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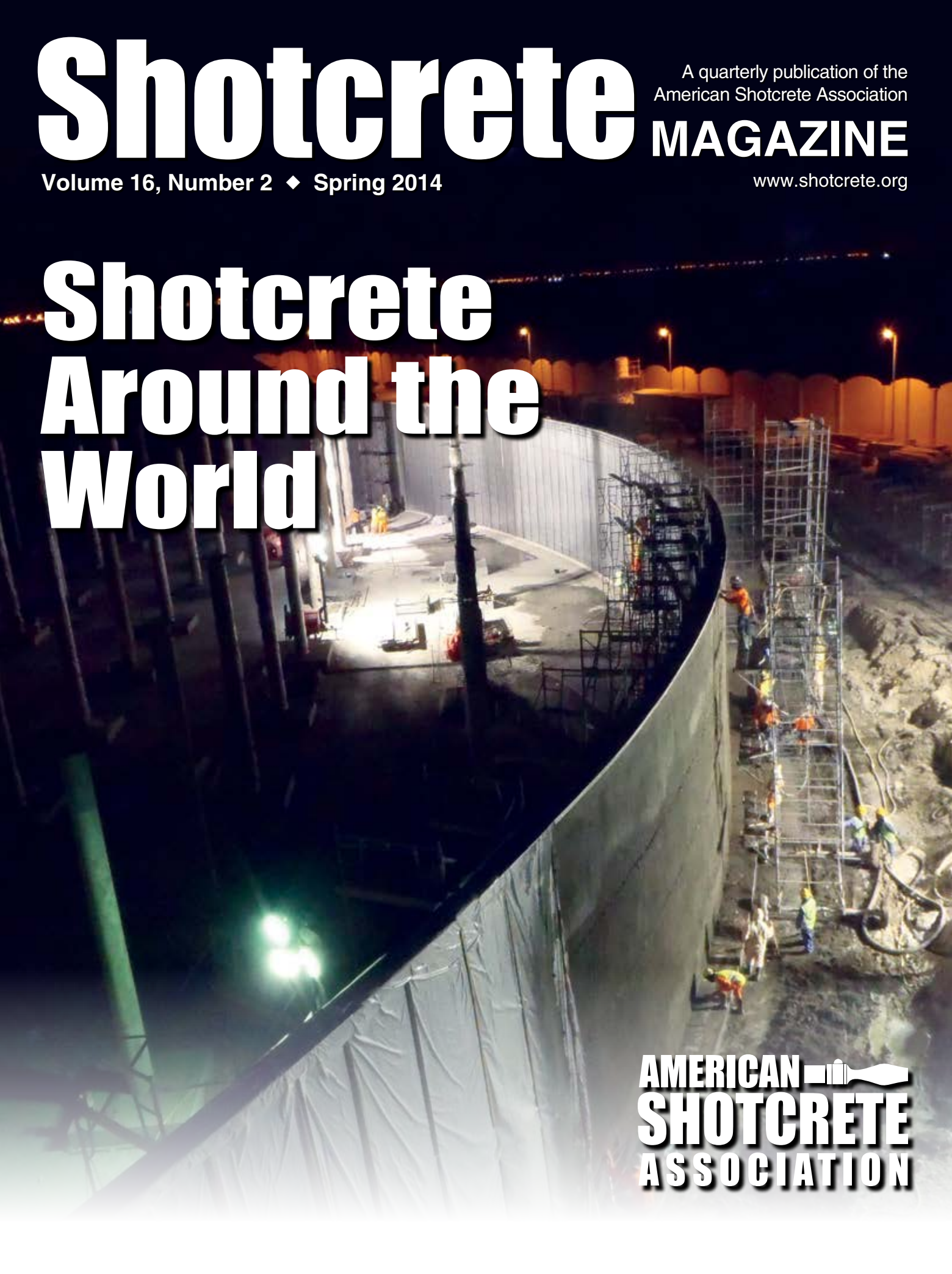
Shotcrete Around the World



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Shotcrete MAGAZINE

Volume 16, Number 2
Spring 2014

Features

Departments

On the cover: GTC 299 Additional Reservoirs | Doha, Qatar
Photo courtesy of Crom International LLC

Moving Forward

By Charles S. Hanskat

As I pick up the reins in leading ASA, I want to first give thanks to the previous Presidents, who have worked long and hard to bring ASA to where we are today. In associations like ours with new leadership transitioning in every year, we must pay attention to continuity and monitoring our progress in achieving our goals. In effect, we build on the foundations laid by those who came before us. Fortunately for me and ASA, our Past Presidents have shared the vision, dedication, and commitment to advancing ASA and our shotcrete industry. I particularly want to thank Michael Cotter, who provided strong leadership and direction as President last year. Under Michael's watch, we set many of our new programs in motion. Also, thanks to Joe Hutter and Ted Sofis, who are rolling off the Executive Committee, but still remaining involved as Committee Chairs.

These are exciting times for ASA. In the last couple of years, we've produced many new products that are of distinct benefit to our members and the shotcrete industry. We've added:

- "Safety Guidelines for Shotcrete"
- Enhanced 1-day Nozzleman Education Session
- Position papers
  - Pool and Spa
    - Minimum concrete strength of 4000 psi (27.6 MPa) for shotcrete
  - Qualifications of the Shotcrete Team

On the horizon, we have three major programs under development, including:

- Shotcrete contractor certification;
- Shotcrete inspector education/training; and
- Shotcrete crew safety educational session.

We've experienced strong growth in ACI Nozzlemen certification over the last 2 years. This is partially a rebound from the economic downturn, but also a result of more specifiers requiring ACI Certified Nozzlemen for their projects. In addition to the revised modules for our ASA examiners to use in the 1-day education sessions, we continually seek to improve the program to help ensure quality in the nozzlemen-certification process. This is exemplified by the great interaction we've had at the annual workshop sessions that we've conducted with our ASA Examiners at World of Concrete.

Moving ahead, I'd like to share my goals for this year with you.

- **Enhance and increase membership**—The strength of our group lies in fully engaging the entire breadth of the shotcrete industry. To focus our efforts on membership, the Board recently approved re-establishing a Membership Committee.
- **Evaluate methods to increase funding**—We need to consider ways to increase funding to allow us to support industry-critical research, as well as development of new programs of great value to our members and the shotcrete industry. There are a variety of avenues to investigate: increasing membership, increasing dues, graduated dues, or establishing specially targeted research or program "funds." These methods and more will be considered by the Membership Committee this year.
- **Engage more members to become active in ASA**—We've had many members give years of service to our committees, programs, and seminars. However, to help assure we represent a broad cross section of our members, we would benefit from getting more of our members actively involved in our committees, programs, and seminars. I'd also like to be sure we attract and involve younger members because ultimately, they will be running our industry.
- **Continue to develop strong liaisons with specifiers, owners, and general contractors**—These are our industry's clients. We must continue to enhance the image of shotcrete with these groups that in turn will increase opportunities for members.
- **Develop a strategic plan for ASA**—ASA was formed in 1998, and has substantial growth in members and activities. Although we have clear Vision and Mission statements, we don't have a road map for how to implement them through strategies and goals. Thus, it is time for ASA to conduct a strategic planning session. The outcome of the planning sessions should be a document that will help guide our progress for the next 5 to 10 years.

I'm optimistic this will be another year with significant progress in developing programs and services of distinct benefit to our members and the industry. We have a great leadership team with Michael Cotter, Marcus von der Hofen, Bill Drakeley, and Oscar Duckworth on the Executive Committee; all of our Board members; and the support of our ASA staff, Alice McComas and Mark Campo.

Finally, I want to thank all the ASA members who have expressed their confidence in me to lead ASA this year. I am honored to have the opportunity and truly excited that we can continue to enhance and improve the shotcrete industry through our work.

Ironically, repairing one of the busiest tunnels in Steel City required our shotcrete.

When Pittsburgh's 80-year-old Liberty Tunnels needed structural repairs, QUIKRETE® Shotcrete MS got the job done. Crews were able to complete their work within tight time constraints using the dry process with a pre-dampener. In fact, our shotcrete products were part of the American Shotcrete Association's "Outstanding Underground Project" for 2009, 2010 and 2012.

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ASA Safety Committee:

The commitment to safety is more than hard hats and safety glasses

By Oscar Duckworth

A strong commitment to safety has always been a primary goal of ASA. Our efforts to promote safe shotcrete practices have been voiced through safety-related resources available through the Association, the Safety Shooter segment of *Shotcrete* magazine, and through the ongoing efforts of the members of the ASA Safety Committee.

ASA Education Module for Shotcrete Certification

Recently, ASA's completely revised ACI Nozzleman Certification Education Module was introduced at the 2014 World of Concrete ASA Committee Meetings in Las Vegas, NV. This module, and the current version of ACI CP-60 (09), "Craftsman Workbook for ACI Certification of Shotcrete Nozzlemen," will function as the primary education and reference components for all Nozzleman candidates who certify through the Association.

The new module shares many of the previous education program's learning objectives regarding concrete and shotcrete properties, mixture proportions, placement principles, and environmental precautions. But the new program focuses more deeply on current techniques, equipment configurations, and concrete admixture selections common to today's typical scope of shotcrete placement.

By far the largest change to the program is the significant addition of safety training material. Throughout the chapters of the module, safe practices and specific worker risks unique to our craft are discussed in great detail.

Typical slide depicting safety hazard

Experienced shotcrete workers know that many of our daily routines can quickly become hazardous if implemented improperly. The new Education Module illustrates safe practices from the shotcrete worker's perspective, through actual job-site conditions.

The Education Module's enhanced safety focus provides an excellent opportunity to deliver an effective safety message to all future nozzleman candidates during the certification process. This group is by far the most at-risk segment of the workforce. Historically, many inexperienced nozzlemen have come into the certification process with little or no structured safety instruction. Because attendance at an ASA-Approved Nozzleman Education program is a mandatory requirement prior to certification, nozzleman candidates will receive critically important information regarding safe shotcrete placement practices.

ASA Safety Guidelines for Shotcrete

Correspondingly, ASA also recently released a completely new document titled "Safety Guidelines for Shotcrete." This enormous undertaking represents over two decades of archived photos and shared personal experiences as a professional nozzleman. Our pride in bringing this document to print cannot be overstated. The results of this effort will function as the primary safety-related reference material for all future education and training programs administered through the Association. "Safety Guidelines for Shotcrete" is by far the largest and most comprehensive shotcrete safety training and education resource ever produced. This informative text includes dozens of illustrations that focus on current techniques, equipment configurations, and work hazards common to today's typical scope of shotcrete placement.

This resource provides an excellent opportunity to deliver an easy-to-understand, effective safety message to the most at-risk segment of the industry. Just like hard hats and safety glasses, a copy of this vital reference material should be within reach of any worker involved with shotcrete placement. Through the continuing effort of the ASA Safety Committee, "Safety Guidelines for Shotcrete" will be developed into and become available as a separate ASA Safety Education training program. The proposed seminar will cover safe placement practices, wear and inspection, blockage, pump operator duties, preventative maintenance, and other critical safety-related topics. Stay tuned for updates on the availability of this program.

Committee Chair Memo

Effective safety training must be available to shotcrete workers. Establishing safe work habits cannot occur too early in a nozzleman's training. Hopefully, our efforts through the nozzleman education and safety programs can make a difference. The Nozzleman Education class is currently available through our certification program and at major tradeshows such as World of Concrete. Refer to ASA's website calendar **www.shotcrete.org/pages/news-events/calendar.htm** for classes offered this year. A copy of the "Safety Guidelines for Shotcrete" is free to ASA Corporate Members or available for purchase at ASA's online Bookstore: **www.shotcrete.org/BookstoreNet/default.aspx**.

Start Thinking Now About Your ASA Award-Winning Projects

By Mark A. Campo, ASA Executive Director

As the construction season kicks off in full force this spring, I cannot think of a better time to remind everyone about the opportunity to make yourself and your company proud by showing off your outstanding shotcrete work. Each year at World of Concrete, ASA holds a banquet to celebrate the year's most remarkable shotcrete projects. The ASA Outstanding Shotcrete Project Awards Program recognizes excellence and innovation in projects in which the application of shotcrete has played a significant role.

Think of this as our industry's opportunity to demonstrate to the greater construction community the many advantages offered by shotcrete placement. Sustainability, formwork cost savings, and speed of construction, among many others—these benefits are inherent to the shotcrete process and play a significant role in winning projects as well as the project owner's ultimate decision to use shotcrete as the method of concrete placement. The ASA Outstanding Shotcrete Project Awards Program provides an exciting real-world demonstration of these advantages, helping to promote and expand the use of shotcrete in all beneficial applications. Greater visibility of these projects leads to greater understanding and specification of shotcrete, which in turn means more business for our members. It's a win that keeps paying you back!

So, What's In It For Me?

Project award winners receive a glass award and are invited to present their winning project at the ASA Outstanding Shotcrete Project Awards Banquet. Winning projects for each category are also publicized at ASA's World of Concrete booth; published in *Shotcrete* magazine's annual Awards issue; highlighted on ASA's website; and announced on ASA's Facebook page, our "What's in the Mix" eNewsletter, and in a dedicated press release from the association. Think of the exposure your winning project will bring to your company!

With all this in mind, we would love to see more of our members—especially the hundreds who attend the banquet—submit their projects in consideration for an award. We know that there are more projects out there in which ASA member companies have participated, and many of those projects deserve recognition by our association.

How Easy Is It?

In recent years, the judging committee has taken steps to simplify the submittal process, making it easier and faster for members to complete and submit their application. A few minutes on the ASA website are all that is required to complete the submittal form and upload some photos.

Speaking of photos, always remember to take pictures of your projects this year. This includes before-and-after images, close-ups of fine detail work, or anything that might show off how challenging yet successful your project was. We all know that a picture is worth a thousand words, and I cannot stress enough how significant a role quality, well-thought-out photos factor into the judges' decision to select your project for an award.

"...Remember to take pictures of your projects this year."

Furthermore, feel free to brag about your company and your project! Are you an ASA member? Did you use certified nozzlemen on your project? Did you take an innovative approach to overcome challenging working conditions? Did the advantages of shotcrete placement help you win this project over other methods of construction? These seemingly obvious answers are all you need to demonstrate the overall success of your project, and why it should be considered for an ASA Outstanding Shotcrete Project Award.

Awards are granted in the following six categories: Architecture, Infrastructure, International Projects, Pool & Recreational, Rehabilitation & Repair, and Underground. For more information on the awards program, or to view previous award winners, visit the awards program web page at **www.shotcrete.org/pages/membership/project-awards.htm**.

So, throughout this year's construction season, carry a digital camera when visiting your job sites and please remember to snap some photos of your favorites. And when it's time to look back on what you've accomplished, don't hesitate to send us an award application to show off your company's finest work. It just may result in an opportunity to boast a little to your peers at next year's ASA Outstanding Shotcrete Project Awards Banquet!

Look for the announcement which opens this year's awards submission in early June via ASA's Facebook page and eNewsletter, "What's in the Mix."

Grab your CAMERA!

Working on an interesting shotcrete project? Proud of the work you shoot?

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

So start taking pictures today!

www.shotcrete.org/ASAOutstandingProjects

Shotcrete in Qatar

By Lars Balck, Robert (Bobby) Oyenarte, Buddy Williams, and T. J. Williams

Crom International LLC (Crom), a subsidiary of The Crom Corporation, recently completed two large shotcrete storage tank projects in Qatar totaling over 144 million gal. (545,000 m^3) of usable potable water storage. In both projects, Crom was responsible for constructing four large-diameter cast concrete membrane floors and cylindrical composite walls of shotcrete with embedded galvanized corrugated steel diaphragm, and circumferential single wire-wrapped prestressing with shotcrete cover. Throughout the course of both projects, Crom placed over 21,000 yd^3 (16,000 m^3) of shotcrete and 2165 miles (4012 km) of galvanized high-tensile-strength prestressing wire for the walls of the storage tanks.

Qatar, a sovereign Arab emirate, shares its only land border with Saudi Arabia to the south, with the rest of its territory surrounded by the Persian Gulf. Doha, Qatar's capital and only major city, has approximately 1.6 million residents. Qatar is estimated to have 1% of the world's oil and the third-largest natural gas reserve, which has helped the nation to become the world's richest country per capita in the last decade. Since Qatar gained independence from the British in 1971, it has embarked on a remarkable transformation recently labeled the "National Vision 2030," where the nation will continue to invest billions of dollars in infrastructure to promote tourism and develop a diverse economy not solely reliant on petrochemicals and hydrocarbons.

Fig. 1: Night finishing exterior

In 2012, nearly all the available potable water was being supplied from desalination facilities with no peak demand production capabilities, which reduced reserves to less-than-desirable levels. As of December 31, 2013, Qatar had a total population of 2.05 million people, of which approximately 300,000 are Qatari nationals. This total far exceeds the originally projected population for 2016. With low reserves and actual population growth rate exceeding the projected rate, the government instituted aggressive measures to boost their potable water storage capacity by building out a number of reservoir pump stations.

Challenges

The combination of weather, silica fume, high-cement content mixture, water availability, and high levels of traffic congestion all presented challenges to having an efficient shotcrete operation.

Weather

Working around the weather was a constant and significant struggle. Sandstorms and fog would occur unexpectedly and would completely "whiteout" the site and access roads, causing a complete shutdown of work. Because of the inherent dangers and recorded incidents in sandstorms and fog, all truck traffic, by law, must pull off the road until the event has passed or face steep traffic violations and even jail time. With the concrete delivery trucks having an average commute of 45 minutes, even a short event would result in the load of concrete being rejected. After a sandstorm, the crew would often need an entire shift to remove the dust, clean up, and start over. Even welcomed fog during the spring months caused delivery delay problems, which resulted in many loads being rejected.

In the summer, nearly all concrete was placed at night due to constant daily high temperatures

that often reach 106°F (41°C) and sometimes exceeding 112°F (44.5°C). For the workers' protection, all work was restricted if the ambient temperature exceeded 113°F (45°C).

Inconsistent Shotcrete Mixture

The concrete mixture used for the wet-mix shotcrete presented the greatest challenge for two reasons. First, although shotcrete mixtures are typically cement rich and, consequently, sticky, adding silica fume caused the mixture to become extremely sticky. The second challenge was that the concrete delivered to the site was rarely delivered with a consistent slump. With over 40 concrete suppliers covering the construction boom in Doha and most concrete placement occurring at night, many people consider the concrete truck Doha's summer nocturnal creature.

Throughout the nation, older concrete structures are crumbling due to corrosion of internal reinforcement caused by the high internal chloride content in the original concrete mixtures. As a result, Qatar has established strict requirements in the national building code called the Qatar Construction Standards (referenced locally as QCS 2010). Local limestone aggregates are only to be used on a limited basis due to their substantial nonuniform qualities, uncontrolled water absorption, and abrasion quality. Imported limestone and Gabbro aggregates (igneous rock) from the United Arab Emirates and Saudi Arabia are widely employed for nearly all construction activities. Although most aggregates are imported with low chloride levels, mixtures are continually checked to ensure the chlorides are kept below allowable levels. Cement, which is produced locally by the government, and chloride-contaminated potable water also contribute to chlorides in mixtures and must be closely monitored.

For both RPS projects, the QCS 2010 required the use of QCS 2010 C40 for the shotcrete mixture. C40 refers to a concrete cube 6 x 6 x 6 in. (150 x 150 x 150 mm) sample that must break higher than 40 N/mm^2

40 N/mm^2 (cube) = 32 MPa (cylinder) = 4600 psi (cylinder)*

Low breaks were never a concern because the mixture design consistently outperformed the C40 requirements with an average 28-day strength exceeding 6700 psi (46.2 MPa).

QCS 2010 C40 requirements for cylinder strength and durability:

	Requirements
Strength (28-day)	4600 psi (32 MPa)
Chloride content ASTM C1281	0.06%
Durability (56-day)	
Water penetration BS 12390-8	15 mm (0.6 in.)
Water absorption BS 1881	2
Chloride migration	5 x 10^{-12}
RCP ASTM C1202	2000 coulombs

*refer to Shotcrete Corner on pg. 22 for a more detailed explanation.

Following is the approved shotcrete mixture design that met the QCS 2010 requirements for C40 strength and durability. To meet the strict durability requirements, silica fume was added to the shotcrete mixture and to provide workability, the maximum allowable plasticizer was added. The high-range water reducer (HRWR), in addition to providing workability, also retarded the set.

	lb/yd³	**kg/m³**
Cement	660	390
Micro silica	50	30
Fly ash	304	180
0-1/4 aggregate	2395	1420
Water	262	155
Glenium 183 (HRWR)	7	4.2
Fiber	1.1	0.7
Total	3679	2180

Acceptance of a concrete mixture design was a lengthy, involved process.

- The first step was submittal of a proposed mixture design along with the concrete supplier qualification, yearly government approval, and current batching equipment certifications.
- After initial acceptance, a trial mixture was arranged in the presence of the owner's inspector, general contractor, and requesting contractor. The trial mixture was batched into a truck. Every 30 minutes, concrete samples, along with slump and temperature measurement, are taken until 90 minutes elapse. Samples were taken for strength, chloride, and durability tests.
- Samples obtained at the trial batch were sent for laboratory testing. It took over 56 days to receive all the results.

Due to the extremely hot weather conditions and the silica fume in the mixture, a maximum dosage of HRWR was required by the supplier to attain workability. With the significant temperature changes throughout the day, the concrete supplier needed to vary the amount of HRWR, which led to constant slump inconsistencies at the time of delivery. Poor equipment maintenance, driver inexperience, and delivery delays all ensured that no two trucks arrived with the same slump. To compound inconsistent deliveries, the inspectors enforced a rule that "not one drop of water can be added on-site." This rule was required because it was not possible to ensure that the water carried onboard the trucks was clean and free of chlorides. At times, adding additional HRWR to the mixture on site led to a false sense that the mixture was acceptable, when in fact flash-setting was experienced while attempting to shoot out of the truck.

To combat the inconsistent slumps of the mixture and flash setting, only 8 yd^3 (7 m^3) loads were ordered, and a concrete triage was set up. When trucks arrived on site, they were either sent immediately to a pump (delivered at just the right slump) or held so the slump could be adjusted. Many times, a small addition of plasticizer would make a drastic change in slump only to be followed by a flash set. With as many as four crews shooting at one time, the triage required significant resources to ensure that the trucks were released as soon as possible. Many trucks, because of frequent traffic problems or weather delays, were rejected, causing the delivery loop to break down and resulting in long days to meet the production schedule. To deal with the delays, shooting was kept to relatively small areas and completed in vertical layers, which minimized moving the pumps and made curing easier. To minimize plugs, the entire pump/shotcrete system would be cleaned out as soon as each truck was emptied. Finishers would begin their work almost as soon as the nozzleman began placing shotcrete and oftentimes, extra finishers were placed on each lift to speed up the finishing operation ahead of the quick set caused by sudden loss of the retarding.

Equipment

A desert environment is particularly hard on equipment. The ultrafine wind-blown sand that causes the "white-outs" penetrates every pore of the equipment, requiring air filters to be changed daily. To prevent overheating, water was run over the radiators of pumps and compressors during high-temperature months. Sticky concrete required that extra time needed to be spent cleaning and maintaining equipment. Although pumps were rotated and the maintenance program was stepped up, pumps would still break down almost every other day due to the sand, heat, and sticky concrete. The number of spare parts ordered more than tripled our normal experience in the United States.

Curing

The availability of a continuous water supply impacted both curing and cleanup. Water was delivered by truck and stored in tanks on site. Truck delivery of water, however, was inconsistent. In addition, electrical power for the water pumps was also intermittent. This combination of factors often meant that there were times the crew ran out of water while shooting, making cleanup a challenge. Curing was accomplished using a variety of methods: evaporation retarder, plastic sheets, and soaked burlap.

Testing

The amount of testing required was substantial. Concrete/shotcrete samples were taken in accordance with the British Standards and rodded into metal cube molds 6 x 6 x 6 in. (150 x 150 x 150 mm), which weighed about 20 lb (9 kg) before adding concrete samples. Every truck was sampled and measured for slump and temperature. Shooting just 100 yd (91.44 m) required taking nearly 60 samples. Samples were kept on site in a special temperature-controlled environment large enough to hold several hundred samples because samples had to be kept on site for 7 days. A chain of custody had to be maintained until the samples were received by the testing laboratory. Over the course of the job, about 5000 samples were taken, stored, and handled.

Fig. 2: Exterior shotcreting from the ground

Summary

Placement of 21,000 yd^3 (16,000 m^3) of shotcrete was completed in just 10 months, although temperatures at times reached 115°F (46°C) in the day. Weather in the form of sandstorms and fog forced a halt to the shotcrete operation and forced the crew to regroup and set up for the following evening. Heat, silica fume, maximum dosage of HRWR, and inconsistent wet-mix concrete delivered to the job caused many loads to flash-set.

Ingenuity, determination, and teamwork enabled our crews to work through the problems and meet the aggressive construction time frames. All eight tanks were leak tested and passed on the first try—a feat we understand is unique for the region.

Lars Balck *is a Senior Vice President of The Crom Corporation, a company that specializes in the design and construction of prestressed concrete tanks using shotcrete for the wall construction. He has been involved in the design and construction of over 550 tanks over the past 40 years. He received his bachelor's degree in civil engineering from the University of Florida and served with United States Army as First Lieutenant in Vietnam as a Combat Engineer. Balck is a Past President of ASA. He is Chair of ACI Committee 506-C, Shotcreting-Guide, a past Chair and current member of ACI Committee 506, Shotcreting, and member of ACI Committees 376, Concrete Structures for Refrigerated Liquefied Gas Containment; 563, Specifications for Repair of Structural Concrete in Buildings; and C660, Shotcrete Nozzleman Certification.*

Robert (Bobby) Oyenarte *is the Vice President and General Manager of Crom International LLC (Qatar), and Vice President and Principal of The Crom Corporation (USA), designer and builders of prestressed concrete tanks for water and wastewater storage. He currently heads The Crom Corporation's International Operations based in Doha, Qatar. Oyenarte is responsible for the supervision of a team of 50 engineers, construction managers, and tank builders. He is a licensed professional engineer with 17 years of experience in the industry. In his 14 years with CROM, Oyenarte has managed the design and construction of over 100 prestressed concrete tank projects.*

Buddy Williams *has been Operations Manager for Crom International for 2 years. He has over 22 years of experience in shotcrete and prestressed concrete water tanks and has been an ACI Certified Nozzleman for 10 years.*

T. J. Williams *is a Supervisor for Crom International. He is an ACI Certified Nozzleman and has 9 years of experience in constructing prestressed concrete water tanks. He has been involved in construction of large water tanks.*

Briardale Gardens

By John Anderson

With a population of over 8.17 million people, the city of London, England, continues to grow. The most recent census, released in 2012, reported a population increase of 12% over the past 10 years.[1] This makes London the fastest-growing city in England.

Hampstead, part of the Borough of Camden in Inner London, is known for some of the most expensive housing in the city. The village of Hampstead has more millionaires within its boundaries than any other area of the United Kingdom. As Hampstead village is located near many transit hubs, it is known as one of London's "Urban Villages." This, along with the tight urban growth boundaries in such a desirable neighborhood, has resulted in clusters of high-density development.

Tight Spaces

With no room to grow outwards, many people outgrowing their current homes have chosen to expand downward, creating subterranean extensions which can sometimes triple the size of the street-level home.

After a unique piling system was developed and implemented for this project, shotcrete containing KIM crystalline waterproofing admixture was applied to the slab and walls of the basement (Photo courtesy of Abbey Pynford—Basement Engineering Specialists)

When homeowners in Hampstead wanted to construct a new home with a basement in the already-dense neighborhood, they knew construction would be a challenge. The proposed basement filled the footprint of the restricted site entirely, sandwiched between two existing luxury homes and immediately adjacent to the narrow road. The local geology, consisting of clays with sandy gravel lenses, gave rise to a very unpredictable hydrogeology (the distribution and movement of groundwater in the soil). This, coupled with the site being located on a hill, created a unique and complicated hydrological circumstance. One thing was certain: the below-grade structure would need a permanent waterproofing solution for the concrete, which could withstand high hydrostatic pressure.

The requirement to achieve the largest possible internal space, without affecting adjoining homes, considerably limited the techniques that could be used both to construct and waterproof the structure. The final design also called for an exposed architectural concrete finish to the internal face of the perimeter walls.

Waterproofing Choices

In accordance with the British Structural Waterproofing Association code of practice for protection of below-grade structures against water from the ground (BS 8102),[2] when exposed concrete finishes are specified, only Type A or B systems are possible as concrete waterproofing options. Type A is defined as "Tanking Protection" and uses an external barrier system, otherwise known as "Sheet Membranes." Water resistance is achieved by waterproofing products applied either externally, internally, or sandwiched between two elements of the structure. Type B systems, or "Structurally Integral Protection," rely entirely on the concrete structure to prevent water ingress. An additive is added to the concrete mixture at the time of batching or on site, and waterproofs the concrete from within. Integral concrete waterproofing systems can be densifiers, water repellents, or crystalline admixtures.

One major drawback to the Type A system in this instance was that these types of systems require significant space around the perimeter for

installation, so the design would not be able to take full advantage of the property footprint. A Type B solution was ultimately selected for this project. Kryton's Krystol Internal Membrane (KIM), a hydrophilic crystalline concrete waterproofing admixture, was chosen for its workability and quality control. As a product fully meeting the requirements of the American Concrete Institute's (ACI's) standard classification of permeability-reducing admixtures under hydrostatic conditions (PRAHs), KIM was the perfect choice for this type of application.

A Unique Approach

Abbey Pynford, a company specializing in ground engineering work, was brought on board to execute the tricky basement construction. With 25 years of experience in specialist ground engineering, a new innovative piling design and technique was developed and designed specifically for this job. This technique—combining the process of mini pile installation, using sectional auger bore string with plunged UC structural steel sections—was necessary to ensure that the basement area could be excavated safely. It was critical that this was accomplished without damaging the two bordering properties, but at the same time providing the absolute maximum internal space. The pile was formed by a restricted access rig weighing 1.7 tonnes (3750 lb) drilling into the ground with an auger string to the required depth. A pre-blended micro-concrete mixture was then pumped down the open pile bore whilst the structural steel section was plunged. A shaft of micro concrete was thus formed, reinforced with a structural steel section.

This unique technique enabled the perimeter of the basement to be formed with the piles retaining the adjacent soils. It also enabled the structures with piles to be half the depth and 70% the width of those formed using traditional steel reinforcement.

When it came to deciding on the best method of concrete application to form the internal reinforced concrete lining wall for the installed piles, Abbey Pynford turned to a shotcrete application. Lining the walls with shotcrete carried the benefit of minimizing the joints in the concrete and accelerating production time. Speeding up the wall installation by using shotcrete significantly reduced costs associated with labor and materials that would have been needed to erect formwork for a cast-in-place method.

KIM is known to be very compatible with shotcrete, not only by waterproofing permanently and effectively but also by improving workability. The proprietary admixture effectively makes the shotcrete mixture more plastic and allows creation of a higher-end architectural finish to the concrete

The integral crystalline waterproofing method also improved the shotcrete mixture's workability and gave the finished product a smoother architectural appearance (Photo courtesy of Abbey Pynford—Basement Engineering Specialists)

Using shotcrete and KIM together allowed the basement to be constructed right to the property line without affecting the neighboring homes (Photo courtesy of Abbey Pynford—Basement Engineering Specialists)

1. Kryton's KIM HS, Treatment and External Grout enabled Abbey Pynford to use their existing design without alterations.
2. Kryton's KIM HS was perfect for sprayed concrete application to save time and money.
3. Private client is very happy with the finish of the concrete and was impressed with the speed of installation.

walls without requiring sealers or finishers. By using KIM, the shotcrete's permeability was successfully reduced and permanent waterproof protection was ensured. To do this, KIM's hydrophilic chemicals react with water or moisture, growing millions of permanent, needle-like crystals throughout the concrete matrix, blocking the movement of water in all directions. These crystals then remain dormant in the concrete, and if new hairline cracks (up to 0.5 mm [0.02 in.]) form, the crystals will react with any incoming water to "self-seal" the hairline crack and maintain a watertight barrier. KIM is an effective waterproofing system for rigid concrete structures only and may not reliably seal cracks and joints that experience variable loading or repeated movement.

Using shotcrete also enabled Kryton's crystalline jointing techniques and associated products (Krystol Waterstop System) to be applied in improved working conditions where necessary, allowing enhanced waterproofing protection to the most vulnerable areas. The KIM/shotcrete mixture was used to waterproof the basement floor slab, lower ground floor slab, and basement walls, and the Krystol Waterstop System was used for all the basement joints.

Using shotcrete and KIM together effectively reduced construction time by 30%. The owners were very pleased with the results and impressed with the speed of the work.

Where Were Kryton Products Used?

	Product Used	**Used Where**	**Quantity**
Product 1	KIM HS	Basement floor slab, lower ground floor slab, lining walls	82 m^3 (107 yd^3)
Product 2	Treatment	Construction joints from slabs to lining walls	17 m^2 (180 ft^2)
Product 3	Internal grout	Construction joints from slabs to lining walls	82 m (270 ft)
Other products	External grout	Vertical construction joints to all lining wall—lining wall junctions	13 m (43 ft)

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John Anderson *is a Territory Manager, Western Canada, for Kryton. With over 20 years of experience supporting projects in the concrete and construction industries, Andersen has spent the past 6 years of his career applying his knowledge and experience to concrete waterproofing projects throughout Western Canada and the Pacific Northwest of the United States. He brings extensive technical knowledge and a diverse history of hands-on experience to every Kryton waterproofing project he supports. Anderson can be contacted at (603) 324-8280 or jandersen@kryton.com.*

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Hagerbach Underground Test Gallery

By Dan Millette

A world-class facility, the Hagerbach underground test gallery is located in Flums, Switzerland. Officially called Versuchs Stollen Hagerbach, which is its original German name, the facility goes by V-S-H for short. It is roughly a 1.5-hour train ride from the Zurich airport to Sargans, and then about a 10- to 15-minute drive to Hagerbach from there.

Construction on this facility began in 1970 with Dr. Rudolf Amberg, a mining engineer, doing research and development for tunnel construction. The facility now has several test galleries, caverns, laboratories, and conference rooms. Research and testing is carried out on all types of underground construction elements, including drilling, blasting, concreting, injecting, and bolting. There are almost 3 miles (4.5 km) of tunnels beneath the mountain that are used for various purposes, such as research and development work and presentations and training seminars, as well as banquets, fashion shows, concerts, and all types of private events. Hagerbach is open to everyone who has a requirement for a portion of the facility, even if it is not typically an underground event or function.

This test site was designed to enable R&D in a controlled environment. The massive ventilation system can be varied to provide as much or as little air as required for a specific task. Being underground, it allows for trials that would be somewhat prohibitive in a populated surface environment, such as drilling and blasting. There is even a shooting gallery in the facility that enables marksmen or trainees to vary the lighting to match day, night, dusk, dawn, or anything in between.

The International Centre for Safety in Tunnels uses the facility for the design and trial of smoke detection systems, fire detection systems, extinguishing equipment, materials testing, and also for training of rescue and firefighting personnel. There is a 650 ft (200 m) long fire tunnel with secondary and parallel tunnels to form a complete testing network. Accredited fire tests are offered here, as this portion of the facility enables tests up to 2500°F (1350°C).

My trip to the Hagerbach facility was to attend a course and examination to become certified as an EFNARC Shotcrete Nozzleman Examiner. This course is offered by the International Center for Geotechnics and Underground Construction. EFNARC (Experts for Specialized Construction and Concrete Systems) is the certifying body. The entire course was taught in the underground environment. Our lectures were held in very comfortable con-

ference rooms. The practical portions of the course took place in a rock gallery using the latest in robotic shotcreting equipment from Normet. It was a very hands-on training session where classroom education was put into practice. The examination consisted of a written exam and evaluation of a nozzleman applying several cubic meters (cubic yards) of concrete using the spraying machine.

Having been in several other underground research and training facilities throughout the world, I was accustomed to rather cool meeting rooms (when they existed) and generally more of a mining-like environment. But Hagerbach was climate-controlled to the same standard as you would get in any large office building. There was no need to leave the underground facility for any reason. It contained clean, modern restroom facilities and even had a large cafeteria where we were served morning coffee, lunch, and afternoon tea.

All of the concrete used at the facility, including the shotcrete material, comes from an underground batch plant that is located within the facility. Along with the batch plant is a concrete testing facility used for QA/QC testing to ensure that the mixture is ready to be shot. Transmixers are used to haul the concrete to the test site or to the shotcreting area, depending on what is being done.

The Hagerbach Test Gallery is definitely a one-of-a-kind facility and it is unfortunate for us that it is located so far away. But then again, there are not that many places that are nicer to visit than Switzerland and if you ever have a need to go to Hagerbach, make sure to take a few extra days to visit Lucerne and Zurich while in the area. And if you happen to be in Switzerland for any other purpose, Hagerbach does offer tours on a regular schedule and it would be something to include during your visit.

References

http://www.hagerbach.ch/sites/esite1.htm

***Dan Millette**, a Mining Engineer, is the Director of the Mining and Tunneling Division of The Euclid Chemical Company. He is a member of ASA, Chairs the ASA Underground Committee, and is also a certified EFNARC Nozzleman Examiner.*

Job Report on Hydropower Station in Stanzertal, Austria

By Sascha Schreiner

It is remarkable that three different tunnel-building methods are being used on this hydropower station construction site: excavator, drill and blast, and tunnel boring machine (TBM) advancement. In addition to the normal horizontal tunnel, a vertical shaft is also being built.

In all tunnel-building methods, Aliva machines and Sika concrete products—such as the rotary machine Aliva 257 Top, the telescopic spraying arm Aliva 302, the Aliva 400 Spraying robot, and the Sika PM 407 concrete pump—are being put to the test. The new Aliva spraying device for robotic concrete spraying—the Aliva® Converto RoboSpray—is also in operation for shotcrete application.

The following Sika chemicals are being used: Sigunit® 49 AF (25 kg [55 lb] bags) and Sigunit L-93 AF liquid accelerator. Shotcrete for dry concrete spraying has been produced directly on the construction site in a separate concrete batching plant.

The project aims to combine the use of water from the local mountain river along with treated waste water that was collected and combined in a buffer tunnel and then fed into the new hydropower station.

Location and Preparatory Work

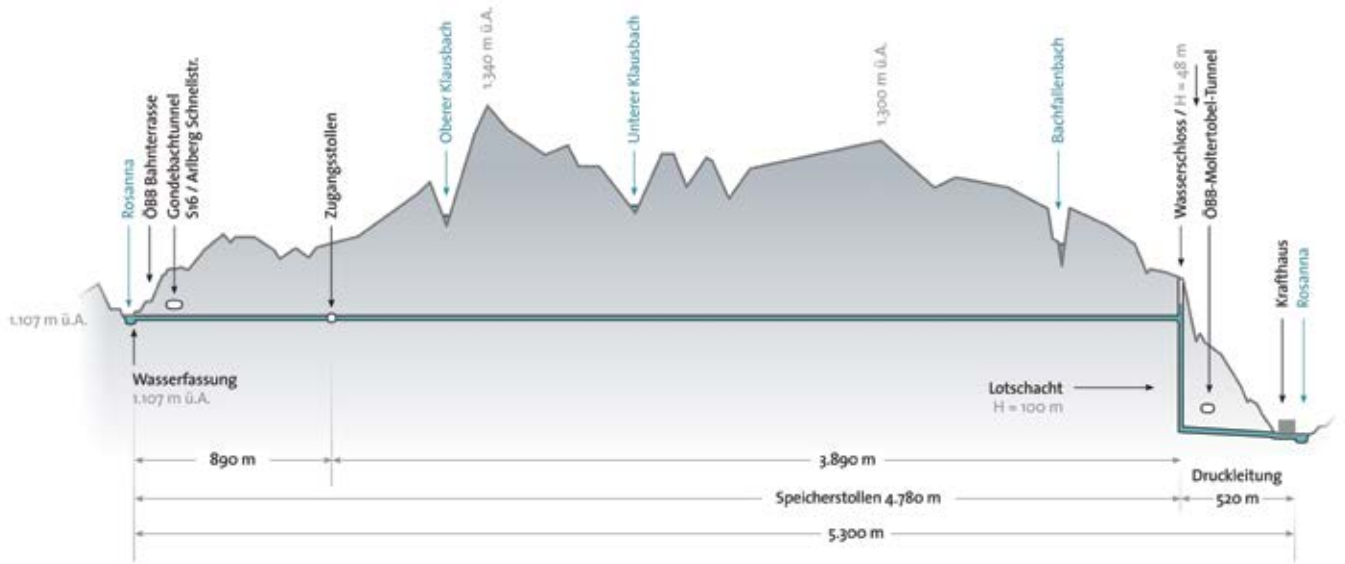
The construction site of this new hydropower station is located in the western part of Austria in the Tirol area. Due to its alpine location as well as its close proximity to the nearby water basin and power station—not to mention the crossing of two existing tunnels—construction work has been very complex and, to a certain extent, only done under extremely difficult conditions. Consequently, flexibility and reliability of the operating team's skills, as well as those of various suppliers/subcontractors, have continually been in demand. The building site facilities, which include the construction infrastructure and the logistics area, are found on the west portal of the site. That is also where the entrance of the tunnel and the disposal area for approximately 100,000 m^3 (130,000 yd^3) of excavated material can be found.

Project Data

- Construction time: March 2013 to September 2014
- ca. 1700 m (5600 ft) conventional drill and blast, excavator
- ca. 3800 m (12,500 ft) machine advancement
- ca. 130 m (430 ft) ALIMAK—advancement
- 3.81 m (12.5 ft) TBM—diameter

Project Execution

The project consists of a main and a secondary tunnel, and a vertical shaft which, upon completion, will all be connected. In addition, there are other buildings on site for energy production



Cross-sectional diagram of project

Telescopic spraying arm, Aliva 302. An automatic measurement system was installed into the road tunnel to detect any potential settlements at an early stage

and administrative work. All operations, such as the construction of the main and secondary tunnels, as well as the vertical shaft and the exit tunnel, were planned and adjusted to a fixed project time schedule. The length of the secondary tunnel is around 1000 m (3300 ft), with the main tunnel measuring approximately 4000 m (13,000 ft). The vertical shaft is 123 m (400 ft) and the exit tunnel 416 m (1360 ft) long. Because the crossing of the road tunnel has just a 4 m (13 ft) overlay, the last 100 m (330 ft) had to be built on a smaller scale. Additionally, three caverns were planned for tunnel crossings and machinery disassembly.

Excavating and Driving the Tunnel

Approximately the first 100 m (330 ft) of each portal were driven using a normal excavator because of the loose stones and sand on the mountain's slopes. Using the same procedure, the secondary tunnel was also constructed.

The entire secondary and exit tunnels were driven by drill and blast due to the geological configuration and other marginal conditions, such as the nearby road and train tunnels.

Spraying machine (rotary) Aliva 257

For both tasks, a Sika PM 407, with an Aliva 302 telescopic arm, in combination with the new Aliva Converto RoboSpray, were used for the application of the shotcrete. Aliva Converto RoboSpray's spraying device was ideal for this application and has exhibited outstanding spraying results.

Thanks to the easy and quick handling of the Aliva spraying arm, the critical part of the tunnel could be completed without a hitch.

Mechanical TBM Drive

During a driving break in the tunnel, an open TBM from Robbins was assembled. The Robbins TBM bored the main tunnel without any considerable breakdowns. An Aliva 257 top was mounted on the TBM. The machine was charged with a train and a shotcrete carrier. The shotcrete carrier was offloaded from a discharging belt on to a steep belt, which loaded the Aliva 257.

Spraying device for dry-mix shotcrete spraying (behind the drill head)

Spraying machine Aliva 257 with on-site conveyer belt

Vertical Shaft

The main tunnel ends in a cavern, which was ideal for the assembly of the ALIMAK machine that dug the 123 m (404 ft) deep shaft. It was comprised of three segments: the 91 m (300 ft) main shaft, a 33 m (110 ft) high water lock, and the transfer into the ventilation tunnel. The disassembly cavern for the TBM was built at the crossing of the main to the vertical shaft.

The vertical shaft was also built using an Aliva 257. This was done together with a conveyer belt and its powder dosing machine right at the bottom of the vertical shaft.

The material was conveyed on a mobile batcher to the portal, and from there it was further transported to the spraying machine by a dumper. The air supply provided was ideal, such that the complete shaft up to 123 m (400 ft) could be sprayed without any problems.

On this construction site, the Aliva machine's Aliva 257 provided the best solution thanks to their easy handling, low maintenance, and high reliability, as well as the availability of the machines. The smooth execution, however, was essentially the work of the highly skilled operating team on site.

Finishing Up and Project Conclusion

After completion of the tunnel advancement, a fiber-reinforced shotcrete lining will be applied in the entire main tunnel. The Sika PM 407 and the Aliva spraying arm Aliva 302 will once again be on hand to get the job done. The finishing touches to the inner lining are made of a steel pipe, which runs throughout the entire tunnel.

This project has proceeded without problems and on schedule thanks to vast experience and extensive know-how in tunnel and shaft construction as well as the reliable performance provided by Aliva machinery.

Sascha Schreiner *is Head of Marketing, Service and Logistics, for Sika Schweiz AG of Widen, Switzerland. He completed his degree in civil engineering at HTW University of Applied Sciences in Saarbrücken, Germany, and has been responsible for sales, service, product development, and business line integration for the Sika Schweiz line of Aliva Shotcrete Equipment. Aliva shotcrete machines have been used extensively for many decades on major mining and tunneling projects around the world.*

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Shotcrete Testing around the World

By Lars Balck

Charles Hanskat's article on "Shotcrete Testing—Who, Why, When, and How"[1] in the Summer 2011 issue of *Shotcrete* magazine provided us with an excellent overview of shotcrete testing in the United States. As Charles pointed out, the purpose of testing is project quality assurance (QA), which should verify the designer's intent, and quality control (QC), which should confirm the contractor's performance. This article is meant to give the reader an introduction into the world of testing of concrete used for shotcrete outside the United States.

Fifty years ago, concrete was just tested for compressive strength. No thought was given to durability other than the concept that "the stronger the concrete, the longer it will last," and to a degree, compressive strength of concrete is a good rough indicator of durability. Today, however, we have a better understanding of concrete properties affecting durability. To properly evaluate concrete's longevity, specific durability tests are needed to give us a better indication of a concrete structure's longevity for a particular service or environment than just testing for compressive strength alone.

Durability requirements not only give us a better understanding of the service life of a structure but can vary depending on location. In Canada, durability requirements are different than in the Middle East. Due to an extended exposure to freezing conditions, concrete durability in Canada focuses on tests that measure concrete's ability to resist freezing-and-thawing cycles and resistance to deicer salt scaling. In the Middle East, older concrete structures are crumbling from within due to corroding internal reinforcement. The corrosion is caused by salts and sulfates included in the original concrete mixtures. Local cement, aggregates, and even water contain chlorides. To prevent internal corrosion, the Qatar Construction Standard (QCS) 2010 specifies frequent testing for chlorides per ASTM C1218, "Standard Test Method for Water-Soluble Chloride in Mortar and Concrete." This is the same test that ACI 318 specifies for measuring chlorides in concrete, but is seldom measured in the United States. In addition, the QCS 2010 requires a test for durability that is actually four separate tests: water penetration, water absorption, rapid chloride penetration, and absorption.

Testing around the world is really no different than testing in the United States. Project needs and often governing codes are what determine which tests are needed or required on a project, whether the project is in Atlanta, GA, or Shanghai, China. Engineers design structures to carry design loads and endure environmental conditions. So project requirements dictate what tests are required. Mining and tunneling shotcrete projects, whether in Canada or Latin America, are concerned about rapid strength gain, so early-strength tests are conducted, and because most tunnel and mining shotcrete is fiber reinforced, it is appropriate that tests for flexural toughness are typically specified.

What makes testing around the world different is standards and which standard developing organization (SDO) develops those standards. There are many different standards throughout the world to test for basically the same thing. Also, the test results can vary significantly depending on what standards are specified. For example, testing results for water-soluble chloride using the ASTM standards can vary substantially from results using British standards due to far different procedures used in the testing, even though both are supposed to result in determining the percentage of chloride in a material.

Every country wants to control commerce within its borders, so every country specifies its own standards. Fortunately, most countries adopt common national standards developed by independent SDOs that are developed using a consensus process involving owners, suppliers, engineers, and contractors. The most prominent international standards are:

- American Society Testing Materials (ASTM);
- British Standards Institute (BSI);
- Deutsches Institut fur Normung (DIN);

- Canadian Standards Association (CSA)
- Association Francaise de Normalisation (AFNOR); and
- Japanese Industrial Standard Committee (JIS).

In addition, there is the International Organization for Standardization (ISO), which has adopted many of the above standards.

China, as an example, has its own national standards, called GB, from Guo Biao, meaning National Standard. The GB 50086-2001 is specifically design for shotcrete, called "Standard for Rock Anchor Shotcrete Support." It was developed based on BS, EN (European Standard), and ASTM test methods. Many countries like China and Qatar have standards that specify tests from multiple organizations such as BS, EN, and ASTM.

Many countries like Qatar hire design consultants from other countries who specify standards that they know. Thus, a project in Qatar or Singapore may have common ASTM tests specified if the designers are from the United States.

When comparing test results from different parts of the world, it is important to know how tests are performed and the units used. Conversions may be needed, and not just from metric to English. For instance, the British Standards (BS) for concrete compressive strength are much different than the ASTM concrete compressive strength standard. BS concrete compression is done on a concrete cube 6 x 6 x 6 in. (150 x 150 x 150 mm), not a cylinder whose height is twice the diameter (2:1). To compare BS results to U.S. units results requires two conversions. First, a conversion is needed to compare testing a cube to testing a 2:1 cylinder. The second conversion is simply converting from metric to English. As an example, QSC 2010 C40 concrete is 40 N/mm^2 compression on a 6 x 6 x 6 in. (150 x 150 x 150 mm) cube, which is equivalent to 32 MPa 2:1 on a 6 in. wide x 12 in. tall (150 x 300 mm) cylinder, which in turn is equivalent to 4600 psi on a 6 x 12 in. cylinder (40 N/mm^2 [cube] = 32 MPa [cylinder] = 4600 psi [cylinder]).

Summary

Testing provides verification to designers and confirmation to contractors. The driving forces behind testing around the world are specific project needs, and the local codes and standards a project must meet will likely be specified by the local government regulatory agency. Standards chosen by different countries often dictate testing, although more countries are choosing to use nationally recognized standards such as ASTM, BS, and ISO. Be careful when evaluating a test that the proper conversions are done, and that the test results are in line with the specific standards requirements. For example, ACI 318 specifies a maximum of 0.06% water-soluble chloride ion content in a concrete mixture by weight of cement for prestressed concrete and as measured by ASTM C1218. One should not use BS 1881 to meet ACI 318 requirements, for while it also measures chloride content, it does so in a substantially different way than ASTM and with differing results. Standards that seem similar can vary significantly. Know the units and how the tests are conducted.

In the Summer 2013 issue of *Shotcrete* magazine, Charles Hanskat updated readers on U.S. shotcrete standards and tests.[2] Below is a condensed summary of his list.

ACI (www.concrete.org)

- ACI 506.2-13, "Specification for Shotcrete"—recently released
- ACI 506R-XX, "Guide to Shotcrete"—in ballot, needs photos
- ACI 506.1 R-08, "Committee Report on Fiber-Reinforced Shotcrete"
- ACI 506.4R-94, "Guide to Evaluation of Shotcrete"
- ACI 506.5R-09, "Guide for Specifying Underground Shotcrete"

ASTM International (www.ASTM.org)

- ASTM C1140/C1140M-11, "Practice for Preparing and Testing Specimens from Shotcrete Test Panels"
- ASTM C1141/C1141M-08, "Specification for Admixtures for Shotcrete"
- ASTM C1385/C1385M-10, "Practice for Sampling Materials for Shotcrete"
- ASTM C1436 -08, "Specification for Materials for Shotcrete"
- ASTM C1480/C1480M-07, "Specification for Packaged, Pre-Blended, Dry, Combined Materials for Use in Wet or Dry Shotcrete Application"
- ASTM C1604/C1604M-05, "Standard Test Method for Obtaining and Testing Drilled Cores of Shotcrete"
- ASTM C1550-12a, "Test Method for Flexural toughness of Fiber-Reinforced Concrete (Using Centrally Loaded Round Panel)"
- ASTM C1609/C1609M-12, "Standard Test Method for Flexural Performance of Fiber-Reinforced Concrete Using Beam with Third-Point Loading"

In addition, the following tests are frequently used on shotcrete projects:

- ASTM C138/C138M-13a, "Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete": Plastic density.
- ASTM C143 / C143M-12, "Standard Test Method for Slump of Hydraulic-Cement Concrete": Wet-mix shotcrete only.
- ASTM C231/C231M-10, "Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method": At pump and as shot.
- ASTM C1604/C1604M-05(2012), "Standard Test Method for Obtaining and Testing Drilled Cores of Shotcrete": Compressive strength at 7 and 28 Days.

Hardened Shotcrete Properties

- ASTM C642-13, "Standard Test Method for Density, Absorption, and Voids in Hardened Concrete": Boiled absorption and volume of permeable voids at 28 days.
- ASTM C1202-12, "Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration": Rapid chloride penetrability testing.
- ASTM C1556-11a, "Standard Test Method for Determining the Apparent Chloride Diffusion Coefficient of Cementitious Mixtures by Bulk Diffusion": Apparent chloride diffusion (chloride ponding) testing.
- ASTM C1585-13, "Standard Test Method for Measurement of Rate of Absorption of Water by Hydraulic-Cement Concretes": Rate of water absorption testing.
- STADIUM Ionic Migration test.
- STADIUM Drying test: flexural toughness for fiber reinforced shotcrete
- RILEM TC-162 TDF

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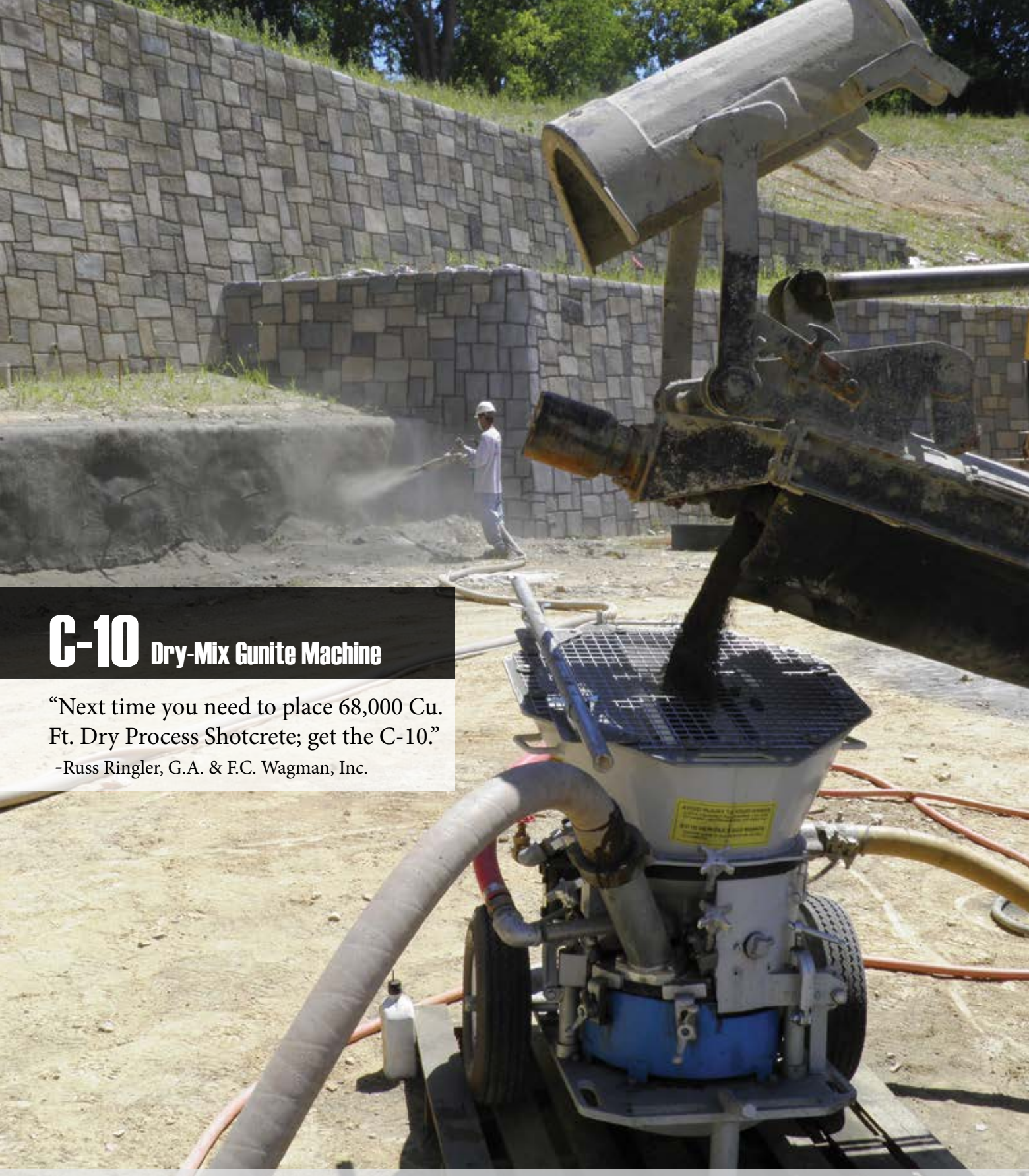
2. Hanskat, C., "US Shotcrete Standards Update," *Shotcrete*, V. 15, No. 3, Summer 2013, pp. 44-46.

Lars Balck *is a Senior Vice President of The Crom Corporation, a company that specializes in the design and construction of prestressed concrete tanks using shotcrete for the wall construction. He has been involved in the design and construction of over 550 tanks over the past 40 years. He received his bachelor's degree in civil engineering from the University of Florida and served with U.S. Army as First Lieutenant in Vietnam as a Combat Engineer. Balck is a Past President of ASA. He is Chair of ACI Committee 506-C, Shotcreting-Guide; a past Chair and current member of ACI Committee 506, Shotcreting; and member of ACI Committees 376, Concrete Structures for Refrigerated Liquefied Gas Containment; 563, Specifications for Repair of Structural Concrete in Buildings; and C660, Shotcrete Nozzleman Certification.*



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Honoring the Past

By William T. Drakeley Jr.

I have always been proud of the fact that my family's roots in our part of Connecticut date back to pre-revolutionary colonial times—1659 to be exact. We were one of the original 13 families that settled in the region, and for 10 generations, we've been an active part of the community and remain deeply involved in the local culture and history.

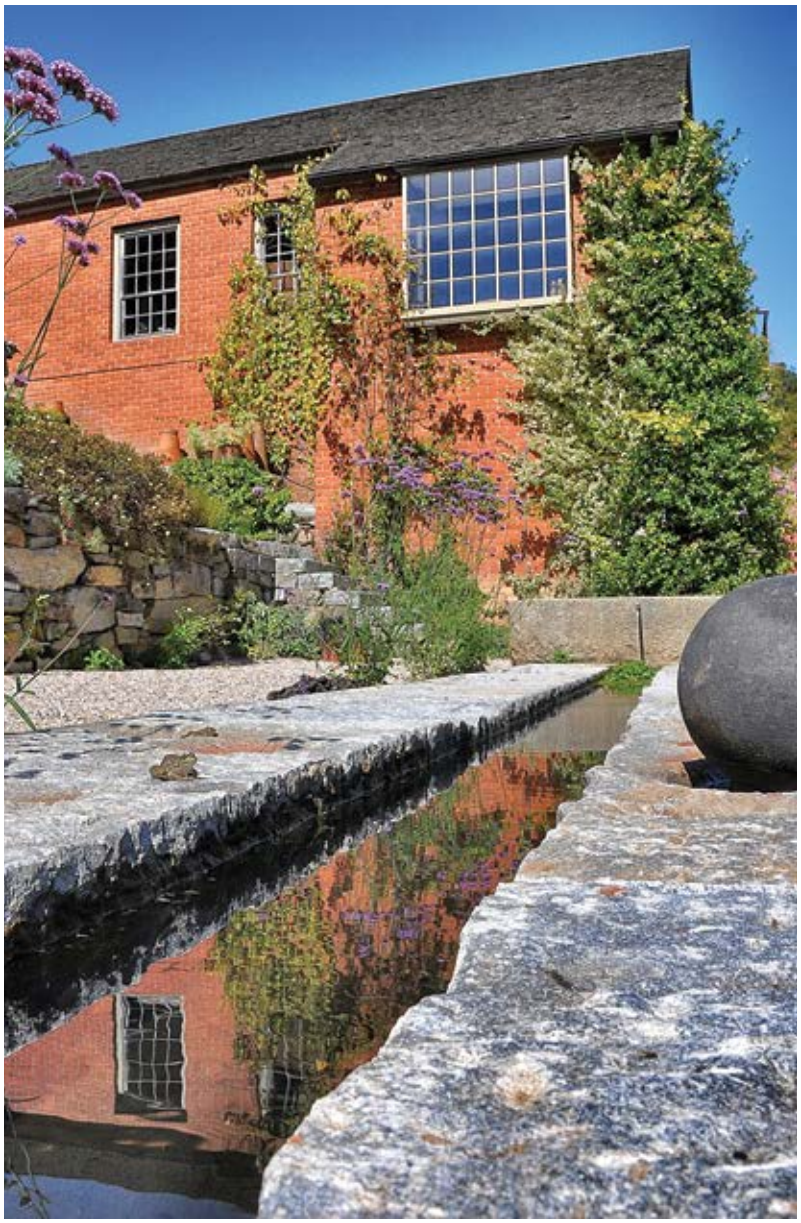

Fig. 1: View of runnel looking north

That history is a big part of our lives today; my daughters are registered members of the Daughters of the American Revolution and I'm a member of the Sons of the American Revolution. One of our ancestors, Jonathon Vale, was a minuteman in the War for Independence. That rich historic tradition recently crossed over into my working life when our firm, the Drakeley Pool Company, was asked to construct a new waterfeature at one of the vintage homes here in Litchfield County.

The property is known as the Hollister House, a beautiful brick-clad colonial home first built in the 1770s. It's located in the town of Washington, CT, formerly known as Judea; part of a group of settlements that used to be within the Woodbury town limits.

The property is owned by George Schoellkopf, a wonderful guy who has been preserving the house since 1979 and making additions to the grounds that loosely follow the great tradition of English gardening. The home is co-owned by Hollister House Garden, Inc., the non-profit aspect of the property, which is "dedicated to the preservation of the garden and house for the education and enjoyment of the public."

The concept of preserving the region's enduring legacy and contribution to the community experience is something Drakeley Pools has always greatly valued. This project served as a great opportunity to honor that tradition and stretch our creative boundaries.

Schoellkopf is constantly making changes to the property in one area or another. It's always a work in progress, and it's fair to say the history of the Hollister House continues to be written. This project was part of that ongoing effort.

The waterfeature is located on an upper yard of the sloped property, just a few steps down from the house, essentially on grade with the home's

basement. Because the overall design is based on English gardening, most of the features in the landscape are rectilinear. In that sense, this elegant waterfeature complies with the aesthetics found throughout the property. The idea was to create this long, granite-lined runnel fed by a reclaimed feed trough, all designed and constructed so it looks as though it's been there for generations.

The area had been covered in grass, which George always thought was boring. He was working with a local landscape architect, Dirk Sabin, who we've worked with on a number of occasions, to create a sort of "garden room" featuring moving water. Together, Dirk and George created a basic design for the feature and, as is often the case with custom work, Dirk called us in to meet with his client.

In this case, the design was driven largely by the materials. George is an avid collector of reclaimed granite pieces originally used in architecture. Most of the old buildings here were built on massive granite slabs, which just happen to be mostly rectilinear and often perfect for re-appropriation into new structures, such as this water feature.

The long, narrow, rectilinear design is a sort of visual homage to the linear aspect of English gardening. It's architectural with what I call a historic/country flair: simple, elegant, and now appears very much at home in the setting (Fig. 1). It also provides the soothing sounds of moving water, which was one of George's top priorities for the piece.

Our job was to put it in the ground and make the whole thing watertight. That meant building a shotcrete basin measuring 35 x 7 x 3.5 ft (11 x 2 x 1 m), with tiered contours to provide a base for the slabs and feed trough. Aside from the unusual shape, which looked like a big concrete canoe prior to the granite installation, the structure is, in many respects, really no different than a typical swimming pool.

The outside edges of the basin were formed with a 45-degree subgrade taper right up to the back of the granite, now covered by pea stone that surrounds the feature. The granite slabs on both sides of the runnel sit on benches we built down the length of the shell. There's a lower level in the middle, also covered in granite, creating the bottom of the runnel. Ultimately, the concrete basin, completely concealed by the granite, is set about an inch higher than the water level (see sidebar).

It's basically a long, narrow, shallow pool with decorative rock set inside. The concrete shell is built to all the watertight and structural standards we use when building a traditional swimming pool. The shotcrete's 28-day compressive strength is 6000 psi (40 MPa) with

A Shotcrete Assist

After we shot the vessel, the landscape architect discovered that the design dimensions were incorrect, leaving the top of the feature a few inches below grade. We were asked if we'd have to rip out the whole thing and start over, an expensive and dreary prospect to say the least.

I was happy to be able say that all we had to do was dowel in some steel at the top of the feature and shoot additional material to raise the structure to the proper level (Fig. 2). In essence, the vessel went from new to renovated before we placed any of the slabs.

I explained that this is one of the great advantages of shotcrete process: You can add to it without sacrificing structural integrity, which is a common practice in highway and bridge construction—just another reason why I believe shotcrete is a beautiful application method.

In this case, it spelled the difference between a major problem that could have threatened the entire project versus making a relatively minor adjustment.

Fig. 2: Image depicts raising the installed shotcrete with a second day of shooting (no expansion joints, no bonding agents, no cold joints)

Fig. 3: Shotcrete trough with reclaimed granite installed. Notice the shotcrete step support for granite stones

Fig. 4: Feed trough with runnel, view to the south

Grade 60 (Grade 420) steel. We reinforced and shot just as we would with any other vessel.

In this area, where we see 100°F (38°C) temperature differentials, controlling the effects from freeze/thaw exposure is always important. This vessel, which is 3 ft (1 m) thick on the bottom, sits atop an 18 in. (0.5 m) layer of gravel with a drainpipe so that we're constantly dewatering the area beneath the feature. Combined, that takes us down to a depth of 4.5 ft (1.5 m) right at the deepest freeze level, meaning water will never gather and freeze around the outside of the structure.

The granite material gives the piece its period-appropriate quality. Both the feed trough and the granite slabs in the runnel were all quarried and used originally more than 100 years ago. The surfaces are rough and weathered, creating the illusion that the feature has been there for hundreds of years.

The slabs are set in a plastic, non-set layer of grout. George didn't want to see any concrete, but we convinced him to give us 1/2 in. (13 mm) between the slabs where we could install recessed grouting. The grout, a concrete mortar mix, enabled us to level the stones, which vary in thickness, as well as control any potential movement. As is, the slabs appear to abut each other with no visible concrete (Fig. 3).

In preparing the stone, we had to remove chunks of old mortar and other material that remained in some of the rougher spots. The pieces in the floor of the runnel varied from 6 to 12 in. (150 to 300 mm) and had to be cut to a uniform dimension so we could create a level surface for the water to flow over. We had to be very careful not to split any of the stones—meaning that we had to be extremely careful when saw-cutting the large pieces while much of the fine work was done with hand tooling. It took quite a long time, but we ended up being able to use all the pieces George had selected for the feature.

The stones were carefully placed with an articulating excavator, which we had to counter balance with extra weight on one side so it wouldn't tip over while moving the slabs. The mortar bed enabled us to level the stones on either side of the runnel, making up for as much as 6 in. (150 mm) variations in thickness.

The water is not recycled, meaning it's not filtered or chemically treated, but instead flows from a natural spring on the property through the feed trough, then down the runnel, which spills into a drain concealed below the pea stone and

out into a natural stream that runs along the lower elevation of the property.

That aspect of the project was quite a departure for a "pool guy" like me who is used to sanitizing water so that nothing grows in it. Here, we just left the water alone knowing that as it flows, it brings its own oxygen, which in turn allows all sorts of life forms to take hold. You can see from the photos that the water is now host to various plants, algae, moss as well as small animals like frogs. And, of course, birds love it as a source of drinking water and bathing (Fig. 4 and 5). Note: the photos displayed here were taken about four months after the installation was complete. Clearly, nature wasted little time populating the water feature.

The water from the spring is gathered in a collection tank near the top of the property maintained by an irrigation company that works on the site. We simply brought a line down to the feed trough. Water flows from the trough through a brass fitting, which is nothing more than a copper pipe with a 45-degree angle, then slowly down the runnel and finally into the buried drain pipe we installed leading down to the stream. The flow is created entirely by gravity and atmospheric pressure; there's no pump, filter or any other device you'd see in a recirculating system. Our system is electricity-free.

These aspects highlight our sustainable structure's environmental friendliness and are examples of practical application of the sustainability principles of LEED ratings.

We used an existing hole in the feed trough to create a drainage line used for winterizing. We simply inserted a piece of schedule PVC, camouflaging the opening with mortar and sand around the pipe's opening, so there's no visual indication of the PVC penetrating the trough.

After we were finished, George adorned the area with a number of plantings, finishing off the garden room effect.

As a member of the Hollister House Association, I've attended events at the property and have been gratified to see how people are drawn to the feature. It's a simple system, to say the least—one that simply allows us to see the water briefly as it makes its way from the spring to the stream.

Despite the simplicity, or perhaps because of it, the feature is perfectly suited to this beautiful and historic setting. My hope is that our family's descendants will someday be visiting the property and look back with pride knowing that we were a small part of the ongoing story of the Hollister House.

Fig. 5: Watertight shotcrete, life-sustaining

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Does Dry-Mix Shotcrete Have to be Dusty?

By Joe Hutter

An underground environment is often fraught with hazards—some obvious and some not-so-obvious. Although the generation of dust may not have obvious, immediate effects, it is recognized as a hazard that can have long-term health effects on the personnel who work in the mining and tunneling industry. It is important to address the causes of dust generation and to recognize what we can do to minimize the effect of this common hazard.

During the development cycle, high amounts of dust can be generated through the processes of extraction, drilling, blasting, crushing, conveying, and shotcreting. With the exception of the shotcrete process, dust generated by each of these processes must be controlled by ventilation, water sprays, or dust collectors. While each of these methods of dust control can be effective, all require that dust particles be removed from the atmosphere. The problem lies in the fact that once the dust is airborne, it is always harder to control.

From the perspective of a shotcrete operation, it is safe to say that when placed by an experienced, properly trained crew using well-maintained equipment, dry-mix shotcrete can have minimal effect on the generation of dust. This statement can be attributed to the fact that dust generation can be controlled at the source so that less dust needs to be removed from the atmosphere (Fig.1).

Fig. 1: When placed by an experienced, properly trained crew using well-maintained equipment, dry-mix shotcrete can have minimal effect on the generation of dust

Dry-Mix Shotcrete Materials and Equipment

When it comes to the production of airborne dust, not all dry-mix shotcrete materials and equipment are created equal. Doing your homework by researching a materials and equipment supplier who has the benefit of experience working in an underground environment will contribute greatly to a clean, trouble-free underground shotcrete application.

Reducing dust at the source can be achieved by adhering to the following accepted practices:

- **Bulk tote bags**—When using prepackaged materials, consider purchasing shotcrete materials in bulk tote bags, which generally release materials into the machine hopper through a chute at the bottom of the bag. One of the greatest sources of airborne dust is created when small 66 lb (30 kg) bags are broken into the hopper of a shotcrete machine.
- **Hopper hoods**—When using bulk tote bags, a hopper hood, manufactured to fit the hopper of the shotcrete machine, will seal the hopper and prevent dust from being released (Fig. 2). Most shotcrete equipment suppliers will be able to supply a hopper hood with their shotcrete machine. Otherwise, many can custom-fabricate a hopper hood to fit any machine.
- **Equipment maintenance**—Keep the shotcrete placement equipment well-maintained. Inspect wear pads and plates to ensure they are well-sealed to prevent dust from escaping the machine. Some shotcrete equipment manufacturers will supply machines with lubricating capabilities to extend the life of wear pads and wear plates and better seal the system.
- **Exhaust port**—Rotary-style dry-shotcrete machines are designed with an exhaust port

to allow low-pressure compressed air to escape from the rotor port prior to being charged with material as it rotates. Ensuring this port is clear and the air being discharged is contained as it is released is very important in controlling dust emissions.

- **Water ring inspection**—Occasional inspection of the water ring will ensure that the holes are not plugged with cementitious material. Plugged holes will restrict the amount of water capable of wetting the material and may lead to increased dust levels at the nozzle.
- **Equipment settings**—Keep wear pads, wear plates, and air settings properly adjusted to prevent "blow back" of dry shotcrete material from the hopper.
- **Wet/dry adjustments**—Ensure sufficient water pressure and water volume to avoid excessive wet/dry adjustments at the nozzle. Be aware when drilling operations may draw water from the same source as the shotcrete operation, causing inconsistencies in the water supply.
- **Pre-dampening equipment**—When using prepackaged material or dry site-batched aggregates, use pre-dampening equipment to reduce the amount of airborne dust at the machine and at the nozzle (Fig. 3).
- **Hydro-nozzles or semi-wet nozzles**—If pre-dampening equipment is not available, ensure that a hydromix-nozzle or semi-wet nozzle (one in which the water ring is moved back several feet from the nozzle) is used (Fig. 4).
- **Conveyance hoses**—Ensure that the size of the material hose is adequate for the material aggregate gradation and mixture design.

The Shotcrete Crew

An experienced shotcrete crew that follows proper shotcrete practices will also contribute greatly to reduced dust levels, but even crews with years of experience sometimes require updated training to ensure that they are following proper shotcrete practices and are operating the equipment as per the manufacturer's recommendations. A good shotcrete materials and equipment supplier should have technical personnel readily available to provide proper recommendations for equipment or materials required for specific projects. Introductory and refresher training can also be a valuable tool when new personnel join the shotcrete crew. Even in cases where the new crew members have previous shotcrete experience, they may have been trained on different equipment or crew operations and may require additional training on the project's specific operating procedures.

Fig. 2: When using bulk tote bags, a hopper hood manufactured to fit the hopper of the shotcrete machine will seal the hopper and prevent dust from being released

Fig. 3: Use pre-dampening equipment to reduce the amount of airborne dust at the machine and at the nozzle

Fig. 4: A hydromix-nozzle or semi-wet nozzle (one in which the water ring is moved back several feet from the nozzle) will also prevent the dust generation at the nozzle

Goin' Underground

There is no doubt that over the years, the label "dusty" has been unfairly attached to dry-mix shotcrete operations, especially in the case of enclosed, underground environments. What needs to be understood, however, is that unlike many other sources of airborne dust (drilling, blasting, crushing, and conveying), dust generated through the dry-mix shotcrete process can be eliminated, or at least controlled, at the source. The first step in controlling airborne dust levels is to evaluate the dry-mix shotcrete machine. Some equipment manufacturers produce dry-mix machines that are better suited for underground environments. Investigate different manufacturers and suppliers before automatically settling on the equipment you have always used. Just like buying a car or truck, test drive a demo machine before committing to a purchase.

Expect more from your shotcrete materials and equipment suppliers. Make sure they are available after the sale to provide initial and follow-up training for the shotcrete crew. One of the most common causes of excess dust is a crew that develops bad habits over time. Refresher training will reintroduce the dry-mix equipment operator to the proper equipment settings and proper maintenance procedures, and lead to a cleaner and more efficient dry-mix shotcrete operation.

Dry-mix shotcrete does NOT have to be dusty. With a little common sense and a little attention to detail, most dry-mix shotcrete crews can operate in an underground environment without anyone even knowing they're there!

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Hose Selection and Safety in Concrete Pumping

By Andy Kultgen

There are many options for hoses to use for the concrete pumping portion of wet-process shotcrete application, and because of the high working pressures involved and the limited life span of all hoses, each member of the shotcrete team should be aware of the limitations of the hose they are working with and keep alert for the signs of impending failure.

Safe concrete pumping begins with hose selection to meet the job requirements. The American Concrete Pumping Association recommends using a hose no less than three times and preferably four times the diameter of the largest aggregate in your mixture. Knowing what pump you are using, and particularly the maximum pressure this pump is capable of producing, will dictate what type of hose you will need. Many pumps commonly used for shotcrete work can produce up to 1000 psi (7 MPa) of pressure on the concrete; however, there are pumps capable of exceeding 2000 psi (14 MPa) at the concrete piston face. Every hose should be labeled to indicate what the maximum working pressure is for that hose (Fig. 1). Most hoses used in shotcrete work are rated between 500 and 1300 psi (3.5 and 9.0 MPa). If your pump is capable of producing a greater concrete pressure than your hose is rated for, you must switch to a hose with a higher rating or a pump with a lower maximum pressure on the concrete. A plug in the hose or at the nozzle can result in a nearly instantaneous spike to the pressure limit at the pump, possibly resulting in a catastrophic failure of a hose. Ensuring the pump pressure will not exceed the pressure rating of the hose and couplings is of utmost importance to the safety of everyone working near the pump, hoses, and nozzle.

The rugged nature of the job site environment, including loading and unloading frequently and being dragged across gravel and exposed reinforcing bar, can quickly damage a hose, even with proper precautions. This tough working environment necessitates regular inspections to catch any impending failures before they happen. A great time to perform a visual inspection is when you are laying out the hose at the beginning of a job, and there are three areas to check: the outer jacket, the liner, and the ends.

Any damage to the reinforcing plies (either wire or fabric) will severely reduce the ability of the hose to withstand pressure. The outer jacket of the hose is there to protect the reinforcing plies from the typical nicks, scrapes, and gouges experienced on the job site. When examining the cover, pay close attention to bulges, kinks, soft spots, cuts, or abraded areas, which may indicate broken or displaced reinforcement. If the hose cover has been damaged to the point where the reinforcing plies are visible, the hose must be either discarded or returned to the factory for the damaged area to be removed (Fig. 2).

Hoses with areas where the liner is excessively worn must be discarded. Typically, the first 1 to 2 ft (0.3 to 0.6 m) from the end of the hose is the highest wear area for the liner. However, smaller-diameter hoses are often difficult to inspect, even with a flashlight. In those applications, some external clues can predict heavy liner wear. Check

Fig. 1: All hoses should be labeled with maximum working pressure. This hose is labeled for a working pressure of 1250 psi (8.6 MPa)

the weight of a hose and compare to a new hose. Check the feel of a hose. Is it "flimsy" when compared to a new hose? A hose that exhibits these characteristics probably has had its liner worn past its practical life span.

Fig. 2: The jacket on this hose has been damaged enough to expose the reinforcing cables, compromising the pressure capability of the hose. This hose needs to be replaced immediately

The steel hose ends are typically the greatest wear points on hoses. Examine the hose body for excessive wear at the inlet and outlet faces, and for any signs of the hose barbs beginning to show on the inside of the hose body. Examine the hose ferrule for any movement between it and the hose body and hose. These are indications that the steel is worn out and the hose should be discarded. Many hoses have a sight hole located in the ferrule so you can check to make sure the hose isn't pulling out of the ferrule (Fig. 3). Also, remember to examine the surfaces where the coupling gasket seats for dents, damage, or concrete buildup.

Hose failure can result in a plugged line in the best case; and injury or death to a shotcrete crew member or anyone else on the job site is a very real scenario. Routine inspections of your pumping hose are crucial to catching worn parts before they fail on the job. A few minutes spent checking over the hoses as they are being laid out or packed up can save a lot of time, effort, and cost spent dealing with a failed hose at a job site.

HOSE SAFETY GUIDELINES

- Always wear proper personal protective equipment (PPE) on concrete pumping job sites!
- Always use the correct hose for the job. A hose should not be used in applications where its rated working pressure is exceeded.
- Never kink the hose. Kinks cause blockages and pressure spikes. The hose may straighten violently and cause personal injury.
- Always verify that a blocked hose is not pressurized before opening any coupling.
- Never look into a hose that is plugged.
- Never use a hose with frays or breaks, or with the braiding or reinforcing exposed. Check both the outer cover and inner liner. A hose with exposed braiding is a guarantee it will not support its rated capacity.
- Never sit, straddle, or stand on a hose.
- Never use compressed air to clean a hose.
- Never drag the hose by the coupling or drag the hose sideways with a manlift or crane.
- Never beat on concrete pumping hose with a hammer or other object. This impact damages the reinforcing material and will lead to premature hose failure and rupture.
- Hoses should be inspected on a daily basis.
- Check the inside surface of the hose body. If there is excessive wear or exposed hose barbs, the hose must be discarded or returned to the factory for re-coupling.
- Verify that the hose cover is visible through the ferrule inspection hole.
- Typical concrete pumping hoses have rubber properties that resist sun damage and oxidation. To maximize the life span of a concrete pumping hose, store unused hoses in a clean, dry, dark place.
- Concrete pumping hoses are designed for pumping concrete. Consult the hose company if any other product is pumped through its hoses.

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Fig. 3: Many hoses have a sight hole so you can check if the hose is seated all the way to the end of the ferrule and is not pulling out

Shotcrete Hose/ System Cleanout Safety

By Carl Baur

I am writing this article to reinforce to the members of wet- or dry-process shotcrete crews that the cleanout process can be very dangerous. There are a few precautions to be taken to ensure safety during cleaning of hoses in shotcrete systems. This is a reminder to take every precaution to be safe, because even some everyday practices can be deadly.

In this past year, I personally knew several people who sustained head injuries requiring hospital treatment. As a result, these individuals have potentially chronic health problems stemming from poor practice. In most cases, it takes at least two crew members to clean out the shotcrete hose. One person controls some source of energy to clean out the hose and the other person controls the end of the hose. The person controlling the source of energy, whether it may be a pump, compressed air, or water, should never allow a person to simply hold the hose during the cleanout process. I have seen large men thrown around like a rag doll by a hose being cleaned out with air pressure. Some of the comments were, "I thought I was tough enough to hold on to a 2 in. (50 mm) shotcrete hose with 120 psi (0.8 MPa) of air and a 700 ft^3/min (340 m^3/h) compressor pushing air through a hose 200 ft (60 m) long." Another comment was, "Just wanted to break the new guy in," or "Let's see how far we can shoot the ball." These comments demonstrate irresponsible actions that could get a crew member severely hurt at some point.

The best way to clean out a shotcrete hose is to have a crew member secure the hose to a solid object and then clear all persons from the area when performing the cleanout. When cleaning out a long-distance system without the crew members able to see one another, some sort of communication is a must; radio contact is the most common. If a 2 in. (50 mm) hose has even a small amount of water in the shotcrete hose and air is then applied to it, the hose will whip violently around even though there is no shotcrete material remaining in the hose. As a result of the potential whipping action, it is important to have the area cleared of all persons.

The following are a few suggestions or ideas you may want to implement in your cleanout procedures.

Best Practice for Cleanout

- Use low-pressure water whenever possible, as it's the safest option.
- Always strap or chain the hose to a solid object; never have a person hold the hose during cleanout.
- Clean hose into a secure, solid container of some sort (Fig. 1 and 2).
- Use a catching device for ball or bullet type, as shown in Fig. 3.
- Have a cleanout plan established before you start your pumping/shooting, including:
  a) Where cleanout will take place; and
  b) What will hold the cleaned-out material; for example, hopper, trash bin, or super sack tote.
- Have all cleanout supplies needed—such as foam balls, adapters to hook up to water fitting, and header to water/air fitting with bleed-offs to safely bleed pressure off (Fig. 4)—including devices to hold the hose, such as straps or chains.

Fig. 1

Fig. 2

A crew member is irreplaceable; the cost of a hose or system replacement is affordable. Irresponsible actions are not worth getting a crew member hurt or seriously injured.

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Fig. 3

Fig. 4

Shotcrete Placed in Multiple Layers does NOT Create Cold Joints

By Charles S. Hanskat

Designers and inspectors often confuse placement of multiple layers of shotcrete in building out a section with cold joints experienced in cast-in-place concrete construction. The American Concrete Institute's (ACI's) Concrete Terminology defines cold joint as:

"*Cold joint—a joint or discontinuity resulting from a delay in placement of sufficient duration to preclude intermingling and bonding of the material, or where mortar or plaster rejoin or meet.*"

In cast-in-place concrete construction, internal vibration is the most common method for providing adequate consolidation of the placed concrete. In cast-in-place work, a cold joint is formed when an initial lift of concrete becomes too stiff for penetration by the vibrator used to consolidate a subsequent lift. This thus precludes the "intermingling" of material in the definition. However, ACI 309R-05, "Guide for Consolidation of Concrete," indicates that if bond is obtained between cast sections, a cold joint is avoided. ACI 309R-05, Section 7.2, states:

"*When the placement consists of several layers, concrete delivery should be scheduled so that each layer is placed while the preceding one is still plastic to avoid cold joints. If the underlying layer has stiffened just beyond the point where it can be penetrated by the vibrator, bond can still be obtained by thoroughly and systematically vibrating the new concrete into contact with the previously placed concrete; however, an unavoidable layer line will show on the surface when the form is removed.*"

Shotcrete does not use internal vibration for consolidation of concrete. Instead, shotcrete provides thorough consolidation and densification by high-velocity impact of fresh concrete material on the receiving surface. It is well proven in laboratory testing that properly placed shotcrete is very well consolidated, and provides excellent strength and durability. The high-velocity impact of shotcrete on a hardened, previously shot layer (or existing concrete surface) provides a strong, abrasive blast to open up the surface, and then provides an immediate exposure of that hardened surface to fresh cement paste. As a result, shotcrete exhibits excellent bond to concrete and previously shot surfaces.

A study on shotcrete bond to concrete repair surfaces that included work on multi-layer shotcrete bond was conducted at Laval University (Beaupré 1999). The study looked at bond with multiple layers of shotcrete shot 4 hours, 1 day, and 28 days apart with four levels of surface finishing (no surface finishing, scratched with steel trowel, scratched and finished with wood trowel, rough broom finish). Table 1 shows the results from Beaupre's (1999) report. The report concluded that "it can be seen that, for the waiting period and the types of finish studied, there is no significant influence of these parameters on bond strength" and "With respect to the multi-layer bond strength of shotcrete, the presence of shotcrete/shotcrete interfaces does not seem to create a large reduction in shotcrete quality in terms of mechanical bond if no curing compound is used."

Table 1: Multi-layer bond strength in MPa (psi) (Beaupré 1999)

	Type of finish between layers (results with no curing compound)			
Time	**None**	**Scratch**	**Scratch + wood**	**Roughen with broom**
4 hours	2.1 (300)	1.8 (260)	2.1 (300)	1.9 (275)
1 day	NA	2.1 (300)	2.1 (300)	NA
28 days	NA	1.8 (260)	NA	2.0 (290)

Note: NA is not available

Specified shotcrete bond strength for shotcrete to properly prepared concrete substrates generally ranges from 100 to 150 psi (0.69 to 1.00 MPa). If a curing compound is used on a layer, it should be completely removed before shooting subsequent layers of shotcrete.

In shotcrete construction, surface preparation between layers to provide full bond is important. ACI 506.2-13, "Specification for Shotcrete," specifically addresses this in the requirements of Sections 3.4.2.1 and 3.4.2.2 that:

"*3.4.2.1 When applying more than one layer of shotcrete, use a cutting rod, brush with a stiff bristle, or other suitable equipment to remove all loose material, overspray, laitance, or other material that may compromise the bond of the subsequent layer of shotcrete. Conduct removal immediately after shotcrete reaches initial set.*

"*3.4.2.2 Allow shotcrete to stiffen sufficiently before applying subsequent layers. If shotcrete has hardened, clean the surface of all loose material, laitance, overspray, or other material that may compromise the bond of subsequent layers. Bring the surface to a saturated surface-dry (SSD) condition at the time of application of the next layer of shotcrete.*"

The shotcrete specification is actually more stringent than ACI 318-11, Section 6.4, on construction joints, because it requires removal of all potential bond-breaking materials immediately after initial set, as well as the cleaning and SSD conditions provided for in 3.4.2.2.

Thus, shotcrete placed in layers does not produce a "cold joint" as defined by ACI, because it produces excellent bond between the layers. This has been confirmed by visual inspection of numerous cores taken through multiple layers of shotcrete, where it is often impossible to identify where one layer stops and the other starts, unlike cold joints in cast-in-place work where the difference between lifts is readily apparent.

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Sawed side of shotcrete test panel shot with multiple layers

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Coastal Gunite Construction Company has provided structural shotcrete services in the commercial, industrial, energy, and public markets for more than 30 years. Since 1983, Coastal Gunite has held an unwavering commitment to providing owners and engineers with technically capable and competent general contractor services, specializing in shotcrete rehabilitation and new construction.

Jacksonville Electric Authority Cooling Tower rehabilitation

Old Mill Creek Sewer rehabilitation, St. Louis, MO

From St. Louis to Miami, Houston to New York, Bermuda to the Bahamas, Coastal Gunite has built and rehabilitated a multitude of concrete structures. By specializing in shotcrete construction services, Coastal Gunite has developed a team of well-trained, highly experienced tradesmen. Coastal Gunite has more than 180 years of shotcrete experience among their site superintendents and over a dozen certified shotcrete nozzlemen. Coastal Gunite is experienced in the application of both wet- and dry-mix shotcrete. Because of the growth and diversity of the shotcrete method, Coastal is a leader in a variety of disciplines, including marine environments, heavy civil, industrial, underground, large-scale commercial, public, and private projects.

Over the last 30 years, Coastal Gunite has completed hundreds of bridge rehabilitation projects—both large and small—including shotcrete rehabilitation, pile jackets, and cathodic protection. Coastal Gunite is prequalified as a bridge repair contractor with Departments of Transportation in over 20 states and has completed rehabilitation on such landmark structures as the Chesapeake Bay Bridge in Annapolis, MD; the Bonner Bridge and Wright Memorial Bridge on North Carolina's Outer Banks; the Howard Frankland Bridge over Tampa Bay in Florida; and the historic Venetian Causeway in Miami, FL.

Coastal Gunite has rehabilitated large combined sanitary and storm sewers and aqueducts for infrastructure owners throughout the eastern United States, including the cities of Atlanta, GA, and Indianapolis, IN, as well as the Army Corps of Engineers. High-profile highway tunnel repair projects have included the Liberty Tunnel in Pittsburgh, PA, and the Fort McHenry Tunnel (I-95) in Baltimore, MD.

Industrial applications have been completed for companies including Potash and Rain CII, CSX and Norfolk Southern Railroads, and Allied

Corporate Member Profile

U.S. Military Academy at West Point shear wall installation

PennDOT Liberty Tunnel wall rehabilitation, Pittsburgh, PA

Chemical. Large-scale infrastructure rehabilitation such as the SJRPP Cooling Towers rehabilitation and structural shotcrete renovation for the U.S. Military Academy at West Point, NY, testify to the depth, breadth, and economy of shotcrete construction undertaken by Coastal Gunite. With the completion of structural rehabilitation on seven large-ship berthing piers at the Norfolk Naval Station—the largest in the world—Coastal Gunite Construction has proven itself as one of the most qualified shotcrete contractors in the country.

As a leader in the industry, Coastal Gunite is committed to furthering the industry through participation with ACI, ASTM International, and ASA committees. Coastal Gunite remains a proponent of the shotcrete method and participates at the highest levels in maintaining and improving the industry's standards. Today, Coastal Gunite provides services from offices located in Maryland, Tennessee, and Florida.

Coastal Gunite Construction Company

Main Office:
Cambridge, MD | 410-228-8100
Southeast Region Office:
Brandenton, FL | 941-744-5500
www.coastalgunite.com

NCDOT Herbert C. Bonner Bridge sub/superstructure rehabilitation, Nags Head, NC

Become an ASA Corporate Member and…

Grow your business

- **NETWORK** with your peers in the shotcrete industry
- **STAY CURRENT** on the latest shotcrete industry trends, strategies, challenges, and opportunities
- Receive **PROJECT LEADS** through project bid alerts and project listings
- Gain **EXPOSURE** through a variety of tools available to members, such as the ASA Buyers Guide
- **INFLUENCE** ASA's direction in serving members and growing the industry
- **SAVE** significantly on ASA products and services

Grow your industry

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

At a time when more and more companies are demanding effective use of their dollars, more and more companies in the shotcrete industry are realizing the benefits of becoming an ASA Corporate Member (***25% increase in the number of ASA Corporate Members over the last 2 years***).

Take the step that will help grow your organization and industry—become an ASA Corporate Member today

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

Shotcrete MAGAZINE

2014 MEDIA KIT

A quarterly publication of the American Shotcrete Association

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Decorative Sculpted Shotcrete Wall Completed in Suburban Denver

Hayward Baker, Inc., recently completed a 6200 ft² (576 m²) decorative sculpted shotcrete wall behind a housing development in Arvada, CO. Hayward Baker's decorative sculpted shotcrete capabilities support customers nationwide with projects ranging from small landscaping to large landslide and highway cuts.

New roadway construction in view of a housing development required a retaining wall to support a deep cut into a slope. To provide a more aesthetically pleasing wall, Hayward Baker constructed a 6200 ft² (576 m²), four-level soil nail wall with a sculpted shotcrete facing. The traditional portion of the soil nail wall was constructed in excavated lifts from the top of the wall to the final bench on the slope. The face of each lift received a 4 in. (102 mm) thick layer of reinforced structural shotcrete. After completion of the final lift, Hayward Baker's shotcrete crew worked from man lifts to construct a 4 in. (102 mm) thick architectural sculpted wall over the face of the soil nail wall. After curing of the sculpted facing, the team stained the shotcrete to match a natural rock face in the area. The project safely stabilized the slope while leaving the homeowners with a view from their backyards of a natural-looking rock formation.

Arvada wall

Sculpted shotcrete walls

Tom Szynakiewicz, Senior Project Manager with Hayward Baker's Central Region, reported that Hayward Baker has provided shotcrete as part of temporary and permanent earth retention systems for many years, and explained the advantages of decorative sculpted shotcrete.

"Sculpted shotcrete offers the benefit of the proven effectiveness of traditional shotcrete over cast-in-place concrete in terms of cost and time savings. Sculpted shotcrete allows aesthetically pleasing surfaces that can maintain the look of the surrounding environment or enhance the surface of existing walls or earth retention systems," he stated.

"Our American Concrete Institute Certified Nozzlemen can create natural-looking rock surfaces as part of any permanent earth retention system," added Szynakiewicz. "Hayward Baker's shotcrete services are available as stand-alone augmentation for existing retaining walls, or they can be part of a complete design-build package. Moreover, our specialized sculpted shotcrete crews are available to quickly mobilize throughout the United States or Canada."

Guinness World Record Set for Largest Continuous Concrete Pour

At 73 stories and 1099 ft (335 m) in height, the new Wilshire Grand project in downtown Los Angeles, CA, will be the tallest structure west of the Mississippi when its doors open in 2017. Following deconstruction of the existing Wilshire Grand Hotel in 2013, construction of the new mixed-use building, designed by AC Martin Partners, Inc., commenced in February 2014 with the world's largest continuous concrete pour. The project's general contractor, Turner Construction Company (Turner), worked

with The Conco Construction Companies (Conco), one of the largest pumping and belt companies in the United States, to coordinate the fleet of pumps, including 16 Putzmeister America, Inc. (Putzmeister) units, required for the record-breaking, 21,189 yd^3 (16,200 m^3) mat pour.

To lay the foundation for the massive Wilshire Grand project, Turner and Conco devised a plan for the continuous 21,189 yd^3 (16,200 m^3) mat pour, which was located 79 to 95 ft (24 to 29 m) below street level. For the past several months, crews have prepared the site by digging a 20 ft (6 m) deep pit and lining it with 3700 tons (3360 tonnes) of reinforcing steel.

During the massive pour, 12 Putzmeister truck-mounted concrete boom pumps ranging from 105 to 154 ft (32 to 47 m), two Putzmeister placing boom towers, and two Putzmeister trailer-mounted concrete pumps were strategically placed both inside and above the excavation.

A total of 19 pumps were used for the pour. Six pumps at street level fed six pumps, including two Putzmeister MX 34-4 Placing Boom Towers, two 32-4- and a 36-4-Meter Truck Mounted Boom Pump, located deep in the excavation. Two Putzmeister BSA 14000 Trailer Pumps at ground level also relayed concrete into the pumps located inside the excavation.

"We used Putzmeister equipment due to its durability and reliability," said Michael Marchesano, Turner's general superintendent. "With a continuous pour of this magnitude, you need to be able to count on your equipment to keep doing its job, even under demanding conditions."

The pour included 227 ready mix trucks making more than 2100 trips and pouring almost 39 million tons (35 million tonnes) of concrete during an 18-1/2 hour period.

"Each truck made 10 to 14 concrete drops, traveling through the night between eight different concrete plants within a 30 km (19 mile) radius," said Marchesano. "The first batch of concrete poured onto the site came from a plant in Vernon that poured the first concrete in Southern California ever."

The structural engineering team, Brandow & Johnston, elected a continuous pour to ensure the mat foundation would yield the maximum strengths. To guarantee the entire pour cured at the same rate, a special C40, 90-day mixture was used. Special admixtures were used to ensure the temperature during the process of hydration didn't exceed the parameters designed for the mixture. Without those admixtures the mat slab could have experienced thermal cracking and lower strength, which could impact the structural integrity of the placing. Following the placement, a cure blanket and a thermal control system were put into place for 15 days.

"We were extremely happy with how all of the Putzmeister equipment performed," said Marchesano. "A pour this size requires extensive planning, precision, and dependable equipment. Everything went more smoothly than we could have imagined."

The mat placement qualified as the largest continuous concrete placing in history and officially claimed a Guinness World Record.

NRMCA Signs On to International Responsible Sourcing Program

The National Ready Mixed Concrete Association (NRMCA) has signed an agreement with several cement and concrete groups from around the world to develop an international responsible sourcing certification program for concrete. The project, which is spearheaded by the Cement Sustainability Initiative (CSI) of the World Business Council on Sustainable Development (WBCSD), includes cement and concrete groups from North America, South America, and Europe. The agreement was signed on February 5, 2014, by NRMCA Chairman Bill Childs during a special ceremony at the International Concrete Sustainability Conference in Medellín, Colombia, one of several such conferences sponsored by NRMCA each year.

Responsible sourcing encourages environmentally, economically, and socially responsible manufacturing and business operations. "NRMCA members are committed to continuous environmental improvement and operational excellence through product and process innovation. Our participation in the development of the international responsible sourcing program for concrete will support efforts toward meeting this commitment," Childs said. The responsible sourcing program framework and details will be developed throughout 2014 and launched in early 2015.

With the recent release of the United States Green Building Council's LEED v4, building product manufacturers are faced with opportunities of contributing to the new Material and Resources Credit: Sourcing of Raw Materials. LEED v4 is encouraging the use of building products that have environmentally, economically, and socially preferable impacts. The new Responsible Sourcing credit rewards project teams for selecting products and materials verified to have been extracted or sourced in a responsible manner. The development of the new international responsible sourcing program for concrete will help concrete producers meet these new LEED requirements.

"NRMCA has been on the cutting edge of responsible manufacturing through programs such as the NRMCA Green-Star Certification and Sustainable Concrete Plant Certification," said Robert Garbini, NRMCA President. The NRMCA Green-Star Certification program recognizes concrete plants that have adopted and implemented an Environmental Management System (EMS) for environmental benchmarking and continual improvement. The NRMCA Sustainable Concrete Plant Certification program provides a quantitative metric to allow ready mixed concrete producers to demonstrate high performance in sustainable extraction and manufacturing practices. It is anticipated that many of the components of the Green-Star and Sustainable Concrete Plant Certification programs will be incorporated into the new international responsible sourcing program for concrete. Details of these and other NRMCA sustainability programs can be found at **www.nrmca.org/sustainability**.

NRMCA, based in Silver Spring, MD, represents the producers of ready mixed concrete and the companies that provide materials, equipment, and support to the industry. It conducts education, training, promotion, research, engineering, safety, environmental, technological, lobbying, and regulatory programs.

Shotcrete Helps Restore Spokane Riverbed

Weirs Improve Water Flow to Reclaim Natural Geology and Landscape

The QUIKRETE® Shotcrete MS–Fiber Reinforced was used to fill channels and create weirs to help return the Spokane River to its natural flow pattern in downtown Spokane, WA. In the late 1800s, the growing demand for increased energy to support the businesses and residents of Spokane, WA, resulted in channels being created at the bottom of the Spokane River's North Channel to divert water from stagnant pools in the city's downtown area to mills using hydropower. While the channels did relieve many of the pools, they also prevented the Spokane River from flowing properly, which basically left the riverbed empty and unsightly each summer. Fortunately, the team of Berry Ellison, LLA, Land Expressions (landscape architect), ARC (architect), TD&H Engineering and Cemrock Concrete & Construction Ltd. (concrete contractor) were able to restore the Spokane River to a more natural flow for Avista Utilities using an effectively creative solution.

After conducting extensive research and considering various building solutions, an approach to spread less water over more area by strategically placing a series of permanent modifications (weirs) to neutralize manmade excavations was initiated. The challenging terrain required the use of material that could be applied in tight spots, far removed from large vehicle access, and finished to match the surrounding landscape. QUIKRETE Shotcrete MS–Fiber Reinforced, 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, was chosen. The undulating riverbed is 150 ft (46 m) deep and 300 ft (91 m)

wide in some areas, so the shotcrete was pneumatically conveyed dry through a hose to each predetermined weir location, in some cases more than 500 ft (152 m). Water was then added to the mixture at the nozzle during the dry-mix shotcrete application process. This minimized material waste, created a consistent application, and made the process extremely mobile, according to the shotcrete contractor. In addition, the shotcrete was artistically finished to match the color, texture, and shape of the natural basalt riverbed as well as the surrounding geology and landscape.

In the end, the project turned out better than imagined. The amount of habitat restored to herons, beavers, raccoons, and native red band trout is immeasurable. The Spokane Falls has been restored as has the sound and intangible energy that the river brings to the atmosphere of downtown Spokane and Riverfront Park. The river corridor is a thriving ecosystem and the restoration will impact the Spokane community for decades to come and remain an example for future environmental improvements.

Industry Personnel

ACI Announces New Officers for 2014

The American Concrete Institute (ACI) introduced its 2014-2015 President, Vice President, and four Board members during the ACI Spring 2014 Convention in Reno, NV.

William E. Rushing Jr.

Michael J. Schneider

William E. Rushing Jr., Vice President of Waldemar S. Nelson & Co., Inc., New Orleans, LA, was elected to serve as President of the Institute for 2014-2015.

Michael J. Schneider, Senior Vice President and Chief People Officer at Baker Concrete Construction, Inc., Monroe, OH, has been elected ACI Vice President for a 2-year term. **Sharon L. Wood**, the Robert L. Parker, Sr. Centennial Professor of Engineering and Chair of the Department of Civil, Architectural, and Environmental Engineering at the University of Texas at Austin, Austin, TX, is now the Institute's Senior Vice President.

Additionally, four members have been elected to serve on the ACI Board of Direction, each for 3-year terms: **Alejandro Durán-Herrera**, Professor and Head of the Concrete Technology Department at the Facultad de Ingeniería Civil of the Universidad Autónoma de Nuevo León (UANL), Monterrey, Mexico; **Augusto H. Holmberg**, General Manager of the Instituto del Cemento y del Hormigón de Chile (ICH), Santiago, Chile; **Colonel Fred Meyer**, Deputy Head of the Department of Civil and Mechanical Engineering at the United States Military Academy (USMA), West Point, NY; and **Michael M. Sprinkel**, Associate Director at the Virginia Center for Transportation Innovation and Research, Charlottesville, VA.

ASA Spring 2014 Committee Meetings in Reno, NV

The ASA Board of Direction and its subcommittees and task groups met on Saturday, March 22, 2014, at the Grand Sierra Resort in Reno, NV. (These committee meetings are held bi-annually in conjunction with the ACI Spring and Fall Conventions.) In addition to its regular committee business, such as maintenance of educational materials and pulling together noteworthy topics and authors for *Shotcrete* magazine, many new and exciting initiatives were set into action at the Reno meetings.

Revisions Bring New Focus to ASA Committees

With a renewed focus on promoting the use and acceptance of shotcrete as well as strengthening ASA membership benefits, ASA President Charles Hanskat outlined his vision to separate the functions of the (existing) Marketing & Membership Committee into two separate committees. The Marketing Committee will be responsible for helping to grow the use and acceptance of shotcrete, promoting its sustainability and cost-savings benefits, and marketing the Association's education and certification products. Recognizing also that its members are the lifeblood of the Association and are critical in achieving ASA's goals and carrying out its mission, the Membership Committee will be responsible for strengthening membership benefits and helping to increase participation in the Association's activities.

A standing Awards Committee will also be formed, with the immediate Past President serving as ex-officio Chair of the committee each year. This committee will primarily be responsible for judging the annual ASA Outstanding Shotcrete Project Awards Program entries each year, but will also consider other honors and awards such as special service awards and honorary memberships.

In an effort to better focus the Association's resources on these new committees and on its larger current initiatives—contractor qualification/certification and inspector education, for example—Hanskat has proposed to close the Sustainability and Underground Committees at this time. Relocating the ongoing tasks that these committees have been responsible for (including educational material and magazine publications) into the Education and Publications committees will ensure that ASA's products and publications in these areas will continue to be as impactful as before.

Updating ASA's Vision and Mission

At its Reno meeting, the ASA Board of Direction also approved to conduct a strategic planning session—updating the Association's vision and mission—and setting strategic goals and objectives for the coming years. With the help of a strategic planning facilitator, key individuals will work to reaffirm ASA's mission to its members and create an enduring future plan for the next generation of officers, directors, and committee members to uphold and execute.

Call for Members to the ASA Marketing and Membership Committees

With separate committees now established to separately promote the shotcrete industry (Marketing Committee) and refine ASA's membership benefits (Membership Committee), now comes the "Association" part of the picture—populating the committees with members like you! If shotcreting is important to your business, please consider taking a more active role in ASA's committees by participating as a member on one of these new committees, or on any of our other committees—Education, Publications, Pool & Recreational Shotcrete, and Safety.

Members are the lifeblood of any association, and the only way to ensure that ASA is working in the best interests of the shotcrete industry is to take part as a committee member so that your valuable ideas are taken into account and put into action. Please make an effort to visit our next round of ASA committee meetings (held on October 25, 2014, in Washington, DC), and don't be surprised if you meet and see everyday shotcreters from around the country just like you looking to grow and improve the industry. Registration for these meetings is free of charge.

For more information on ASA's committees or to apply for membership to a committee, please contact ASA at (248) 848-3780 or **info@shotcrete.org**.

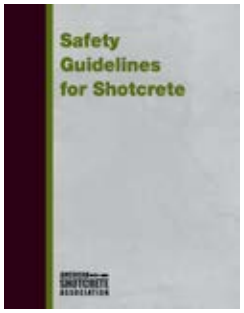
Updated ASA Education Module Released

A significant part of what makes ASA's sponsorship of the ACI Shotcrete Nozzleman Certification program so successful is ASA's 1-day Nozzleman Education course provided to all first-time certification candidates. Many returning (re-certifying) candidates elect to re-take the course as well, hoping to refresh their knowledge and catch up on the latest information regarding shotcrete technology and safety. Administered by its core team of approved certification Examiners, ASA regards this education module as one of its most valuable products serving the shotcrete industry.

It is with great excitement that we announce the launch of an all-new, updated education presentation for 2014. The overall format, presentation slides, and presenter notes have been completely overhauled to better correspond with study content in the ACI CP-60 nozzleman workbook and provide more comprehensive coverage of relevant information for the shotcrete nozzleman. Look for this new education module as part of your next ASA certification or re-certification session. For more information on ASA's educational offerings, visit **www.shotcrete.org/education/index.htm**.

Safety Document Published

ASA is proud to announce the publication of a new document, titled "Safety Guidelines for Shotcrete." Chapter topics include:



- Personal Protective Equipment;
- Communications;
- Lighting, Back, and Spine Safety;
- Shotcrete Materials;
- Shotcrete Equipment; and
- Shotcrete Placement: Wet- and Dry-mix Processes.

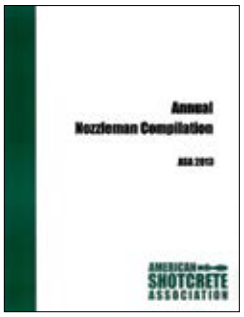
As a significant benefit of membership, all Corporate Members will receive one complimentary copy of this publication. Additional copies are available through the ASA Bookstore for $25 each (for members; $100 for nonmembers). It is available in both print and electronic formats; the details of each are as follows:

- Print: Soft cover, 8.5 x 11 in., 20 pages, color-printed, and staple-bound.
- Electronic: Copy-protected PDF, viewable using only Adobe Reader or Acrobat software on up to three different desktop and laptop computers only—not compatible with tablet computers or mobile devices at this time.

For more information or to purchase a copy of this publication, visit the ASA Bookstore at **www.shotcrete.org/BookstoreNet/default.aspx**.

New 2013 Nozzleman Compilation Published

ASA has recently published a new edition of its annual Nozzleman Compilation. Each year, the Nozzleman Compilation is updated with articles from the previous year's issues of *Shotcrete* magazine; the articles are selected specifically for their relevance to the shotcrete nozzleman. Sources include Technical Tips, Nozzleman Knowledge, Safety Shooter, and other relevant feature articles.



The Nozzleman Compilation will be sent free of charge to all current ASA Nozzleman Members as part of their overall membership benefits. Additional copies of the document can be purchased from the ASA Bookstore at **www.shotcrete.org/BookstoreNet/default.aspx**.

ACI 506.2-13 Specification for Shotcrete Now Available

Now available in the ASA Bookstore is the latest revision of ACI 506.2-13, "Specification for Shotcrete." This specification contains the construction requirements for the application of shotcrete. Both wet- and dry-mix shotcrete are addressed, as well as fiber-reinforced shotcrete. The minimum standard for materials, properties, testing, and application are covered. ACI recommends that the materials, processes, quality control measures, and inspections described in this specification should be tested, monitored, or performed as applicable only by individuals holding the appropriate ACI certifications or equivalent.

For more details or to order a copy, please visit the ASA Bookstore at **www.shotcrete.org/BookstoreNet/default.aspx**.

New Putzmeister Mixkret 5 Low-Profile Concrete Mixer for Mining

Since its foundation in Germany more than 50 years ago, Putzmeister has been a leading provider of concrete pumping and placing equipment. With this know-how as a vantage point, Putzmeister has developed a range of mining and tunneling machinery, including shotcreting equipment, as well as low-profile concrete mixers ("Mixkret") to complement the concrete spraying process and optimize shotcrete logistics in mining.

Putzmeister has now extended its Mixkret series by the Mixkret 5 model, offering a concrete mixing and transport capacity of 6.5 yd^3 (5 m^3). The machine will be presented at EXPOMIN, Santiago, Chile, this year. With this new launch, Putzmeister offers a compact machine equipped with a powerful Caterpillar 6-cylinder diesel motor (168 kW/225 hp), providing great traction force and climbing ability.

Thanks to the automatic altitude compensation system (AAC) of the diesel motor, Mixkret 5 is able to operate at high altitudes without loss of performance. This has been proven by the numerous Mixkret 4 equipped with the same system (diesel-motor Caterpillar C6.6 with 130 kW/174 hp), which are currently working in the toughest conditions at altitudes of up to 16,000 ft (5000 m) above sea level.

For customers who also wish to optimize their shotcrete additive logistics, Mixkret 4 and Mixkret 5 optionally include a liquid additive discharging system, including an additive tank and pump. In this way, the concrete mixers can feed any concrete spraying equipment not only with concrete but also with additives, reducing working time and increasing safety in the operation.

For more information, contact info@putzmeisterunderground.com or visit **www.putzmeisterunderground.com**.

Blastcrete Upgrades MX-10 Mixer/Pump for Greater Efficiency

The upgraded MX-10 Mixer/Pump from Blastcrete Equipment Company delivers greater speed and torque to quickly and effectively mix dense refractory materials in less than 2 minutes. The new system provides greater efficiency that leads to faster and greater ROI on demanding refractory, wet shotcrete, and pump-cast applications in foundries, power generation, petrochemical, steel mills, and cement-manufacturing facilities.

The MX-10's hopper handles up to 2500 lb (1134 kg) of material, and its high-speed hydraulic agitator keeps materials blended and in suspension as the material flows to the pump. The unit's 3 in. (76 mm) swing tube piston pump operates with up to 2200 psi (15 MPa) for consistent installation of as much as 12 tons (10,800 kg) of material per hour. The high-pressure pump also allows customers to achieve vertical pumping distances in excess of 300 ft (91 m) when installing refractory materials.

The MX-10's 22 ft^2 (2 m^2) platform provides 50% more space than competitive equipment to give operators ample room to maneuver easily. The electrical controls are mounted on the platform and positioned away from the mixer to remain free from debris and water.

The unit is mounted on dual 7000 lb (3175 kg) capacity axles with electric braking and lights for enhanced safety when traveling. Lifting eyes on the platform allow operators to use a crane to lift the machine and place it on a flatbed for traveling longer distances. It also allows users to place the unit on work platforms in larger factories. Blastcrete offers the MX-10 with an optional skid-mounted framework that reduces the overall length, width, and height of the machine.

The new MX-10 can be equipped with a John Deere 4045T 99 hp (74 kW) or Deutz BF4M 2012 102 hp (76 kW) water-cooled diesel engine. Blastcrete also offers the unit with electric motors. The engine on the MX-10 is placed away from the mixer and receiving hopper to prevent thermal transfer that causes refractory materials to set prematurely.

The MX-10 is faster and easier to clean than traditional swing-tube piston pump units. The swing-out receiving hopper provides easy access to the lower hopper and swing tube section for cleaning and maintenance. Blastcrete offers an optional 2000 psi (14 MPa) hydraulic pressure washer for easier cleanup and an automatic lubrication system to ensure proper greasing of the swing tube pump.

The MX-10 is CE-certified to meet European Union safety standards for equipment operation.

Blastcrete has been manufacturing safe, reliable, and user-friendly solutions for the refractory and shotcrete industries for more than 60 years. With a complete product line consisting of concrete mixers, pumps, and related products, the company serves the commercial and residential construction, ICF and SCIP building systems, refractory, and

underground markets. For more information, contact: Blastcrete Equipment Company, 2000 Cobb Ave, Anniston, AL 36202; 800-235-4867; fax 256-236-9824; info@blastcrete.com; **www.blastcrete.com**.

American Concrete Institute Announces the Reorganized ACI 318-14

The American Concrete Institute (ACI), an organization whose mission is to develop and disseminate consensus-based knowledge on concrete and its uses, is finalizing a completely reorganized ACI 318-14, "Building Code Requirements for Structural Concrete." ACI 318 is one of the most essential and valuable standards with respect to the design of concrete structures, and is published every 3 years. The announcement was made at World of Concrete 2014 in Las Vegas, NV.

Scheduled for publication in late 2014, the reorganized 318-14 is organized from an engineer's perspective. By focusing on member design, ACI 318 requirements will flow more intuitively and have fewer cross-references. Significant highlights include:

- Greater ease of use;
- Improved logic and flow of information;
- Member-based organization to quickly locate relevant code information; and
- Construction requirements centralized in one chapter.

"ACI is proud and excited to announce the reorganized ACI 318-14 will be published later this year," said Randall W. Poston, Chair, ACI Committee 318. "This first major reorganization of ACI 318 since 1971 represents nearly a decade of work and will feature improved language and style consistency, more expansive use of tables and charts, and be organized so that engineers have increased confidence they have satisfied all necessary code requirements."

The United States and more than 22 countries around the world base their national building codes on all or part of ACI 318, and the document is used globally. ACI 318-14 will be available in English, Spanish, and Chinese and in both U.S. Customary units and the International System of Units (SI). In addition to the traditional printed copy, ACI 318-14 is expected to be available in various electronic formats for access on desktop, tablet, and mobile devices.

The public comment period on ACI 318-14 will take place this spring, with users and stakeholders encouraged to review provisions and submit feedback. This summer, ACI Committee 318 will address those comments. Along with several transition resources, ACI 318-14 is expected to be published in late 2014.

"To aid engineers in transitioning to the member-based ACI 318-14, the American Concrete Institute will publish a transition key that maps provisions in ACI 318-14 to provisions in ACI 318-11, publish a Reinforced Concrete Design Manual consistent with provisions in ACI 318-14, host educational programs online and around the world, and participate in industry conferences," added Poston. "Plus, ACI will share additional resources on its website **www.concrete.org** and on its Facebook and Twitter pages."

To learn more about ACI 318-14, review sample chapters and the Table of Contents, obtain the schedule to publication, and register to receive notifications for the public comment period and when the published document is available, visit **www.concrete.org/ACI318**.

Have YOU Visited the ASA Website Lately?

There have been significant changes and new services added!

WWW.SHOTCRETE.ORG

Shotcrete Calendar

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
Washington Hilton
Washington, DC
www.shotcrete.org

OCTOBER 26-30, 2014
ACI Fall 2014 Convention
Theme: "Spanning the Globe"
Washington Hilton
Washington, DC
www.concrete.org

NOVEMBER 5-7, 2014
2014 International Pool | Spa | Expo
Orange County Convention Center
Orlando, FL
www.poolspapatio.com

DECEMBER 7, 2014
Workshop on Methods for Investigation of Unexpected Performance and Properties of Cementitious Mixtures
Sheraton New Orleans
New Orleans, LA
www.astm.org

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www.spritzbeton-tagung.com

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FEBRUARY 3-6, 2015
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Las Vegas Convention Center
Las Vegas, NV
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APRIL 11, 2015
ASA Spring 2015 Committee Meetings
Marriott & Kansas City Convention Center
Kansas City, MO
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APRIL 12-16, 2015
ACI Spring 2015 Convention
Theme: "Fountains of Concrete Knowledge"
Marriott & Kansas City Convention Center
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JUNE 14-17, 2015
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Anaheim, CA
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NOVEMBER 7, 2015
ASA Fall 2015 Committee Meetings
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NOVEMBER 8-12, 2015
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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: *I have a newly constructed in-ground pool in which shotcrete was used. The pool has been holding dirty water since just after the shotcrete cured. Does the shotcrete have to be cleaned and/or treated before an overlay is applied?*

Answer: To ensure a good bond between the shotcrete shell and the overlay, the surface should be cleaned and allowed to dry before application of the overlay material.

Question: *We are using wet-mix shotcrete for culvert linings, with an existing corrugated steel plate pipe stream culvert. The pipe is 96 in. (2438 mm) long and deteriorated. There is a water diversion, but there is a pressure gradient forcing water through the voids. Any ideas on leak repair procedures?*

Answer: Installing a shotcrete lining requires a somewhat dry substrate and certainly is not compatible with running water. The water needs to be blocked or diverted.

A means of blocking the inflow is to inject a swellable urethane grout through the openings in the existing pipe. The grout, if done properly, will expand upon contact with water and seal the outside of the pipe. Another means of diverting the water is to install drainage material over the inflowing area to collect the water and remove it from the pipe. The shotcrete can then be applied over the drainage material.

Question: *I need to find the reference in ACI standards indicating the technical and practical reasons why thermal expansion joints and contraction settings are eliminated in the stabilization of nonstructural slopes covered with shotcrete and steel fiber. Can you help?*

Answer: Shotcrete is a method of placing concrete. Fibrous shotcrete will have very similar, if not identical, properties as fibrous cast concrete. Expansion and contraction joints should be similar in shotcrete to those needed in cast concrete. ACI 224.3R-95, "Joints in Concrete Construction," covers joints in many different applications. The closest relevant document for eliminating joints is ACI 360R-10, "Guide to Design of Slabs-on-Ground," where, in Section 8.3, it states:

"To eliminate sawcut contraction joints, a continuous amount of reinforcement with a minimum steel ratio of 0.5% (PCA 2001) of the slab cross-sectional area in the direction where the contraction joints are eliminated is recommended."

This 0.5% reinforcement is consistent with the provisions of ACI 350-06, "Code requirements for Environmental Engineering Concrete Structures and commentary," for the minimum reinforcement for temperature and shrinkage without contraction joints.

You can refer to ACI 506 series documents regarding shotcrete, and possibly the FHWA SA-96-069R "Manual for Design, Construction, and Monitoring of Soil Nail Walls" for additional guidance. Copies of the ACI 506 series documents are available in the ASA Bookstore: **www.shotcrete.org/BookstoreNet/default.aspx**.

Question: *What is the* R*-value per inch for shotcrete without any integrated insulation?*

Answer: Shotcrete is concrete, pneumatically applied. So the same *R*-value fire ratings for concrete would apply to shotcrete. The standard is Joint ACI - TMS 216.1, "Code Requirements for Determining Fire Resistance of Concrete and Masonry Construction Assemblies."

Question: *My company has been using the gunite process (dry-mix shotcrete) for years now. What I have been finding lately is that a lot more questions are being asked by outside safety services, neighbors to our facility, etc., about the health effects of the shotcrete process. I believe that with the new proposed laws dealing with silica, everyone is paying more attention to products with sand and cement, and shotcrete has both. To try to educate myself and to answer these questions I am on the search for enlightenment and am coming up short.*

Here is where I am falling short: there is no (or I haven't found a) general material safety data sheet (MSDS) on shotcrete. Most MSDSs I have found on the Internet are for proprietary mixtures. I have yet to find an MSDS or any safety info on just plain sand and cement mixture.

Answer: Shotcrete is a method for placing concrete, so an MSDS for concrete or its constituent components would be appropriate. MSDS sheets for cement, aggregates, and concrete are readily available from cement manufacturers, aggregate suppliers, and concrete producers, as evidenced by a simple web search. This is the type of issue that can be discussed and effectively addressed by networking with other contractors and suppliers in the shotcrete industry. This is a primary benefit of actively participating in ASA—you or your organization should join ASA and attend committee meetings. ASA meetings are held three times a year; the next one is in October and is concurrent with the ACI Fall 2014 Convention in Washington, DC.

Question: *We are designing a 41 x 60 ft (12 x 18 m), 2.5 to 4.5 ft (0.8 to 1.4 m) deep swimming pool. The walls and floor are 8 in. (203 mm) thick with No. 4 (No. 13) bars. We are specifying shotcrete to build the pool. What should be the minimum spacing for the expansion joint?*

Answer: You need to address this question to a professional engineer who is knowledgeable in the characteristics of shotcrete

and concrete. Shotcrete is a method of placing concrete and the same parameters used in concrete design apply to shotcrete placements. Many pools of this size are designed and built without expansion joints, but it is beyond the scope of our association to provide further guidance.

Question: *We are developing a tunnel. At the tunnel portal (entrance), we have high walls around the portal about 60 ft (18 m) tall. They will have an inner structural shotcrete layer (4 in. [102 mm]) and outer architectural shotcrete (12 in. [305 mm]). Between the structural shotcrete and rock/soil, we have a drainage system to handle the groundwater. At the same time, we may have water at the top ground surface that will drain from top to bottom of the wall.*

The owner didn't want to make the water flow as a sheet over the wall surface. We proposed an inlet and vertical 6 in. (152 mm) pipe drop from the top to bottom and band to a ditch at the base of the wall. Can we locate the 6 in. (152 mm) pipe between the structural shotcrete and the architectural shotcrete?

Answer: The Federal Highway Administration's "Manual for Design & Construction of Soil Nail Walls" should address this issue. Many soil nail wall systems incorporate a drainage ditch at the top of the wall that catches the runoff and takes it to the ends of the wall. Your concept of a catch basin and drain between the layers is not something we have seen in the past and we are not qualified to express an opinion on this. We have seen systems with catch basins at the top of the wall and the drains behind the initial layer of shotcrete requiring notching the subgrade. To answer your question, yes, a 6 in. (152 mm) pipe can be fully encased in shotcrete between the layers. Complete encasement of an embedment of this size needs an experienced shotcrete nozzleman with properly sized equipment, appropriate concrete mixture design, and a trained shotcrete crew. The issue of appropriateness of the approach is better answered by a licensed professional engineer familiar with soil nail systems or retaining walls, and shotcrete/concrete.

Question: *I am currently involved in the design of several long retaining walls. One option under consideration is the use of soil nails with shotcrete reinforced by welded wire fabric (WWF) and the other is the use of mechanically stabilized earth (MSE) reinforcement (geogrids) with shotcrete reinforced by WWF. What is the best method (or product) to anchor each*

system to the shotcrete, and how are shotcrete-to-shotcrete (gunite) anchors treated in an MSE wall?

Answer: There are many ways to attach a shotcrete facing to a soil nail shoring system or an MSE wall system. For the attachment to a soil nail wall system, you could review the Federal Highway Administration's "Manual for Design & Construction of Soil Nail Walls." For MSE wall systems, you should consult with the MSE wall system vendors. Shotcrete facing systems are commonly used on both types of walls, but it is beyond the scope of our association to provide further guidance.

Question: *I'm looking for information on the quantity of rebound expected when applying shotcrete against soil. We have a W4 4 x 4 in. (102 x 102 mm) layer of mesh 2 in. (51 mm) from the soil face that is covered by a 4 in. (102 mm) initial layer of shotcrete. Is there a general ballpark figure that can be used, such as a percent of the total shotcrete placed?*

Answer: Your question does not indicate the orientation of the application. If the shotcrete is being applied to a sloped surface for a channel or slope the rebound should be incidental. If shooting a vertical wall, the amount of rebound is relative to the skill of the nozzleman, the quality or nature of the mixture, the shotcrete process being used (wet-mix or dry-mix), the stability of the wire mesh, and other parameters. The range could easily vary from 5 to 20% on vertical walls relative to the aforementioned listed parameters.

Question: *I have been hired to design a large concrete pit for a fertilizer plant. The pit will need to be approximately 13 ft (4 m) deep by 55 ft (17 m) long by 15 ft (5 m) wide. The pit will contain water at varying depths and will support grating covering the pit that will support equipment. The state is requiring the pit slab and walls to be a monolithic pour. Could shotcrete be used in this situation and be considered a monolithic pour?*

Answer: If the directive from the state is to cast (or shotcrete) both the slab and the walls monolithically, this would be a difficult task with either shotcrete or cast concrete. If the directive is to cast the floor monolithically, and then the walls monolithically, shotcrete could certainly be used and would be considered a monolithic placement. Once the state's intent is clarified, this question should be posed to a shotcrete contractor who might be the actual contractor on the project for their input.

As this is a fertilizer plant, there may be additional considerations due to the potentially aggressive nature of the fluids introduced into this pit.

Question: *We own a 200-year-old house with a rubble foundation. The foundation is structurally sound, but needs to be repointed, and some of it has no mortar at all. We would like to seal it to make it watertight and keep out radon. Could shotcrete be applied directly to the interior of the rubble wall (which includes small, loose stones; large gaps; and cracks), or would we have to first have the walls repointed and smoothed over?*

Answer: Yes, shotcrete would be an excellent method to fill the voids, open mortar joints, and gun an overlay over the irregular stone foundation. The use of shotcrete would be dependent on the access and ability of the applicator to safely place the shotcrete. A tight or low crawl space would make it difficult. We would suggest cleaning out loose materials with compressed air and water prior to the shotcrete placement. We recommend installing either a 2 x 2 in. (51 x 51 mm) 12-gauge or a 3 x 3 in. (76 x 76 mm) 11-gauge wire mesh over the stone foundation and gunning the shotcrete in place to fill in the mortar joints, creating a shotcrete overlay over the entire stone surface.

Question: *We will be shotcreting a pool and the designer has put an expansion joint in the pool going from the top of one wall through the floor to the top of the other wall. It also shows a 9 in. (229 mm) polyvinyl chloride (PVC) waterstop in this joint. I have seen this used with cast-in-place concrete, but not with shotcrete. I was wondering if there are any guidelines on shooting around a PVC waterstop.*

Answer: This detail is normally only used on very large competition pools on the order of 164 ft (50 m) in length. It takes a lot of skill, technique, and care to properly encapsulate the waterstop and it should only be attempted by a shotcrete contractor with experience in this application. The successful encapsulation of the waterstop is more challenging with the dry-mix process than when using wet-mix shotcrete. The techniques for the proper encapsulation are generally developed by the individual shotcrete contractor and there is no specific "guideline" available for encasing waterstops.

Question: *We are, and have been, designing and constructing permanent soil nail and shotcrete retaining walls. Typically, our designs consist of a primary nozzle-finished shotcrete facing to shore during our top-down construction, followed by a secondary shotcrete facing that is shot and sculpted once the full height of the wall has been excavated, drilled, and shot with the primary facing.*

We had a comment recently that only the secondary facing thickness can be used in our design for the wall's flexural capacity because the shotcrete layers may delaminate. Our general practice is to pressure-wash the primary nozzle-finished shotcrete facing before our approved and experienced nozzlemen place the secondary layer. From our experience, this procedure has been very effective and we have not experienced any delamination between shotcrete layers on any of the millions of square feet of shotcrete we have placed this way.

Shotcrete FAQs

If installed correctly with our general practice, is there any reason the shotcrete layers would delaminate? If not, have any studies been done to prove this to our reviewer?

Answer: All of your points are valid, but the Engineer of Record or the owner makes the final decision on recognizing a composite system or ignoring the value of the initial layer. As your experience shows, shotcrete provides an excellent bond between freshly placed layers and properly prepared concrete or shotcrete substrates. There are many articles available in the *Shotcrete* magazine archives—found on our website, **www.shotcrete.org/pages/archive-search/archive-search.asp**—that may provide the designer or owner more information to allow them to make their design decision.

Question: *I have been experiencing slow curing times (early set times). Every year during the wet season, my shotcrete curing times go from 1 MPa (145 psi) in 2 hours to 1 MPa (145 psi) in 8 hours. I believe that there is a change in the materials when the groundwater comes up. I have had water tests done, but I'm not sure what to be looking at. The recycled water that was being used had a pH of 5.7. We changed water, the problem was still there, and the pH is now 9.7. What effects does the pH level have?*

Answer: A pH of 5.7 is slightly acidic, while 9.7 is quite alkaline. According to PCA's "Design and Control of Concrete Mixtures," most inorganic acids have no adverse effect on concrete. Organic acids (such as tannic acid) can significantly reduce strength when present in higher concentrations. Some alkaline materials, such as sodium hydroxide, in higher concentrations may cause a quick set. However, because this occurs in the rainy season, another factor that may have an impact is an increase in dissolved solids. PCA states that solid contents exceeding 50,000 ppm can increase water demand, accelerate set, lower compressive strength, and increase permeability of the hardened concrete. The appropriate test for acceptable nonpotable concrete mixing water is ASTM C1602/C1602M, "Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete."

Question: *We are working on an historical renovation project where the existing structure has been reinforced with shotcrete. We need to attach structural studs/furring members to the face of this shotcrete. Is there any difference between standard concrete and shotcrete when it comes to fastener embed depth? We are considering powder-actuated fasteners (Hilti-type) or Tapcons.*

Answer: The embedment depth of anchors in shotcrete would be the same as it would be for conventionally formed and placed concrete. Shotcrete is essentially a method of placing concrete and the same rules would apply. As with any anchoring system, it is important to make sure that you are anchoring to sound material.

Question: *Our company is carrying out a tunnel project in rather poor geological conditions, including water seepage and poor rock, with wire mesh and two layers of steel mat. What is the reasonable rebound percentage in such conditions?*

Answer: Shotcrete rebound varies for many different reasons, many of which you mention in your question. The water seepage must be controlled or the shotcrete will likely not adhere to the surface and will slough off as the water saturates the fresh shotcrete. Accelerator will help, but it is difficult, if not impossible, to achieve good results against a seeping surface. ACI 506R-05, "Guide to Shotcrete," estimates approximate range of shotcrete losses from 10 to 30%.

Some other factors affecting the percentage of rebound are:

- Mixture design
  - Shotcrete process (wet- or dry-mix)
  - Concrete mixture design and materials (for example, microsilica will tend to create less rebound; more than 30% coarse aggregate can cause more rebound)
  - Plastic concrete properties (air content, slump)
  - Nozzleman competence
  - Vertical placement generally has less rebound than overhead
  - Thickness of buildup per layer
- Reinforcing grid
  - Size and spacing of reinforcing
  - Stability of reinforcing grid

Question: *I had wallpapered over a cement interior basement wall years ago. Recently, When I removed the wallpaper and the liner beneath it, the shotcrete came off with the paper. Is there any way I can repair these spots? Can the shotcrete process cover a garage floor that is heavily pitted, has a few cracks, and has some dirt and road salt marks? Will it hold up to road salt and prevent further deterioration?*

Answer: You mention that you had originally wallpapered over a cement interior basement wall. It is not clear that the cement interior wall was placed using the shotcrete process. If it was installed with the shotcrete process, then the application was flawed due to improper surface preparation or application. There are many concrete repair products on the market which could be used to repair the surface. Many of these are troweled on by hand or sprayed. Check with a local building supply company or on the Internet.

With respect to the garage floor, we would not recommend the shotcrete process for a thin overlay on a horizontal surface. Again, there are many products on the market that are designed for resurfacing floor slabs. Check with a local building supply company or on the Internet for potential products.

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