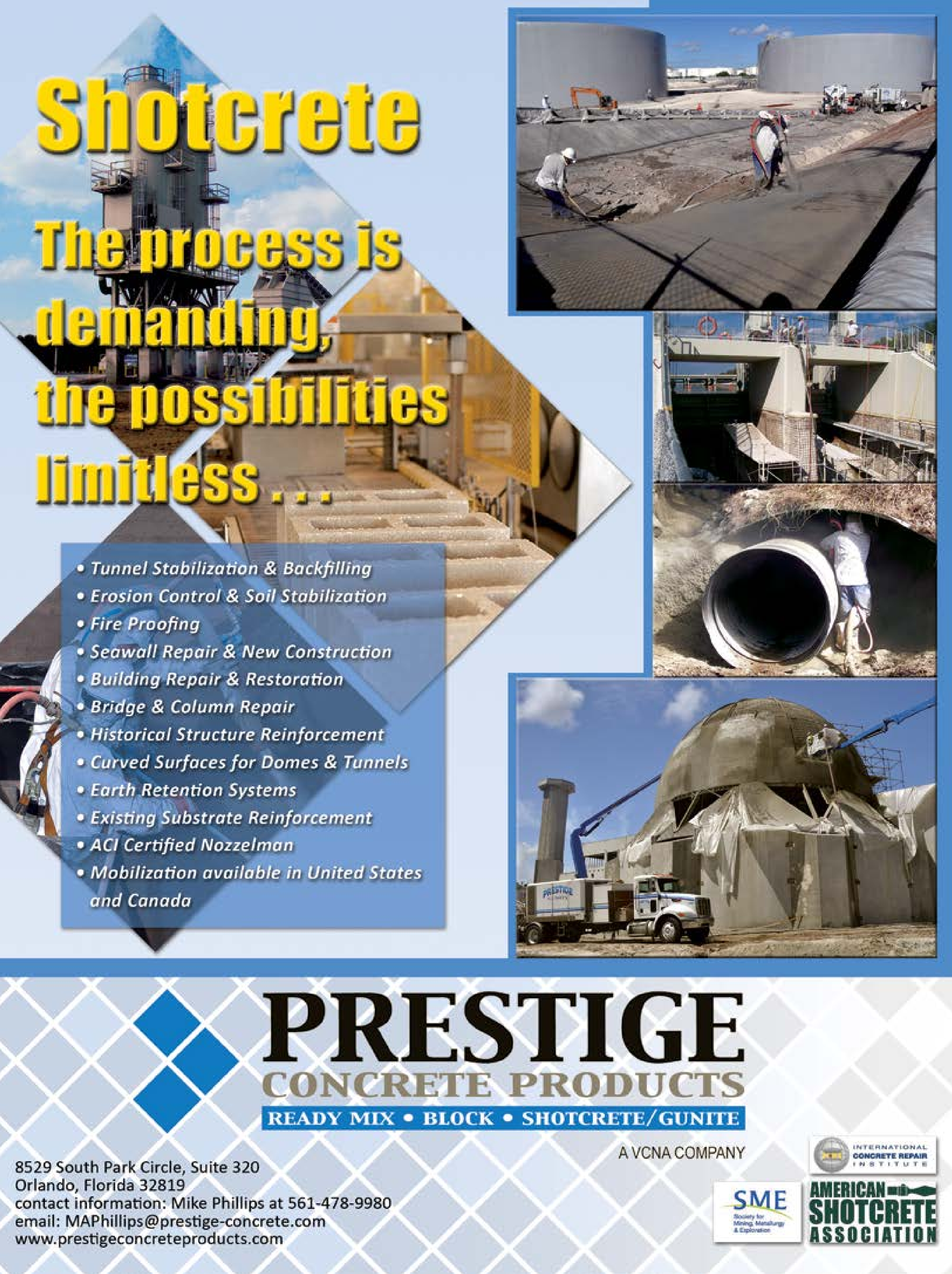
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The Oregon City Bridge, Part II

By Marcus H. von der Hofen

This is the second of two articles discussing the Oregon City Bridge. The first article, "The Oregon City Bridge, Part I," was published in the Fall 2012 issue of Shotcrete *and discussed the historical background of the bridge. This article covers the recently completed rehabilitation project.*

The Oregon City Arch Bridge Rehabilitation project was officially completed on October 31, 2012, by the Wildish Standard Paving Company. Dedication to quality and professionalism, along with a true partnering between owners, contractors, and suppliers, helped find ways to solve problems that could have easily turned the project into overwhelming confrontation and failure. This article is dedicated to those who pride themselves on working toward the best solutions.

Wildish was tasked with renovating a historic bridge that is 90 years old, replacing structurally deficient components and accurately replicating the details and architectural features of this Conde McCullough through-arch bridge. McCullough's signature detailing is evident in the arches, obelisk pylons with sconce light fixtures, ornate railings, and art deco piers. It is believed to be the only bridge of its kind in the entire United States—a through-deck steel arch covered with shotcrete that incorporates concrete spandrel columns, corbels, a sidewalk, deck approach spans, and a bridge rail (refer to Fig. 1).

The shotcrete covering had caused many a bridge expert to be deceived into thinking this was a structure made entirely of concrete. In all actuality, it is a steel structural arch design encased in shotcrete to protect it from the emissions from industries located in close proximity. Originally placed using the dry-mix method nearly a century before, the protective concrete would need to be removed and replaced to the original lines and grades (refer to Fig. 2 and 3).

One of the first questions to contemplate was: Should it be done wet or dry? Should it be both? Today's shotcrete technology offers efficient site batching of material in small amounts both wet and dry; state-of-the-art batch plants and testing facilities also allow ready mix producers to perform various adjustments and quality control that simply was not available 90 years ago. The project has areas that really lend themselves to either method. The bottom line in this case came down to what the personnel felt the most comfortable with. I don't find this reason brought up in the discussion very often, but it really should be part of the process. Many contract specifications are

Fig. 1: Oregon City Bridge—multiple access methods

Fig. 2 and 3: Shotcrete placement inside the arches written making the choice, and I personally don't think that is the right answer. The fact is that many jobs can be done efficiently and correctly either way, so the choice should be left up to the qualifications of the contractor.

In this case, my personnel and I agreed that we could perform the job more effectively using the wet process. At first, I believed that we would do the project using both site-batched bagged material and ready mix. After initial testing, I became convinced that the ready mix supplier CEMEX, with whom I had a long working relationship, could lend invaluable expertise to the project. As it turned out, it was a good decision (or maybe just lucky) on my part, as their ability to provide extensive resources, quality information, and testing played a large part in the success of the project.

Initial trial batches based on the project specification seem to function reasonably well, but there were definitely some issues. The specification called for specific levels of 8% or less boiled absorption. The initial test came back at 7.6 to 7.9%, leaving little margin for variation. Secondly, there was a great deal of reluctance to allow a hydration stabilizer because it might affect the bond. The bond was specified at 150 psi (1 MPa) shotcrete-to-steel, but no data were available showing this was achievable. The specification required hydrodemolition of the existing shotcrete followed by an abrasive blast of the surface. This created some degree of ambiguity. Thus, it was decided that a surface preparation mockup test should be conducted.

The initial surface preparation test section was divided into three areas: one with a walnut shell blast, the second with a light sand blast, and the final area with just an air and water blast. The initial process was the belief that minimizing the removal of the existing material (steel surface and attached mesh) would be a good approach, and to then build the sections back up from there. The surface preparation tests had almost identical results from each of the three methods, with values ranging from 0 to 120 psi (0 to 0.83 MPa) with the majority being 0. After this initial test, it was obvious that more extensive testing would be required. Steel road plates were used to represent the bridge surface during the next test, which included a variety of differing parameters, including more extensive sand blasting, bonding agents, accelerators, hydration stabilizers, and different curing methods. In the end, a complete white blast of the steel surfaces proved to be the most effective with a multi course sandblast material. But even then, the results were still not very consistent. Sections would bond well and meet the specification and others would have no bond at all. Another effect that seemed to be creating the variability was the shrinkage and the

Fig. 4: Repairing mesh prior to shoot

Fig. 5: Positioning the equipment for the next shoot

Fig. 6 and 7: Ever-changing shooting positions flexural properties of the shotcrete material. The specification called for minimum levels of silica fume and cement, but we decided we needed to rethink this.

This is typically where I've seen a great number of projects become dysfunctional. The focus changes from getting the job done correctly to minimizing the damage and protecting one's best interest. The parties become more adversarial than trying to work together to solve the problems and move forward. Fortunately, with this project, the Oregon Department of Transportation (ODOT) and its team stepped up not only financially but also (and more importantly) remained focused on finding the best solutions. I believe their role was instrumental in allowing both the contractors and suppliers the means to find the best answers in a timely manner. I think a statement made by a member of Wildish Standard Paving sums it up best:

"Our shotcrete applicator was committed to achieving the very best mix design that could be developed. From the original mix we reduced the silica fume content; used other supplemental cementitious material, including fly ash and added fiber; and a W R Grace retarder to slow the set time. After developing eight different trial batches for the project, they were able to identify a concrete mix that exceeded the requirements of the specifications, while offering better adhesion and more elasticity than originally specified. Were it not for their perseverance in obtaining the best possible product, the shotcrete applied to the bridge might have met the original project specification, but would not have been as durable over the years. From the original mix, which produced a 10 to 30 psi (0.07 to 0.21 MPa) bond pulloff strength, we increased to getting over 300 psi (2.1 MPa) with the final mix."

I would add, it was really the commitment of all the parties to achieve the best quality and durability that allowed this to take place (refer to Fig. 9).

As a result of the efforts by many, including Wildish Standard Paving, Johnson Western Gunite, CEMEX, and ODOT, the project team rehabilitated a beautiful historic landmark of the region in a safe and effective manner. Through working together toward a mutually desired end goal, I believe we produced a durable, serviceable, and aesthetically pleasing project that will be enjoyed by many generations to come. For information on the concrete mixture designs and specific test results, please contact ASA.

Fig. 8: Overhead finishing

Fig. 9: The finished product

***Marcus H. von der Hofen**, Vice President of Coastal Gunite Construction, has nearly two decades of experience in the shotcrete industry as both a Project and Area Manager. He is an active member of American Concrete Institute (ACI) Committees 506, Shotcreting, and C660, Shotcrete Nozzleman Certification. He is a charter member of ASA, joining in 1998, and currently serves as Secretary to the ASA Executive Committee.*

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Meadow Brook Hall Historic Bridge Restoration

By Jessica S. Farley

Meadow Brook Hall was built in the early twentieth century from the successes of automobile mogul John Dodge, his widow Matilda Dodge, and Matilda's second husband Alfred Wilson. After John's death, Matilda purchased additional acreage at their farm property in Rochester, MI, expanding the home to include 1200 acres (490 hectares). The construction of the main house included 88,000 ft^2 (8200 m^2) of space in the much-celebrated Tudor Revival style. Their home and surrounding acreage was donated to Michigan State University – Oakland, later to become Oakland University. Last year, the main house and 37 associated farm buildings and structures were recognized by the United States Secretary of Interior with a designation by the National Park Service as a National Historic Landmark.

RAM Construction Services was awarded the contract to restore the bridge adjacent to Meadow Brook Hall (refer to Fig. 1). The work consisted of wood, brick, and concrete repairs. The decorative wood railing was completely replaced with a new custom white oak railing. The deteriorated brick veneer on the piers was removed and replaced with a blend of three brands of brick for a perfect match to the existing masonry.

The structural concrete beams under the bridge had deteriorated to such a degree that the bridge was considered unfit for large tour buses to pass. A coating was applied to the concrete on a previous repair that was not breathable and trapped all moisture and further deteriorated the concrete and reinforcing steel. The repairs necessary to restore

Fig. 2: Underside of bridge prepared for repair

Fig. 1: Bridge approach to Meadow Brook Hall

Fig. 3: Placement of shotcrete under confined working conditions

Fig. 4: Close-up of shotcrete placement

the structural beams consisted of full- and partial-depth concrete removal and replacement (refer to Fig. 2). The use of shotcrete was an integral part of this repair. With the difficulty of access to the underside of the bridge, logistics, and the confined working space, dry-mix shotcrete was the smart choice (refer to Fig. 3 and 4).

All materials and equipment were at the top of the bridge and just the hoses were mobilized to the work area. The ACI certified nozzlemen at RAM Construction repaired a total of 1200 ft^2 (110 m^2) of concrete on the structural beams. All of the exposed reinforcing steel was cleaned and coated or replaced if deterioration was significant. All seven support beams were finished to the original historic "chamfered" profile (refer to Fig. 5).

One of the main concerns of the owner's representatives at Meadow Brook Hall and Oakland University was to not impede the schedule of main events, including weddings that took place during the week and on weekends. According to Damian Farmer, Project Foreman for RAM Construction, planning the work around the schedule of events at Meadow Brook Hall was the most challenging part of this project. With the multiple mobilizations, using the dry-mix shotcrete method was an advantage to decrease the duration of the project while offering a cost saving to both the owner and contractor.

This project is reminiscent of the "glory days" of the automobile industry in Metropolitan Detroit. The triumph of the Meadow Brook Hall bridge renovation and revitalization symbolizes the historic turnaround of the auto industry and Detroit (refer to Fig. 6).

Fig. 5: Finishing the beams

Fig. 6: Oakland University's Meadow Brook Hall Bridge

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Jessica S. Farley *is a Project Manager at RAM Construction Services and has over 12 years of experience in the Masonry Restoration industry as a Project Manager/Estimator. She specializes in historic preservation of masonry buildings and structures, including replacing; repointing; and patching of brick, stone, terra cotta, and concrete. Farley is the Developer and Co-Chair of the Masonry Restoration Technical Committee, an in-house committee that focuses on standardizing work procedures in the field and educating on historic practices and techniques.*

Surface Preparation for Shotcrete Repair

By Simon Reny

When placing shotcrete in a concrete repair application, one cannot overstate the importance of the bond between the shotcrete and the concrete substrate. This bond is a critical factor in determining the overall performance and durability of a repair. Research has demonstrated that bond strength between the concrete substrate and the concrete repair, whether it is shot or cast in place, is directly related to the quality of the surface preparation, as demonstrated by Talbot et al.[1] Good surface preparation requires correct concrete demolition practices and properly cleaned surfaces. This Technical Tip briefly covers the best of these techniques for preparing the receiving surface of a shotcrete repair. The first section will cover demolition of the deteriorated concrete. The second section will treat the surface-cleaning requirements. The third segment will explain quality control testing of the surface preparation.

Concrete Demolition

Concrete structure rehabilitation requires proper removal of deteriorated concrete to a sound concrete substrate before the surface preparation takes place. Qualified personnel must first determine the deteriorated concrete area and mark the surfaces to be repaired. It is recommended, but not mandatory, to saw cut the perimeter of any concrete sections to be repaired, and feather edging should be prohibited. The saw-cut perimeter separates the repair area from sound concrete. The depth of the saw cut also determines the minimum thickness of the repair. To prevent further damage to the sound concrete and ensure long-term performance of the repair, hydrodemolition (refer to Fig. 1) is the preferred concrete demolition method, as it is most effective in preventing the concrete substrate from further damage, such as microcracking, that often results from using impact hammers. It is strongly recommended to conduct a test on a concrete sample that best represents the project conditions before the project begins to calibrate the pressure of the hydrodemolition equipment to obtain the desired results. It is also acceptable to use other methods, such as jackhammering, but the equipment used should be selected to minimize the potential damage by microcracking of the substrate.

Fig. 1: A concrete surface after hydrodemolition

Surface Cleaning

After the concrete removal process is completed, it is recommended that all exposed concrete surfaces be cleaned with a high-pressure water blast or with wet sandblasting, as dry sandblasting can be a safety hazard in some areas (refer to Fig. 2). This statement does not apply in the case of the hydrodemolition surface preparation method because this method provides the same result as water or sandblasting.

It is important to differentiate high-pressure water *blasting* and normal high-pressure water *washing*. High-pressure water blasting characteristics are considered to be as effective as wet sandblasting and are capable of cutting into the concrete surface. Depending on the concrete substrate quality the required pressure can vary between 3000 and 7000 psi (21 and 48 MPa). Normal high-pressure water *washing* requirements can be defined as follows: pressure (2200 psi [15 MPa]) and flow (5.3 gal./min [20 L/min]).

High-pressure water washing is mandatory for the last cleaning procedure before shotcreting

Fig. 2: High-pressure water blasting the concrete substrate after concrete removal with a jackhammer

starts, even when hydrodemolition is used. Although this procedure may seem redundant, it is a crucial step to ensure good quality bond between the substrate and the shotcrete repair by removing any microfractured concrete, dust particles, debris, and loose sand. This procedure is specified by the Ministry of Transportation of Quebec.[2] In addition to the cleaning procedures, it is also recommended that adequate prewetting of the concrete substrate is performed before shotcreting (refer to Fig. 3). This procedure has been described by Dufour et al.[3] Concrete substrates should be in a saturated surface-dry (SSD) condition immediately prior to the shotcrete application.

Bonding agents are never recommended when using the shotcrete process. Firstly, it is not necessary, as the shotcrete process provides excellent bond by itself. Secondly, if the bonding agent is not installed properly or the shotcrete material placement is delayed and the bonding agent dries out before the repair material is placed, the bonding agent will act as a bond breaker. Thirdly, it is another step added to the repair process. The more steps one adds to the repair process, the greater an opportunity for mistakes to happen. Finally, it will also create two layers where there could be potential for debonding instead of only one, which also increases the risk of failure. These comments on bonding agents are also reported in the Report Number MERL 12-17.[4]

Surface Preparation Testing

Evaluating the quality of surface preparation and ultimately the durability of bond is a critical factor in determining the quality of a repair. At the beginning of a major project, a qualification test of the repair method should be conducted. A representative surface area should be prepared with the selected technique and repaired with the chosen repair method. After a certain period of

Fig. 3: A worker prewetting the concrete substrate

time (for example, 28 days) after the repair is complete and the shotcrete has developed adequate strength, a pulloff test (refer to Fig. 4 through 6) should be conducted according to ICRI Technical Guideline No. 210.3-2004.[5] A proper bond should be typically higher than 145 psi (1 MPa), as reported in ACI 506R-05[6] but this value can vary depending on the substrate to repair, as mentioned in the Report Number MERL 12-17.[4]

Fig. 4: A pulloff test being conducted on a test panel (photo courtesy of the Centre de recherche sur les infrastructures en béton (CRIB))

Fig. 5: Extracted cores after pulloff tests (photo courtesy of the CRIB)

Fig. 6: A hole after a core has been extracted during a pulloff test

The values obtained during the qualification of the repair method should be treated as a reference for the rest of the project. To assure quality during the project, surface preparation should be tested by repeating the pulloff test periodically.

Conclusion

A strong, durable bond is critical to a successful concrete repair. Surface preparation is a key element to achieving a strong, durable bond, but other aspects should not be neglected, as they also play a significant role in bond performance. Curing, carbonation, material selection, exposure, and load transfer, among many other factors, can influence the bond of any repair system.

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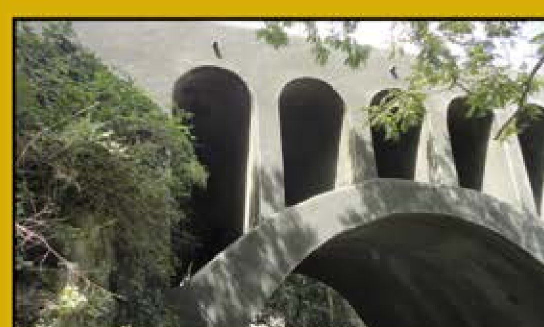
***Simon Reny**, Eng., is Manager of the Technical Services for King Packaged Materials Company (an ASA Corporate Member), where he is responsible for all mixture design development, quality control, and technical support. He received his degree in civil engineering from Laval University in 2004. He is a member of the American Concrete Institute; an associate member of ACI Committee 506, Shotcreting; and is a member of the Shotcreting-Guide Subcommittee and the Shotcreting-Underground Subcommittee. He is also currently President of the International Concrete Repair Institute's Quebec Chapter.*



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Perfecting Placement

By William T. Drakeley Jr.

Concrete is the construction material used most by humankind—wood, stone, brick, asphalt, and glass don't even come close. In a sense, our world is made out of concrete and I am among those who believe the very best way to apply it, without question, is by way of the shotcrete process.

The reason that shotcrete, both dry and wet (both versions of the "pneumatically applied" process) are superior to other forms of properly mixed concrete application boils down to one word—velocity.

When you shoot concrete onto a form or the earth at 300 to 400 feet per second (90 to 120 m per second), it compacts and becomes dense. The problem is, most people, even those in the pool and spa industry who use shotcrete on a regular basis, often don't understand the basics of installation, beginning with proper velocity.

That starts with an air compressor with enough air volume to deliver the required material at the desired speed. Unfortunately, most companies I've come in contact with use compressors that are undersized, delivering, say, 185 cubic feet per minute (CFM) [315m^3/hr]— not nearly enough capacity to drive the wet mix properly into place. (More on compressor size below.)

That's just one common mistake that compromises the end product. Beyond that most basic issue, there are a number of specific measures before, during and after the application process that must be scrupulously observed; otherwise, you'll wind up with an inferior product that doesn't provide the structural integrity necessary to create a watertight pool vessel. The ACI has always stated that structural concrete built for water retention or a water environment needs to have a minimum compressive value of 4000 psi [1.3 MPa] (ACI-318, ACI-350).

With that in mind, let's dive right into the basics of making the most of pneumatically-placed concrete.

Prior To Placement

To begin, you must be certain the substrates receiving the concrete are rigid and non-vibrating. That means your forms must not move during application and the soil has to be competent enough to provide a solid support. Your steel and

Proper shotcrete placement requires everyone, from the pump operator to the nozzleman, to know his role

form installations should be built to structural specifications based on the soil conditions and set up to withstand the impact of the concrete as it's shot into place.

One of the ironies here is that by using compressors that don't deliver adequate velocity, forms don't need to be as rigid to prevent movement. That's what one might call a fool's paradise, because as stated above, it's material velocity that produces reliable compaction. (Velocity = compaction, compaction = density, density = strength, strength = water tightness.)

Beyond that rigidity of the substrate, there are a number of other pre-placement issues, all of which, if not observed, will result in inadequate structural integrity.

- The excavation site should be free of standing water. You should have a layer of stone in the bottom of the pool to ensure control of subsurface water movement.
- Steel should be raised 2 to 3 in. (50 to 75 mm) above the floor and away from the sides. The American Concrete Institute specifies a minimum 2 in. (50 mm) coverage around any concrete encapsulated reinforcement. (ACI 350-06)
- Freestanding walls require support mechanisms so there is no vibration. These walls should be secured and fastened properly.
- All plumbing lines should be mounted firmly in place if they are to be part of vertical wall. Otherwise, run plumbing in the floor stone to avoid vibration during the shoot, and make sure the plumbing is pressure-tested. (Consider the difference in hassle and cost of correcting a plumbing problem before the concrete is installed versus afterwards.)

Wet v. Dry

Many in our industry believe that either wet shotcrete or dry shotcrete is superior to the other. That's simply not true — both methods can produce quality concrete if used correctly. The difference is that each method can be better for certain types of applications or certain regions of the country.

Our firm uses wet mix shotcrete because we work in high-volume applications most of the time, not only building large swimming pools but also doing work in highway and subway tunnels. Wet mix is better suited for those applications. Dry on the other hand is better suited for smaller applications when you're starting and stopping more frequently. Dry or wet are equally suited for the swimming pool industry.

So, the difference is really like the hammer and the screwdriver, it depends on the application. But for the record, both wet mix and dry mix are the best methods of concrete application, no ifs, ands or buts about it.

After placement, the success of the project depends on crucial details including "cutting" the interior structures to their exact specified shapes and wetting the concrete as it cures

- All of these preparations should be inspected and verified prior to the shoot.

What happens if you get these basic measures wrong? If you have movement of a pipe or a piece of steel, you'll leave a shadow or gap in the concrete which increases porosity and permeability. This can also lead to cracking.

In that scenario, even if the shotcrete applicator has done everything correctly, delivering concrete that measures 4000 psi [1.3 MPa] on a compression test, the flawed preparation results in an unsound structure, which in turn leads to surface failures or water loss.

Bottom line: Proper substrate, plumbing and steel preparation are essential to create a reliable concrete shell, no exceptions!

During The Shoot

Let's assume everything is right prior to the shoot, all verified and built to spec, the substrate is dry, free of debris, etc. Unsurprisingly, the application process also comes with an important checklist.

- First, be sure you have the proper equipment for the shoot. As mentioned at the outset of this discussion, undersized compressors represent one of the most common mistakes. Be sure the unit you're using can deliver that all-important (and highly recommended) 250 CFM (425 m^3/h) minimum for wet (shotcrete), or 700 CFM (1200 m^3/h) for dry (gunite). You can never really have too big a unit, because to compensate, you'll merely have to either step back or turn down output. Inadequate CFM is always, always the problem! In addition, you have to be sure the pump for wet mix or gun for dry mix respectively have the capacity or ability for the shot process.
- Equipment setup is crucial in that you want it as close to the shoot as possible. When you close the gap between the pump and where the material comes out of the nozzle, everything works better and more efficiently. In the pool industry we're doing small-line pumping, meaning we're working with 2-inch (5 cm) hoses, pumping or gunning between 8 and 10 yd^3 (6 to 8 m^3) of concrete per hour. When you are forced to shoot for distances of more than 100 ft (30 m), you have to account for the loss of velocity that takes place due to the friction inside the hose, as well as diminishing air pressure and changes to the concrete mix that occur over long distances.

When the wet mix concrete is pumped a long distance and the heat from friction builds, the composition of the concrete changes in that the liquids, fines and cream begin to migrate to the interior surface of the pipe while the aggregates stay in the center. When you have that separation of material, the aggregate may not be properly coated by cement paste, which means you're not delivering a mix design to the nozzle that can be properly placed.

- When shooting, shoot everything. What I mean by that is never start hand-packing large volumes of material. This does not mean finishers can't hand-compact and work into place material at guide wires with finishing tools. Again, the velocity is critical in that it is necessary to compact the material and fully coat the aggregate. When you start placing shovels full of material by hand, the process is no longer monolithic. Do not, under any circumstance, use rebound in steps, walls, benches, floors or anywhere else. When you hand-pack, you are no longer using pneumatically-placed concrete. You'll get weep holes, seams, separations and all sorts of points of weakness in the material.
- The distance between the nozzle and the substrate should be no farther than 6 ft (2 m), always at a 90-degree angle to the receiving surface.
- Always start in the corners or the radius first. It reduces trapped rebound, which is generated to a greater degree when first applying the material to the substrate.

Shooting in layers: I'm a proponent of full-thickness shooting, meaning you don't build up the walls and floor in layers. The concern is that the material won't stand up beyond a certain thickness. When shooting steps or other structures that are more than 12 in. (300 mm) thick, we will use a layering technique. For walls and floors up to 12 in. (300 mm), we use a full-thickness shooting technique. Layered shooting is absolutely acceptable as long as each previous layer has been properly prepped to receive new materials.

- Air temperature can be an issue. According to ACI, you should be shooting between approximately 40 and 100°F (4 and 38°C). You can bypass those parameters with mix chemistry in the form of either retarding agents or accelerants. Personally, I'm not a big proponent of admixtures for the pool industry in a local short travel shoot because in most cases simplicity of mix design is better understood with most pool crews.
- Thieves of strength: In order to achieve desired strength, you must avoid the "thieves" that will reduce strength. First, do not add extra water to the mix for the sake of speeding up the placing process. Doing so will result in shrinkage cracks and other failures. Next, when the concrete mix truck arrives, start shooting right away. You always want to use the material within 90 minutes from when the truck was loaded or 45 minutes from when your material is placed in the dry-mix gun to maintain proper moisture content. Next, you need proper ratio of cement, aggregate and water. A typical ratio is four to one aggregate to cement. If you decrease the binder/Portland to save money, you're cheating the end product because you're not properly coating the aggregate with cement paste.
- Orchestration: The process of applying either shotcrete, dry or wet, should be carefully choreographed. A typical crew consists of the nozzleman (the most important member of the team), along with the pump operator or gun operator, hose tenders and finishers. Everyone needs to know their job and be aware of what's going on as the work progresses. The best crews anticipate what's happening and make appropriate adjustments for each other.

Post Shoot

- Once you've finished shooting, a thorough cleaning of the equipment is critical. All hoses and the nozzle need to be free of any residual material. This is essential for proper function at the next shoot.
- Setting up for curing is the next step and of extreme importance. The concept is simple enough. You have to make sure the surface stays wet as the concrete cures to prevent the evaporation of mix water. The idea is to allow the water in the mix to hydrate all the cement particles. The more particles you hydrate, the more strength you gain. Those chemical reactions generate heat, which promotes evaporation of the mix water. Therefore, you want to keep the exterior temperature cool, which in turn reduces evaporation and leaves more water available for the hydration process—all of which leads to a stronger end product.

Contrary to what some people think, you're not adding water to the surface with the idea that it's penetrating into the concrete. If that's happening, the concrete is no good to begin with. You're curing to minimize temperature gain, which in turn minimizes evaporation and maximizes strength.

The surface should remain wet for the first seven days minimum. You can use misters, soaker hoses, sprinklers or even wet burlap if you're in an area with water restrictions. However you do it, the concrete must be wetted for at least seven days.

Elevating The Game

If you follow the above measures with each and every project, your results will be far superior to the majority of concrete pool structures now being built. In my years studying pneumatically placed concrete and teaching people in our industry how to do it correctly, I've found numerous examples where every basic step I've outlined here has been compromised to some degree or another.

The result is an inferior end product usually of low compressive strength, all of which leads me to a final point.

Over the past few years I've stirred up more than my share of controversy saying that waterproofing agents should not be necessary. The reason I say that is if you initially (design the mixture and shoot to) achieve 4000 psi (1.3 MPa) concrete, the shell is well on its way to becoming water tight without any additional membranes, coating or penetrating sealers. Unfortunately, the vast majority of projects don't meet that standard and waterproofing becomes a necessary prophylactic measure.

I'm not an opponent of waterproofing per se, but rather a proponent of quality concrete. When these fundamentals are followed, we create structures that will endure the test of time. Miss those marks and you've stacked the deck in favor of failure.

Consider this final thought: In the end it doesn't cost more to do the job right, it only requires that you embrace a set of basic and necessary steps. Doing so will ultimately save money and heartaches down the line.

There's simply no downside to doing the job correctly. I'll go so far as to argue that as professionals we have what amounts to a moral obligation to follow guidelines set forth by ACI/ASA and give our clients the best possible concrete structures (yes, a shell that does indeed hold water), each and every time you fire up the equipment.

Seamless Structures

In shotcrete, there's no such thing as a cold joint. You can stop shooting and come back a year later and if the surface and surround are properly prepared you can resume shooting and still come away with a monolithic structure.

We use a method called saturated surface dry (SSD), which simply means that after you've roughened a receiving surface, cleaned out the pores and the surface is free of loose material, it is then wetted or dampened as a condition of the substrate which helps ensure good bondability.

For many of our commercial projects, the vessels are so large that they require multiple days to shoot. Using the SSD procedure, we create what are known as construction joints, which in effect disappear completely once you resume shooting. It's not a so-called cold joint, control joint or expansion joint, these "joints" don't exist in shotcrete construction.

William T. Drakeley Jr. *is President of Drakeley Industries and W. Drakeley Swimming Pool Company. Drakeley Industries is a shotcrete consulting firm that is dedicated to the training and implementation of the shotcrete process in regards to building water-retaining structures, ground support, and underground shotcrete application. Drakeley Pool Company is a design/build construction and service firm specializing in in-ground, high-end commercial and residential pools. Drakeley is an active member of ACI Committee 506, Shotcreting. He is the first ACI Certified Shotcrete Examiner from the pool industry nationwide. Drakeley is also an ACI Certified Nozzleman, ASA Board of Direction member, ASA Technical Advisor, and Chair of the ASA Pool & Recreational Shotcrete Committee. His writings have been published in national and international trade magazines, including* Shotcrete*,* Watershapes*,* Pool and Spa*, and* Luxury Pools *magazines. In addition, Drakeley is a Platinum Member of the Genesis 3 Group, a licensed member of the Society of Water Shape Designers, and a member of the Association of Pool and Spa Professionals (APSP). He is also the concrete/shotcrete instructor at the Genesis 3 Pool Construction Schools and NESPA Region 1 Show in Atlantic City. As an instructor/trainer, Drakeley has given lectures on shotcrete applications for various pool trade shows and for World of Concrete. Drakeley is an Expert Witness regarding shotcrete applications for the swimming pool industry.*


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Shotcrete Work in Confined Space Areas

By Ted Sofis

Shotcrete work, by its very nature, provides an excellent method of installing concrete materials in storage bins, hoppers, culverts, inlets, vaults, tanks, and other areas, where it is difficult to transport and efficiently install materials by conventional casting methods. The shotcrete equipment and materials can be staged outside the enclosed area and the gunning hose can be fed in through an access hatch, a manhole, or any other small opening to convey the shotcrete material into the internal enclosed area and onto the receiving surface. Many of these tight or restricted areas are regarded as confined spaces. When working in confined spaces, it is of utmost importance to ensure the safety of those working in the enclosed area and to follow all OSHA safety requirements (refer to Fig. 1 through 3).

OSHA defines a confined space as a space that has a restricted or confined area that hinders the activities of employees who must enter, work in, and exit from the space. Such areas fitting the definition of a confined space have a limited or restricted means of entry or exit and are not designed for continuous employee occupancy. Confined spaces may include inlets or manholes, vaults, process vessels, tanks, excavations or pits, boiler dead air spaces, or a multitude of other areas where the configurations and entry issues meet the defined criteria.

Permit-required confined spaces are spaces that OSHA describes as having one or more of the following characteristics: contains or has the potential to contain a hazardous atmosphere, contains a material that has the potential to engulf the entrant, has walls that could converge or collapse inward, a sloping floor or bottom that slopes into a taper or smaller area that could trap or asphyxiate the entrant, or contains ANY OTHER RECOGNIZED SAFETY HAZARD. These may include unguarded machinery, exposed live wires, or high-temperature areas that can cause heat stress.

When dealing with permit-required confined spaces, it is mandatory to have an attendant at an opening into the confined space at all times while entrants are in the space. There are specific OSHA

Fig. 1: Worker entering a manhole opening into a confined space along the side of a ventilation tube

Fig. 2: In confined areas like this steel mill smokestack and ductwork, a refractory lining is being gunned in place using the dry process

Fig. 3: In this confined space area in a power plant ash pit, dry-process shotcrete is being gunned in place

Fig. 4: Nozzleman shooting overhead in a tightly confined area. In areas where visibility and ventilation are concerns, adequate lighting should be provided and the appropriate personal protective equipment should be worn

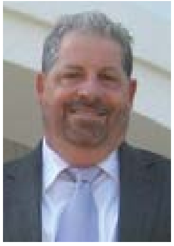
requirements for the entry supervisor, the attendant, and the entrants that must be followed. Before the initial work assignment begins, the employer must provide training for all employees who are required to work in permit-required spaces. If anything changes, additional training becomes necessary. Atmospheric testing is required for two reasons: evaluation of the potential hazards of the permit space and verification that acceptable atmospheric conditions exist for entry into the space.

There are many additional OSHA requirements regarding written safety plans, entry permits, retrieval and rescue operations, identification of hazards, and training, so please refer to OSHA Standards 29 CFA 1910.146 for all the specific requirements and procedures.

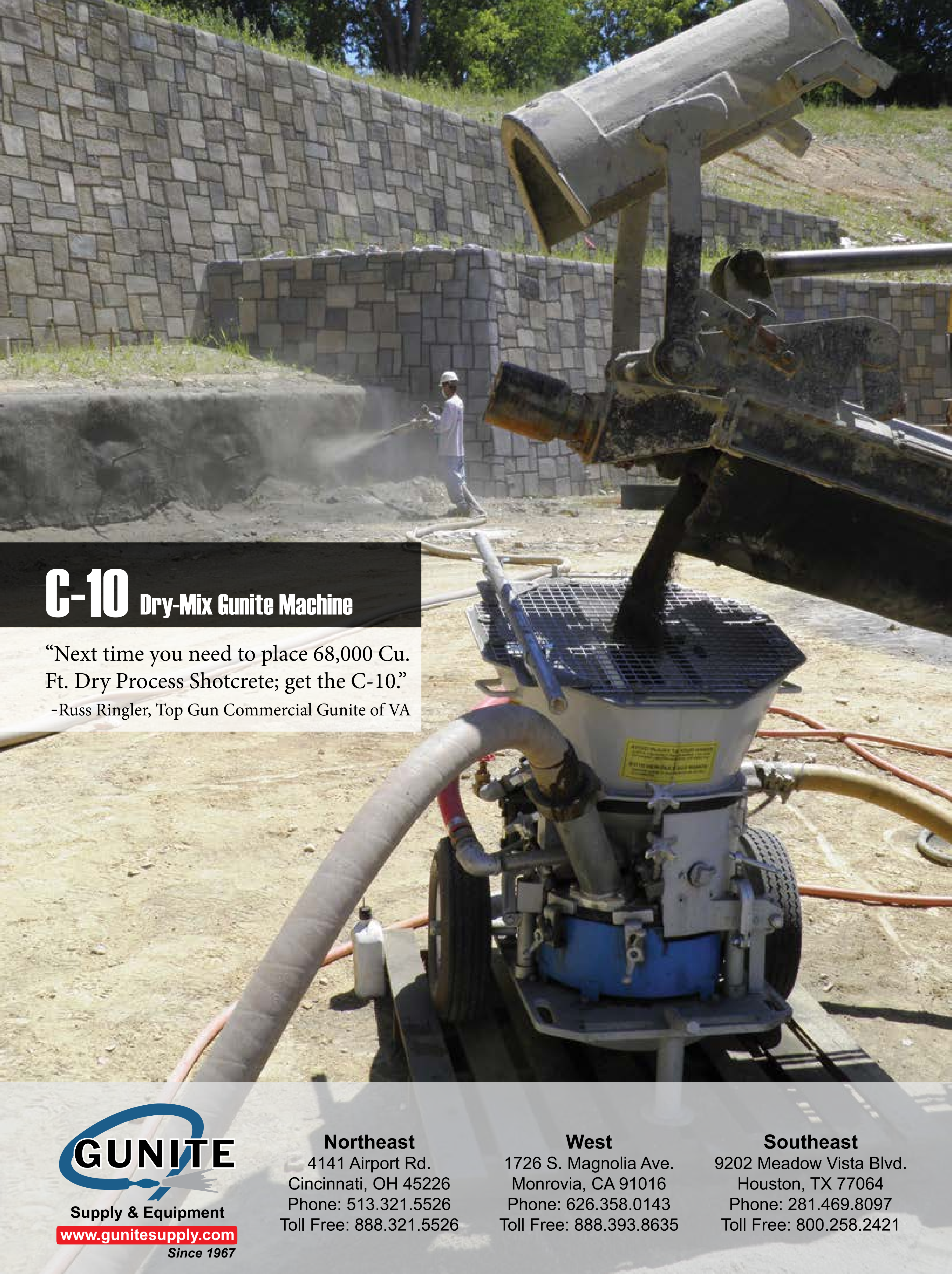
In addition to the specific OSHA requirements, there are a few rules of thumb that warrant mention and are specific to shotcrete applications. First and foremost is having and maintaining good communication. It is imperative that clear radio or wire communication exist between the nozzleman and others working within the confined space, and with the equipment operator outside. In the event of a problem, such as with a plug-up or an injury, the material flow can be shut off quickly. Also of concern is visibility; in enclosed areas, it is important to have adequate lighting. It is not only necessary for the nozzleman to see well for his gunning but it is also imperative that those inside the space can see and clearly identify any obstacles and potential hazards. Finally, with confined spaces, ventilation options can often be limited, so care should be exercised to provide proper respiratory protection for the workers (refer to Fig. 4 and 5).

Fig. 5: Dry-process shotcrete being gunned overhead in an underground culvert

It is good practice to identify all the potential hazards beforehand. Make sure that the workers have received the necessary training, that they wear the proper personal protective equipment, and that all OSHA requirements are addressed and followed. No one wants to see an injury or a fatality; the OSHA standards were established for this reason. Therefore, in addition to your concerns involving the performance of the work, take the additional measures to ensure a safe workplace.



Ted Sofis *and his brother, William J. Sofis Jr., are the Principal Owners of Sofis Company, Inc. After graduating from Muskingum College, New Concord, OH, with his BA in 1975, Ted began working full time as a shotcrete nozzleman and operator servicing the steel industry. He began managing Sofis Company, Inc., in 1984 and has over 38 years of experience in the shotcrete industry. He is the Treasurer for ASA, Chair of the ASA Publications Committee, and a member of multiple ASA committees. Over the years, Sofis Company, Inc., has been involved in bridge, dam, and slope projects using shotcrete and refractory installations in power plants and steel mills. Sofis Company, Inc., is a member of the Pittsburgh Section of the American Society of Highway Engineers (ASHE) and ASA.*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Top Ten Sustainability Benefits of Shotcrete

The United States Green Concrete Council's (USGCC) book, *The Sustainable Concrete Guide—Applications*, includes a list of the top 10 sustainability benefits of shotcrete in its chapter on shotcrete. Over the next 10 issues of *Shotcrete* magazine, this Sustainability column will elaborate on each one of the listed advantages. Previous discussion of advantages from past issues can be viewed on the ASA website at **www.shotcrete.org/sustainability**.

U.S. GREEN CONCRETE COUNCIL

1. Formwork savings of 50 to 100% over conventional cast-in-place construction.
2. Formwork does not have to be designed for internal pressures.
3. Complex shapes require very little—if any—formwork.
4. Crane and other equipment savings or elimination.
5. Labor savings of at least 50% in repair applications.
6. New construction speed savings of 33 to 50%.
7. Speed of repair reduces or eliminates downtime.
8. Better bonding to the substrate enhances durability.
9. **Adaptability to repair surfaces that are not cost-effective with other processes** (see below).
10. Ability to access restricted space and difficult-to-reach areas, including overhead and underground.

Adaptability to Repair Surfaces That Are Not Cost-Effective with Other Processes

The Abraham Lincoln Memorial Bridge, located in LaSalle, IL, is the longest bridge in the state, with a total length of 7122 ft (2170 m) and supported by 86 piers, with 43 in each direction. The bridge is elevated approximately 70 ft (21 m) above the Illinois River, numerous local roads, lakes, wetlands, and railroads. The piers range from 50 to 100 ft (15 to 30 m) high, 41 ft (12 m) wide, and 4 ft (1.2 m) thick at the caps while increasing to 6 ft (1.8 m) at the base. The piers span between 135 and 165 ft (41 and 50 m). (Refer to Fig. 1.)

Bridge deck access to the piers below was severely limited to a 10 ft (3.048 m) area adjacent to live traffic. Access on the ground was limited to only a handful of piers but they were virtually inaccessible, as they were surrounded by the Illinois River, wetlands, lakes, and the historic Illinois-Michigan Canal. For the piers that were surrounded by land, 70 ft (21 m) tall boom lifts were placed over the side of the bridge with cranes. Platforms set under the deck were constructively engineered as a safe way to be used at all finger-joint piers over the river, lakes, and wetlands that were otherwise inaccessible. (Refer to Fig. 2.)

The adaptability of shotcrete provided a superior solution to undertake the repairs. All of the shotcrete work was done from the bridge deck; and the use of shotcrete and its versatility had many advantages compared with other processes, such as form and cast. One example was the ability to remove concrete on the piers segmentally. On several piers that were severely deteriorated, one-third of the pier was prepared and then shotcreted to structurally replace the removed concrete. Once the shotcrete in the repaired section reached 70% of its required strength, the crew remobilized and repeated the procedure on the next one-third of the pier. This eliminated any concern for destabilization of the structure. (Refer to Fig. 3.)

Fig. 1: The Abraham Lincoln Memorial Bridge

Using a packaged, preblended shotcrete material mixed on site as needed allowed a fresh, quality-controlled mixture with a consistent water-cementitious material ratio (*w/cm*). Ready mixed concrete that would have been used in a "form-and-pour" process would have a short open time to work with after driving to the site from the batch plant. There would have also been risk of a form blowout and polluting the river and wetlands below the working area. Shotcrete was also chosen for safety reasons. The air and water hoses going over the side offer considerably less risk than lowering and roughly handling lumber in the limited spaces underneath the bridge deck. Also, if a problem occurred with concrete placement in the middle of casting the "form-and-cast" repair, it would be hidden inside the form and require removal of the form to correct. Shotcrete placement by an ACI certified nozzleman could immediately follow the surface preparation of the repair area by sandblasting or a high-pressure water blast of the edge of the patch. The shotcrete process allows a visual confirmation of full encapsulation of the reinforcing bars, while casting into a closed form could result with voids that aren't apparent until the formwork is stripped. The curing of shotcrete by use of wet cotton mats was superior compared to a form left in place because it provided supplemental water to the concrete for curing rather than depending on the original mixture water. Safety, time, quality, adaptability, and cost all significantly contributed to the use of shotcrete, which also resulted in a durable, affordable repair with enhanced sustainability benefits.

Fig. 2: 50 x 6 ft (15 x 2 m) platforms used to perform work

Fig. 3: 15,000 ft^3 (425 m^3) of removal and replacement

QUIKRETE Reshapes a National Historic Landmark

QUIKRETE CEMENT & CONCRETE PRODUCTS™ BOULDERSCAPE®

The QUIKRETE® Companies recently supplied shotcrete in 3000 lb (1361 kg) bulk bags for a restoration project on Alcatraz Island, also known as The Rock. Boulderscape, a premier design architect that specializes in shotcrete application, used QUIKRETE Shotcrete MS – Fiber Reinforced and QUIKRETE Shotcrete MS to successfully repair and stabilize a failing slope on the 22-acre island. In addition to facing dangerous application conditions, a condensed 6-week shotcrete schedule was required to avoid disruptions to regular tour operations while considering the habitat and migration patterns of local sea birds.

"Navigating a variety of unique factors made this a very fulfilling project for everyone," said Steve Jimenez, Senior Vice President of Commercial Sales for Boulderscape. "We couldn't start until the indigenous birds migrated from the island in November, and we had to complete our portion of the work before the birds returned in February, which meant everything had to be expedited starting with the delivery of material. Beyond the challenging schedule, the application process was full of danger. The nozzlemen had to be hoisted more than 60 ft (18 m) in lifts to spray apply the shotcrete before sculptors repelled down the cliff to shape the material. The end result was a structurally sound slope that matched the surrounding environment."

In one weekend, 131 bulk bags of QUIKRETE Shotcrete MS–Fiber Reinforced and 126 bulk bags of QUIKRETE Shotcrete MS were delivered to Alcatraz Island for the project. QUIKRETE delivered16 truckloads of material to Pier 50 in San Francisco before being shipped on two barges to Pier 33 on Alcatraz Island where it was offloaded at night by crane one-by-one before finally being transported to the job site on trailers pulled by four-wheel all-terrain vehicles.

QUIKRETE Shotcrete MS–Fiber Reinforced is a single-component micro silica-enhanced repair and restoration material that achieves more than 9000 psi (62 MPa) at 28 days and features very low rebound and permeability characteristics. The QUIKRETE Companies offers a full line of shotcrete products that can be applied through a wet or dry process to deliver high strength, high adhesion, low rebound, and low sag in rehabilitating bridges, tunnels, parking garages, ramps, piers, dams, and other concrete structures. QUIKRETE shotcrete has been used on many unique and high-profile renovation and restoration projects including the Pleasure Pier in Texas, the Stanford Linear Accelerator in California, the Spokane River in Washington, and the Dennis Edward Tunnel in Oregon.

For more information on QUIKRETE and its products, visit **www.quikrete.com**, Like it on Facebook, and follow it on Twitter @QUIKRETE.

Blastcrete's Concrete Pump Attachment Features Universal Design

Blastcrete Equipment Company, a manufacturer of concrete mixers, pumps, and related products, offers the Model RD6536 skid steer pump attachment.

The 3 in. (76 mm) hydraulic squeeze pump is ideal for ICF, block fill, form and pour, driveways, basements, and various shotcrete applications, with an ability to pump grout materials, 3/8 in. (10 mm) shotcrete and 3/4 in. (19 mm) structural concrete mixtures. This provides a fast, efficient solution for contractors performing a variety of concrete and shotcrete applications. The pump features variable speeds of 0 to 25 yd^3 (0 to 19 m^3) per hour. Vertical pumping distance reaches 50 ft (15 m) with the use of a rubber delivery line, whereas horizontal distance can reach up to 250 ft (76 m).

For 60 years, Blastcrete Equipment Company has been manufacturing solutions for the shotcrete industry. With a complete product line consisting of concrete mixers, pumps, and related products, Blastcrete Equipment Company is poised to meet the needs of commercial and residential construction, ICF and SCIP building systems, and refractory and underground markets.

For more information, call (800) 235-4867 or visit **www.blastcrete.com**.

New ASTM C1550–12a Released

An updated version of ASTM C1550-12a, "Standard Test Method for Flexural Toughness of Fiber Reinforced Concrete (Using Centrally Loaded Round Panel)," has recently been released. The scope of this updated document includes:

1.1 This test method covers the determination of flexural toughness of fiber-reinforced concrete expressed as energy absorption in the post-crack range using a round panel supported on three symmetrically arranged pivots and subjected to a central point load. The performance of specimens tested by this method is quantified in terms of the energy absorbed between the onset of loading and selected values of central deflection.

1.2 This test method provides for the scaling of results whenever specimens do not comply with the target thickness and diameter, as long as dimensions do not fall outside of given limits.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Rapid-Setting Cement in Shotcrete

By Mike Ballou

Evolving technology in the shotcrete industry using a rapid-setting mixture with calcium sulfoaluminate (CSA) cement in lieu of a more common portland cement mixture is helping to meet the challenges for shotcrete repairs and underground projects throughout the world.

Repairs performed with ordinary portland cement (OPC) concrete mixtures can take up to 28 days before they reach design strength. This can slow down projects and cycle time for mining and tunneling. Shotcrete using rapid-setting CSA cement can reach full design strength in only a few hours. In about 15 minutes—without any accelerator—dry-mix shotcrete commonly reaches strengths of 2200 psi (15 MPa); in an hour, the strengths can be close to 3600 psi (25 MPa).

What Makes It Different and How Does It Work?

First of all, CSA cement is not a new product—it has been around for years and is manufactured in a way similar to OPC. Most of the same raw materials or ingredients are used to make rapid-setting cement, such as limestone, clay, gypsum, silica, and alumina. The materials are mixed, the clinker is made, and the clinker is ground to fine powder—much like OPC. The hydration or chemical reaction is similar, but the reaction time with the CSA cement is much quicker.

Fig. 1: Shotcrete repair on bridge abutment using low-permeability, rapid-setting cement

Where Do You Use It and Why?

Time Savings

I won't get into the "time is money" clichés, but we all know that the more effective we are with our work force, the better. Time spent watching over concrete/shotcrete while it cures is a thing we've grown accustomed to but have never accepted—we've just dealt with it.

So, if we have a cement that cures in about an eighth of the time that OPC cures—and if we don't need to stand over it for hours, days, or weeks keeping it wet so that it won't develop shrinkage cracks—well, perhaps that's something we ought to consider for some applications. Oh, sure, you still need to cure it, and water curing is good for that, but it doesn't take nearly as long. Rapid-setting shotcrete, if care is used in placing, needs only a few hours of water curing. You can do it longer than that, but the hydration process or the chemical reaction is completed. The water helps to cool the hydrating CSA cement but is not a critical factor like it is for OPC shotcrete.[1]

Strength and Durability

There's been a lot of very intensive testing done to show how well rapid-setting shotcrete gains strength and holds it in compressive tests. The results are incredible—3600 psi (25 MPa) in an hour, easily—without any accelerator. Shotcrete accelerators can promote cracking due to early-age plastic shrinkage and should be avoided if possible unless used with care.[1] Rapid-setting cement is not only strong in compression but also very durable. It has been used with steel fibers and several types of

Fig. 2: Screeding new rapid-setting, low-permeability shotcrete

macrosynthetic fibers in shotcrete; the result is a shotcrete that is really tough and durable that provides great abrasion resistance in areas where a lot of scraping and gnashing of shotcrete surfaces occur, such as in the grizzly screener, vertical shafts, and horizontal transport drifts in mines.

Is It Easy on the Environment?

Green Technology

Rapid-setting cement is considered a sustainable (green) product, as it is manufactured at a fraction of the temperature that is used in kilns to make OPC. The result? Fewer hot gases and CO_2 into the atmosphere. We can do our part to help save the planet for future generations—pretty simple.

Will It Work in Dry-Mix Shotcrete?

It works **really** well in dry-mix shotcrete and is being used to line hundreds of sewer pipes and drainage culverts throughout the United States. It's been used in underground mines for years and continues to gain favor in the mining industry.

How About Wet-Mix Shotcrete?

Whoa—hang on a minute. This stuff sets up really fast, my friend. Don't think that you are going to mix it and pump it and 10 minutes later pump it through a typical wet-mix machine. That is not advisable. You could get rapid-setting concrete into your shotcrete hoses that will set up in that length of time and cause major problems. The only practical method for placing wet-mix shotcrete is if a mobile mixer or a "dry-to-wet" system is used. These work great and are standard in some mines in Australia. If the wet-mix shotcrete goes straight from the mixer to the pump, things work out well; however, use too much hose with a longer transport time to the nozzle and problems ensue.

Mixture Design

Apart from not needing any shotcrete accelerators, rapid-setting shotcrete is much the same as OPC-based shotcrete. The main difference is the pot life. Even with retarders, rapid-setting shotcrete starts to harden quickly. If extra time is needed to finish or screed off rapid-setting shotcrete, it must be done soon after it is shot.

Winter Work

Because rapid-setting shotcrete reacts so quickly, the chemical reaction of hydration gives off a lot of heat in the **beginning** of the curing cycle. This heat helps the shotcrete sustain a high enough temperature to cure without the need for hot water. Although the hydration process does not take place if it is too cold—say, below 40°F (5°C) as per ACI 306R-10[2]—work can be done in cool weather without worrying about protecting the top layer of shotcrete from freezing during the hydration process. Spray in the day and it's cured out before night, when the colder temperatures freeze OPC-based shotcrete because of the high water content.

Conclusions

CSA shotcrete is a very good choice for many types and applications for shotcrete, including areas that need special attention where abrasion is an issue and shaft liners, grizzlies, hoppers, chutes, open drifts, and stopes where there is a lot of equipment traffic. Only operators and nozzlemen who have been trained and are experienced with rapid-setting shotcrete should be permitted to place it, especially in underground conditions. Once the hydration reaction starts, there is not much time to get it through the equipment. Equipment does not need to be modified to use the rapid-setting shotcrete, but it needs to be cleaned and maintained properly before and after the use of rapid-setting shotcrete—and straight away. Rapid-setting shotcrete will gain a good deal of its final strength in the first 8 hours. Postponing the cleaning of equipment and tools can result in a great deal of extra effort if the shotcrete is allowed to harden; however, it's fine if it is cleaned within a few hours. As with any product that is new to us, it's best to find out how it works on the surface before using it underground in mines and tunnels.

References

1. Morgan, D. R., and Chan, C., "Technical Tip," *Understanding & Controlling Shrinkage and Cracking in Shotcrete*, *Shotcrete* magazine, V. 3, No. 2, Spring 2001, pp. 26-30.

2. ACI Committee 306, "Guide to Cold Weather Concreting (ACI 306R-10)," American Concrete Institute, Farmington Hills, MI, 2010, 26 pp.

Mike Ballou *works as a Tunneling and Mining Sales Engineer for CTS Cement, Cypress, CA. He is a Graduate Civil Engineer and has worked in and around the tunneling and mining industry throughout North America for over 25 years. He has served on several American Concrete Institute (ACI) and ASA committees and subcommittees for underground, shotcreting, and grouting.*

Kryton Celebrates 40 Years of Concrete Waterproofing

Kryton International Inc., a Canadian-based manufacturer and pioneer of crystalline concrete waterproofing products worldwide, is celebrating 40 years in business in 2013.

Like many companies, Kryton was built to solve a problem. R.G. (Ron) Yuers, the current Chairman of the Kryton Board, first opened the doors of CanWest Waterproofing Company, a waterproofing applicator company. It soon became apparent that the materials they purchased from a local supplier weren't working satisfactorily. Yuers decided that if a solution wasn't available in the market, he would create one. So, he hired a chemist. After hundreds of hours in a laboratory, Krystol® technology was born; and in 1973, Kryton was formed as a new company to launch this new technology into the global market.

Since its launch, Kryton has been the leading manufacturer of concrete waterproofing products, using its proprietary integral crystalline formula—Krystol. This success has expanded the company worldwide, with offices in Canada, China, India, Dubai, and the UK. Massive projects such as Las Vegas CityCenter, Marina Bay Sands, and the Palm Jumeirah were completed using Krystol technology, propelling Kryton into new markets.

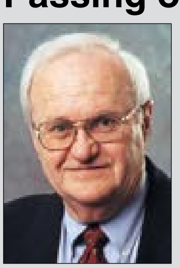
"We feel very fortunate to be a contributing member of the construction industry for these many years and look forward to many more," says Kryton's President and CEO Kari Yuers.

Kari Yuers has been in a managerial position at Kryton since 1991 and CEO of the company since 2001. She has led the charge in legitimizing the category of integral crystalline technology and the use of admixtures for concrete waterproofing. She was recognized as the Ernst and Young Entrepreneur of the Year in 2003 in the Business-to-Business category.

Under Kari's leadership and her commitment to value the people and company culture, Kryton has become an award-winning company that was recognized as one of the Best Companies to Work For in British Columbia for 4 consecutive years. Recently, Kari was appointed the new Chair of the American Concrete Institute (ACI) International Advisory Committee.

Kryton continues to evolve and adapt its product line toward future trends. By maintaining close relationships with distributors and customers worldwide, Kryton has a strong presence in the future of concrete waterproofing.

Passing of Peter C. Tatnall



We regret to announce the death of our good friend Peter C. Tatnall. Tatnall served as one of ASA's earliest Presidents in addition to providing many years of service on its Board of Direction. ASA extends its sincerest condolences to his family, friends, and colleagues in the concrete industry. Please refer to the subsequent issue of *Shotcrete* magazine for more information in honor of Tatnall and his legacy.

BASF and Atlas Copco to Cooperate on Sprayed Concrete Innovation

BASF and Atlas Copco have signed an agreement to cooperate on sprayed concrete technology and expertise for tunneling and mining, following the sale of BASF's MEYCO Equipment business to Atlas Copco.

"BASF's expert knowledge in chemical solutions for sprayed concrete together with Atlas Copco's global expertise in underground tunneling and mining equipment will drive the optimization of sprayed concrete application," said Daniel Ruckstuhl, Vice President and Head of BASF's Global Underground Construction business. "The cooperation between the two market leaders creates a globally unmatched partnership to further develop sprayed concrete chemistry and equipment technology. This joint effort is formed to enable high-performance solutions supporting safety and cost and time efficiency in tunneling and mining projects. We are pleased to announce this cooperation and look forward to working together," he added.

The demand for high-quality, durable, sprayed concrete that offers greater safety and reduces health risks and a negative impact on the environment in tunneling and mining is ever increasing.

Further information on BASF is available online at **www.basf.com**.

Cement & Concrete Institute Closes

In February, after 75 years of serving the construction industry in South Africa, the Cement & Concrete Institute closed. The decision to cease operations followed the resignation of the Institute's main funding members. The Cement & Concrete Institute was established to promote the interests and general advancement of the portland cement and concrete industries as a whole in southern Africa.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ASA Officers Elected

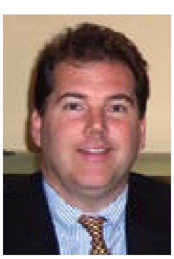
The ASA membership has elected the following individuals to leadership roles in the association, with terms beginning February 4, 2013. President: **Michael Cotter**, Consultant; Vice President: **Charles Hanskat**, Hanskat Consulting; Secretary: **Marcus von der Hofen**, Coastal Gunite; and Treasurer: **Ted Sofis**, Sofis Company, Inc., were all elected to 1-year terms.

These four individuals will join immediate Past President **Joe Hutter**, King Packaged Materials Company, to form the 2013 ASA Executive Committee.

Left to right: Michael Cotter, Charles Hanskat, Joe Hutter, and Marcus von der Hofen. Not present: Ted Sofis

ASA Directors Elected

Three individuals were (re)elected to 3-year terms as ASA Director, beginning on February 4, 2013. **William Drakeley**, Drakeley Industries, and **Oscar Duckworth**, Valley Concrete Services, were reelected to second terms. **Andrea Scott**, Hydro Arch, was elected to her first term.



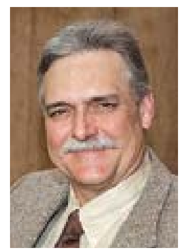
William Drakeley

Oscar Duckworth

Andrea Scott

These three Directors join the previously elected Directors and the ASA Executive Committee to form the 14-member ASA Board of Direction.

ASA Board Appoints Brady to Director Position

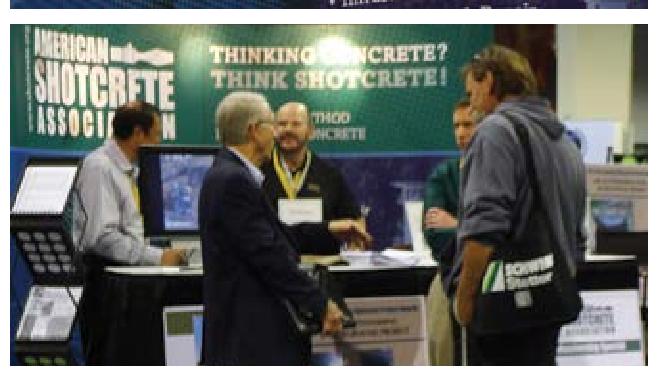


Edwin Brady

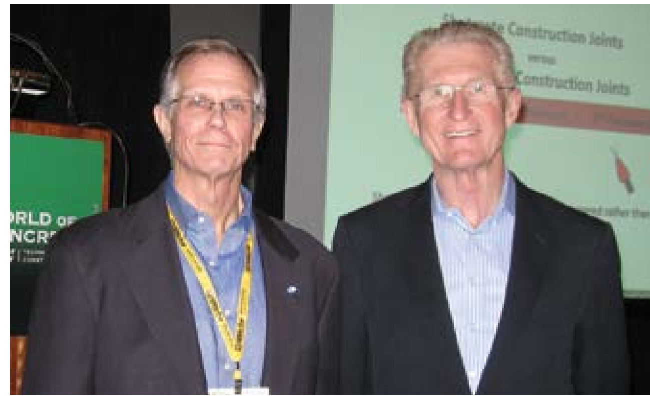
With the election of Marcus von der Hofen to the Officer position of Secretary (a mid-term move from his position as a Director), a vacancy was created in one of the nine Director positions on the Board. Following protocol by the ASA Bylaws, the Board received and unanimously approved the nomination of **Edwin Brady**, Edwin Brady Construction Company, Inc., to complete the remaining 2 years of the open Director term.

ASA at World of Concrete 2013

ASA's booth at this year's World of Concrete drew a considerable amount of traffic as visitors stopped by to inquire about shotcrete and its applications and benefits, the numerous benefits of ASA membership, and ASA's education and certification offerings. The booth featured a video demonstration of the shotcrete method in a variety of applications, as well as posters of this year's Outstanding Shotcrete Project Award winners and banquet sponsors. Many members of the ASA Board of Direction were also available to greet attendees and answer their specific technical inquiries.



In addition to ASA's presence on the convention center floor, an open-attendance Shotcrete Forum was presented on Monday, where the ASA Safety Committee Chair provided updates on the all-new safety manual under development. Later, the recent and upcoming activities and documents of American Concrete Institute (ACI) Committee 506, Shotcreting, were reviewed. This led the group into the final topic of the afternoon—the need for ASA to develop specific contractor qualification guidelines. The intent of these guidelines is to look past certification and focus on the greater picture of providing the specifier with a means of evaluating an entire shotcrete team and its proven ability to consistently place quality shotcrete.



Left to right: Charles Hanskat and Larry Totten

ASA speakers Charles Hanskat and Larry Totten also presented a 90-minute seminar on "Structural Shotcrete—Design and Construction." Drawing roughly 80 attendees, the seminar identified designing, specifying, and detailing considerations for delineated field advantages on the use of shotcrete and reviewed placement techniques and inspection critical to producing quality shotcrete structures.

Finally, an all-day ASA shotcrete nozzleman education session on Tuesday provided an in-depth review of critical concepts that are vital to the process of shotcrete placement. Course attendees gained invaluable knowledge from some of the leaders in shotcrete education in preparation for achieving their ACI Shotcrete Nozzleman certification.

Eighth Annual ASA Outstanding Shotcrete Project Awards Banquet

It was a packed house at the Paris Las Vegas Hotel & Casino for ASA's Eighth Annual Outstanding Shotcrete Project Awards Banquet on February 5, 2013, as a record number of attendees gathered to celebrate the awardees and meet with fellow members of ASA.

It should be noted that this event would not be possible without the generous donations from ASA's awards program sponsors. For a complete list of our 2012 awards program sponsors, please visit: **http://shotcrete.org/media/pdf/ProjectAwardsBanquetSponsors.pdf**.


2012 Outstanding Shotcrete Project Awards
THE OUTSTANDING INTERNATIONAL PROJECT
THE OUTSTANDING INFRASTRUCTURE PROJECT

Eighth Annual ASA Outstanding Shotcrete Project Awards Banquet, cont.

ASA at the International Bridge Conference

Visit ASA Booth #331 at this year's 30th Annual International Bridge Conference at the David L. Lawrence Convention Center in Pittsburgh, PA, from June 2 to 6, 2013. The event promises to cover all aspects of bridge practice, including engineering, construction, maintenance, preservation, fabrication, design, and rehabilitation. ASA members and staff will be available to discuss the benefits of shotcrete as a preferred method for infrastructure repair and rehabilitation and promote ASA's education and certification programs to the many specifiers, designers, and public authorities in attendance.

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Exterior restoration, before and after

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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: *What is the standard method for steel fiber-reinforced shotcrete (SFRS) testing? Are you supposed to core test panels or do you only do that for plain shotcrete? Additionally, is round panel toughness testing on SFRS standard today in the United States?*

Answer: SFRS is routinely cored from shotcrete test panels or in-place shotcrete linings without difficulty. The shotcrete should, however, have a minimum compressive strength of about 10 MPa (1450 psi) at the time of coring.

Round panel testing of flexural toughness of fiber-reinforced shotcrete to ASTM C1550 is often specified and used for quality control (QC) purposes in tunneling and mining projects in North America and elsewhere (for example, mines in Australia) virtually every day of the year.

Question: *We have a client with a 6 1/2 in. (165 mm) thick reinforced concrete roof slab, the underside of which is in need of repair. There are places where the concrete has spalled, exposing reinforcing bar that has a 3/4 in. (19 mm) cover. There is efflorescence, and there is spalling that does not expose reinforcing bar and some at the steel supporting the concrete slab. In addition, there are hairline cracks and rust spots.*

Is shotcrete a feasible overhead repair for this situation? What holds the shotcrete to the slab? What is the minimum thickness of shotcrete we should specify? Should we specify shotcrete to be used only at the spalls, cracks, and efflorescence or the whole underside of the slab? Do you have a shotcrete repair procedure that we can put in our specification?

Answer: This type of repair is commonly done using the shotcrete process. The extent of the repair is an engineering issue, not a shotcrete issue—shotcrete can and is used for patches and overlays. The shotcrete will adhere to the properly prepared existing concrete. It is installed such that the weight of the plastic shotcrete does not;exceed the adhesion to the existing surfaces; if additional material is needed, it is added at the initial layer or layer set up. The minimum thickness is related to the material used for the repair and the need to establish cover on the existing or added reinforcing. Some repair mortars can be placed as thin as 1/2 in. (13 mm).

Please find a link to a paper on "Concrete Repair by Shotcrete Application: h**ttp://shotcrete.org/media/Archive/2010Sum_ACIRAPBulletin12.pdf.**

The success of the shotcrete repair will be highly dependent upon using a qualified shotcrete contractor and doing an excellent job of preparing the surfaces. Where the reinforcing is exposed, you should require that it be chipped out the entire perimeter allowing for a space of 3/4 in. (19 mm) behind the reinforcing bar so that the repair material can completely encase the reinforcing.

Question: *Is shotcrete a viable option to encase galvanized steel beams at a coal unloading facility to protect them from impact and abrasion? Will the galvanizing on the steel inhibit bonding?*

Answer: Yes, shotcrete would be suitable for this application. A well-installed shotcrete lining will be durable and protect the steel from impact, abrasion, and from the acid attack that occurs from sulfur in the coal. Shotcrete is used to cover both the steel hopper walls and to encase the steel beams. Calcium aluminate cement is typically recommended for coal bunkers because of the mild acid condition that occurs that can attack the steel. Whether or not the steel beams are galvanized or not is irrelevant because the shotcrete will not bond well enough to any steel surface without welded studs and mesh to hold it in place. The beams will need to have studs welded and mesh installed around the beams for the shotcrete placement. With galvanized steel it is often necessary to grind off a spot of the galvanized coating at the spot of each stud weld location to properly weld the studs.

Question: *We are working on a geotechnical project in the northwest to repair an existing rockery retaining wall. The wall is around 750 ft (229 m) in length and up to 12 ft (4 m) in height. The issue is that some of the basalt boulders within the wall are weathered soft and falling apart. The total weathered rocks that are falling apart comprise approximately 7% of the wall. Can we use shotcrete on the weathered rocks to give them more stability as a repair process? If not, is there a process we can use with shotcrete to repair the wall without having to rebuild the entire wall?*

Answer: Shotcrete has been used in the Northwest to strengthen and overlay existing rockery walls. The need to remove the weathered material is dependent upon the need for the overlay to bond with the existing wall, which is an engineering issue and not a shotcrete issue. Shotcrete can and is shot successfully against soil and other weathered surfaces.

Question: *I'm planning to add 6 in. (152 mm) of shotcrete to an existing 12 in. (305 mm) wall of a below-surface concrete tank to accommodate the removal of an existing middle support slab. The soil grade is approximately near the top of the existing tank wall. I've been told that since the existing wall is preloaded with soil, adding shotcrete will not increase the strength of the thickened wall and that the only way the wall will act as a whole (based on 18 in. [457 mm] thickness) is if the retained soil load is removed, then the shotcrete is added, and then soil is put back in place. Is this assessment accurate? Is there a way make this wall work as 18 in. (457 mm) without removing the existing soil?*

Answer: Stress distribution from external loads through the tank wall with the shotcrete lining will depend on the geometry of the tank and the structural function of sections to be removed. A professional engineer experienced in shotcrete and concrete tank design should be consulted to ascertain the structural capacity of the completed wall. It would certainly be important to create a good bond plane by roughening the surface and removing any loose or fractured materials and using sufficient drilled dowels to make the existing 12 in. (305 mm) wall and new 6 in. (152 mm) overlay work well together. Also, it might help to specify the use of a shrinkage reducing admixture.

Question: *When was the 4000 psi (28 MPa) standard set for shotcrete?*

Answer: ASA has taken the position that structural shotcrete is shotcrete that meets or exceeds a compressive strength of 4000 psi (28 MPa). Looking at pertinent ACI Codes related to watertight concrete, as we would expect in a pool, we find ACI 318-95, "Building Code Requirements for Structural Concrete," introduced a provision in 1995 that required: "Concrete intended to have low permeability when exposed to water shall have a Minimum f′c of 4000 psi (28 MPa)". Similarly, ACI 350-01, "Code Requirements for Environmental Concrete Structures," first issued in 2001 required: "Concrete intended to have low permeability when exposed to water, wastewater, and corrosive gases shall have a Minimum f′c of 4000 psi (28 MPa)". Since ACI 350 is more directly applicable to water-containing structures, the 2001 date is probably the most relevant, though ACI 318 introduced the concept in 1991. We do, however, see shotcrete specified at lesser levels for different types of uses.

Question: *We have a unique situation where we need to apply shotcrete around a steel plate that is surrounding a beam supporting a floor. Can you provide any UL listings for applying shotcrete to a steel beam, column, or plate?*

Answer: UL designs are typically for the hourly fire proofing ratings on structural steel members such as I-beams, wide flange beams, and vessel skirts. The beams and columns are tested for specific fireproofing products, beam sizes, and configurations. The thickness of the steel and other considerations factor in the evaluation; therefore, there is no blanket UL design number that you can use for steel plate. You can get guidance on the cover needed for different fire ratings in ACI 216.1-97/ TMS 0216.1-97, "Standard Method for Determining Fire Resistance of Concrete and Masonry, Construction Assemblies."

Remember that shotcrete is a process for applying concrete. You may also consider looking for a similar concrete UL design and submit it for consideration. Applying the shotcrete at a greater thickness to compensate for any variances should be proposed and presented to engineer or the owner for consideration.

Please note: *ASA's technical team provides the answers to submitted questions as a free service. The information is based on the personal knowledge and experience of the ASA technical team and does not represent the official position of ASA. We assume that the requester has the skills and experience necessary to determine whether the information ASA provided is appropriate for the requester's purposes. The information provided by ASA is used or implemented by the readers at their OWN RISK.*

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Sindh, Pakistan

INTERESTED IN BECOMING A MEMBER OF ASA?

Read about the benefits of being a member of ASA on page 61 and find a Membership Application on page 62.

AMERICAN SHOTCRETE ASSOCIATION

ASA Membership Benefits

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Annual Dues	$750	$100	$250	$50	Free	Free
Company and specialty information listed in ASA's online Buyers Guide and in hard copy via *Shotcrete's* annual Buyers Guide	X					
Discount on ACI Nozzleman Certification and Education	X					
Opportunity to submit items for Industry News and New Products & Processes sections of *Shotcrete* magazine at no charge	X	X	X		X	
Discounted ASA Member prices on all ASA products	X	X	X	X	X	X
Networking and participation opportunities at Annual Membership Meeting and committee meetings	X	X	X	X	X	X
Opportunity to respond to bids from our Online Project Bid Submittal Tool	X	X				
Subscription to quarterly *Shotcrete* magazine (hard and electronic copy)	X	X	X	X	X	X*
Links to shotcrete related government projects open for bid (*sent twice a month in the member edition of the ASA e-newsletter*)	X	X	X	X	X	X
Permission to include ASA logo on corporate letterhead and business cards	X	X	X		X	
Permission to display ASA logo on company Web site	X					
Discounted pricing on advertising in *Shotcrete* magazine, including free linked logo advertising from the ASA homepage during your advertising quarter	X	X	X		X	
Voting privileges at meetings and director/officer elections	X	X	X			
Free advance general admittance registration to World of Concrete	X	X	X	X	X	X
Opportunity to submit entries for the annual Outstanding Shotcrete Project Awards Program	X					
Free Lunch & Learn Seminars upon request					X	
Complimentary copy of ASA's Shotcrete Specifiers Education Tool—a 4GB USB flashdrive					X	
Complimentary copy of "Sustainability of Shotcrete" each year	1				1	
Discounted Corporate Additional ASA Memberships are available for all company employees ($150 savings per employee)	X					
Discount on ASA Underground Shotcrete Education Program	X					
Complimentary copy of ASA's Annual Nozzlemen Compilation each year				1		
Complimentary ASA shotcrete brochure each year	25	1	1		1	
Complimentary ASA reflective hardhat sticker each year	10	1	1	1		
Education & promotion of your shotcrete industry to the overall concrete industry	**X**	**X**	**X**	**X**	**X**	**X**

* Student members outside North America will only receive electronic copies

AMERICAN SHOTCRETE ASSOCIATION

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Please indicate your category of membership:

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❑ Special Application
❑ Stabilizing
❑ Water Proofing
❑ Water Reducing-Accelerate
❑ Water Reducing-High Range
❑ Water Reducing-Mid Range
❑ Water Reducing-Normal
❑ Water Reducing-Retarding
❑ Water Repellent

Cement/Pozzolanic Materials
❑ Cement-Blended
❑ Cement-Portland
❑ Cement-White
❑ Fly Ash
❑ Ground/Granulated Slag
❑ Metakaolin
❑ Pozzolan
❑ Silica Fume-Dry
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❑ Forensic/Troubleshooting
❑ Project Management
❑ Quality Control Inspection/Testing
❑ Research/Development
❑ Shotcrete/Gunite
❑ Skateparks

Contractors
❑ Architectural
❑ Canal Lining
❑ Culvert/Pipe Lining
❑ Dams/Bridges
❑ Domes
❑ Flood Control/Drainage
❑ Foundations
❑ Grouting
❑ Lagoons
❑ Mining/Underground
❑ Parking Structures
❑ Pumping Services
❑ Refractory
❑ Repair/Rehabilitation
❑ Residential

Contractors, contd.
❑ Rock Bolts
❑ Rock Carving
❑ Seismic Retrofit
❑ Sewers
❑ Skateparks
❑ Slope Protection/Stabilization
❑ Soil Nailing
❑ Storage Tanks
❑ Structural
❑ Swimming Pools/Spas
❑ Tunnels
❑ Walls
❑ Water Features

Equipment
❑ Accessories
❑ Adaptors
❑ Air Vibrators
❑ Bowls
❑ Clamps
❑ Compressors
❑ Couplings
❑ Feeder/Dosing
❑ Finishing
❑ Grouting

Equipment, contd.
❑ Guide Wires
❑ Gunning Machines
❑ Hoses
❑ Mixers
❑ Nozzles
❑ Pipe/Elbows/Reducers
❑ Plastering
❑ Pre-Dampers
❑ Pumps
❑ Robotic
❑ Safety/Protection
❑ Silo Systems
❑ Valves
❑ Wear Plates

Fibers
❑ Carbon
❑ Glass
❑ Steel
❑ Synthetic

Shotcrete Materials/Mixtures
❑ Dry Mix
❑ Steel-Fiber Reinforced
❑ Synthetic-Fiber Reinforced
❑ Wet Mix

Shotcrete Calendar

JUNE 2-6, 2013
International Bridge Conference
Come visit ASA at Booth #331
David L Lawrence Convention Center
Pittsburgh, PA
www.eswp.com/bridge

JUNE 9-12, 2013
ASTM International Committee C09, Concrete and Concrete Aggregates
JW Marriott Indianapolis — Indianapolis, IN
www.astm.org

OCTOBER 19, 2013
ASA Fall 2013 Committee Meetings
Hyatt Regency & Phoenix Convention Center
Phoenix, AZ
www.shotcrete.org

OCTOBER 20-24, 2013
ACI 2013 Fall Convention
Theme: "Innovation in Conservation"
Hyatt Regency & Phoenix Convention Center
Phoenix, AZ
www.concrete.org

NOVEMBER 9-14, 2013
2013 International Pool | Spa | Patio Expo
ASA's Nozzlemen Education Class—details to follow
Mandalay Bay Convention Center — Las Vegas, NV
www.poolspapatio.com

NOVEMBER 13-15, 2013
ICRI 2013 Fall Convention
Theme: "Looking Back"— ICRI Celebrates Its 25th Anniversary
Fairmont Chicago — Chicago, IL
www.icri.org

DECEMBER 8-11, 2013
ASTM International Committee C09, Concrete and Concrete Aggregates
Hyatt Regency Jacksonville Riverfront
Jacksonville, FL
www.astm.org

JANUARY 2014—DETAILS TO FOLLOW
ASA Shotcrete Seminar: Shotcrete for Infrastructure and Building Repair, Rehabilitation and Repurposing
Speakers: Charles Hanskat and Marcus von der Hofen
WOC 2014 — Las Vegas Convention Center
Las Vegas, NV
www.shotcrete.org

JANUARY 20, 2014
ASA WOC 2014 Committee Meetings
Las Vegas Convention Center
Las Vegas, NV
www.shotcrete.org

JANUARY 20-24, 2014
2014 World of Concrete
Exhibits: January 21-24
Seminars: January 20-24
Visit ASA's Booth #S10839 (New location!)
Las Vegas Convention Center
Las Vegas, NV
www.worldofconcrete.com

FEBRUARY 23-26, 2014
2014 SME Annual Meeting & Exhibit
Theme: "Leadership in Uncertain Times"
Salt Palace Convention Center
Salt Lake City, UT
www.smenet.org/meetings

MARCH 22, 2014
ASA Spring 2014 Committee Meetings
Grand Sierra Resort — Reno, NV
www.shotcrete.org

MARCH 23-27, 2014
ACI 2013 Spring Convention
Grand Sierra Resort — Reno, NV
www.concrete.org

JUNE 22-25, 2014
ASTM International Committee C09, Concrete and Concrete Aggregates
Sheraton Toronto — Toronto, ON, Canada
www.astm.org

OCTOBER 25, 2014
ASA Fall 2014 Committee Meetings
Hilton Washington — Washington, DC
www.shotcrete.org

OCTOBER 26-30, 2014
ACI 2014 Fall Convention
Hilton Washington — Washington, DC
www.concrete.org

DECEMBER 7-10, 2014
ASTM International Committee C09, Concrete and Concrete Aggregates
Sheraton New Orleans
New Orleans, LA
www.astm.org

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