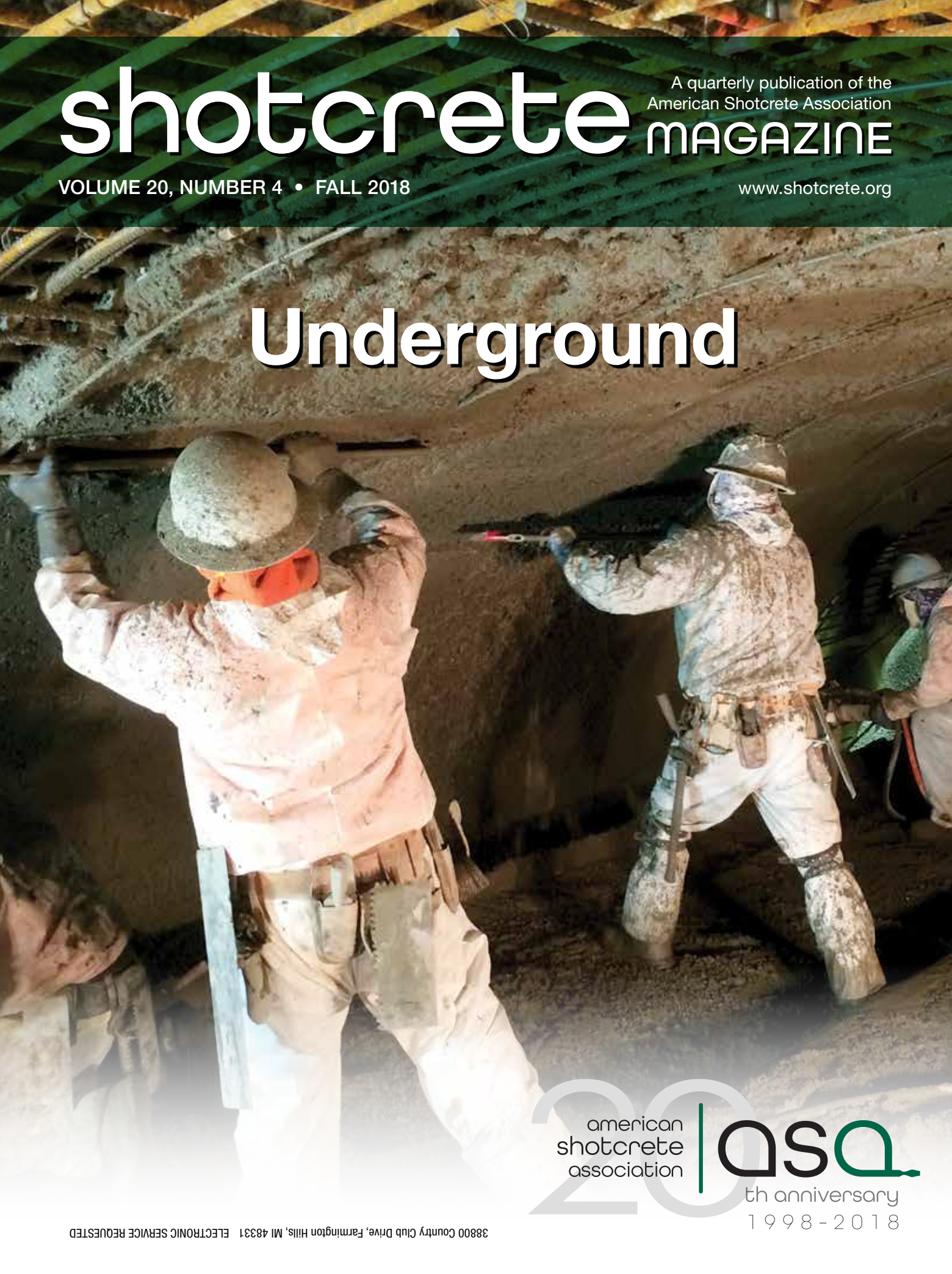
shotcrete MAGAZINE

A quarterly publication of the American Shotcrete Association

VOLUME 20, NUMBER 4 • FALL 2018

www.shotcrete.org

Underground



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Volume 20, Number 4 • Fall 2018

FEATURES

Shotcrete is a quarterly publication of the American Shotcrete Association. For information about this publication or about membership in the American Shotcrete Association, please contact ASA Headquarters at:

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

DEPARTMENTS

On the cover: MTA East Side Access project
Photo courtesy of Frank Townsend, Superior Gunite at ESA

ASA CONTRACTOR QUALIFICATION PROGRAM

Quality, durable, and economical shotcrete placement requires an experienced shotcrete team, not just an ACI-certified nozzleman.

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Shotcrete Technology Transfer

By John (Lihe) Zhang

Shotcrete's origins in the United States began with the development of the dry-mix shotcrete (gunite) process by Carl Akeley in 1907. By the 1920s and 1930s, its use had expanded to many places around the world, including Canada, the United Kingdom, Europe, China, and South Africa. In the mid-1950s, the wet-mix shotcrete process was developed and started to be used, initially in North America and Europe. By the 1970s, both the wet- and dry-mix shotcrete processes were being used in most industrialized countries on every continent on earth. This was no passing fad. Shotcrete was increasingly being used because of the many benefits it could bring to a project, both technically and financially. The requirements for formwork were either eliminated (as in shotcrete shoring, slope stabilization, and ground support in tunnels and mines) or reduced to single-sided forms (as in construction of free-standing structural shotcrete walls and other structural shotcrete elements). This resulted in economies due to reduced construction materials costs and reductions in construction schedule times. Also, technically it has been demonstrated on numerous projects over many decades that properly designed shotcrete mixtures and systems that are constructed by competent shotcrete contractors using qualified nozzlemen and crew can provide high-performance, durable shotcrete structures, and is equivalent or superior to conventional form-and-pour concrete construction.

Shotcrete technology has, however, evolved in different ways in different countries. In China, for example, there has been a long-standing (over 80 years) use of the dry-mix shotcrete process for applications such as slope stabilization and ground support in tunnels and mines and in refractory applications. Since the 1980s, they have also increasingly used remote control manipulator arms (also known as robotic placement) of wet-mix shotcrete with accelerator added at the nozzle for ground support in hundreds of kilometers of road, rail, and water supply tunnels. However, unlike North America, they have had hardly any experience in the construction of structural shotcrete buildings (walls, pilasters, columns, etc.) using hand-applied wet-mix shotcrete. Recently, an opportunity arose for transfer of this technology from North America to China.

China was awarded the Beijing 2022 Winter Olympics and one of the venues requiring new construction is the sliding track for bobsleigh, luge, and skeleton competitions. Prior to this award, China had no such sliding tracks and consequently no experience in the shotcrete methodology required to construct such tracks. Sliding tracks are some of the most complex and difficult to construct structures encountered in the shotcrete industry. Shotcrete must be applied to fully encase densely spaced large (30 mm [1 in.] diameter) cooling pipes embedded between layers of reinforcing steel and finished to very exacting tolerances (6 mm [0.2 in.]) at any geometric point on the 2 km (1 mile) long track. A team was assembled of myself; Rusty Morgan from Vancouver Island, BC, Canada; and Brad Martin from Prince Edward Island, Canada, to provide this technology transfer to China. Morgan was a shotcrete consultant on the Calgary 1988, Whistler 2010, and PyeongChang Korea 2018 Winter Olympics sliding tracks. Martin has been the lead shotcrete nozzleman on virtually every sliding track constructed in North America since the 1980s. The Chinese showed great interest and enthusiasm in learning how to apply wet-mix shotcrete in sliding track construction. In a short 6-month period, under the training and direction of the Canadian team, using a Chinese contractor, nozzlemen, and crew, they were able to construct a large-scale mockup of a section of the Beijing 2022 Winter Olympics track, which passed the rigorous scrutiny of the German track designer, the International Sliding Federation members, and the Beijing 2022 Winter Olympics committee. Construction of the full track, which includes a world-first 360-degree spiral loop, is now underway. The contractor and trained nozzlemen from this project is well placed for the transfer of structural shotcrete technology to other projects in China once the sliding track is completed.

We owe much of the technology and skills developed for hand-applied shotcrete to reinforced buildings and other structures to the seismic retrofit work that was carried out in California after the Long Beach earthquake in 1933. While initially placed with the dry-mix shotcrete process, today, most structural shotcrete work is now performed using the wet-mix shotcrete process. Pioneers in the field include the late Chris Zynda. He started his career in the shotcrete industry shoveling rebound for his father's shotcrete construction company in the 1960s. By 2000, he had taken the hand-applied wet-mix structural shotcrete process to

a whole new level. Conventional form-and-pour concrete contractors in the Silicon Valley (San Jose, Santa Clara, and Stanford) had difficulty competing with structural shotcrete construction for industrial and commercial buildings. Ever innovative, Zynda was the first in the United States to use the new hemp-based fiber for enhanced adhesion, cohesion, and "stackability" and the increased productivity that it provided. Some of his architectural shotcrete work is remarkable.

It has not, however, all been a one-way transfer of shotcrete technology from North America to other parts of the world. Europe has a long history of shotcrete use in civil tunnel construction. Much of the "robotic" shotcrete application technology was developed in Europe several decades ago. The so-called "Sequential Excavation Method" (SEM) used for construction of tunnels and other underground openings is based on the "New Austrian Tunneling Method" (NATM) and relies on "robotic" application of shotcrete with accelerator addition at the nozzle. The J1, J2, and J3 curves developed by the Austrian Concrete Society for evaluating early-age compressive strength development are fundamental to underground shotcrete construction and are now widely used in North America and around the world. George Yoggy worked his entire life to develop, promote, and apply new products including alkali-free accelerator, hydration control admixture and other chemical mixtures, wet-mix and dry-mix pump, robotic sprayer, mixture design, and nozzleman certification. Many of us benefit from his work in the shotcrete industry.

In the fiber-reinforced shotcrete field, we owe a lot to Stefan Bernard, Chairman of the Australian Shotcrete Society. He developed what was first called the "Australian Round Panel Test" method. After encountering the use of this test method with steel fiber-reinforced shotcrete and later macro synthetic fiber-reinforced shotcrete in mines in Australia, Morgan brought this technology back to North America where it has now become the ASTM C1550 test method. This method, together with the ASTM C1609 flexural beam test method, are the most widely used test methods for evaluating the toughness of fiber-reinforced shotcretes in North America and many other countries around the world.

In summary, shotcrete technology advances by sharing and learning from others around the world. The American Shotcrete Association, through the work of its technical committees, outreach programs, and its quarterly publication of *Shotcrete* magazine plays a major role in international shotcrete technology transfer.

Safety Committee

By Andrea Scott

When I last wrote my Committee Chair Memo, we were hard at work putting together a standalone safety presentation. It has evolved since our first drafts but is now out for ASA Board approval. Often impatience sets in when you find how long it can take to develop committee documents. Part of the reason for this is because ASA is made up of members who are passionate about shotcrete and most, if not all, have strong opinions. This same passion motivates them to volunteer to serve on the various committees and the ASA Board of Directors. And their desire to produce something of real value to the industry can lead to animated discussions during our meetings about what to put in and what to leave out. This same desire for it to be relevant and as close to perfect as possible makes the process take longer than one would expect.

Within our industry, we strive to have perfect safety programs. But accidents still occur.

Perfection doesn't exist, but forward progress is always attainable. With that in mind documents produced by our committees are reviewed and do evolve over time. The goal of the ASA Safety Committee is to provide resources to help make our members' existing safety programs stronger and provide information to the industry about shotcrete specific safety issues. ASA's "Safety Guidelines for Shotcrete" was our first attempt at providing such a document. The Guidelines contain a wealth of information that can greatly assist shotcrete contractors in keeping safety at the forefront within their organization. Just like your safety glasses won't help you if you don't wear them, the Guidelines are of no use unless you own a copy (or two).

One of the best things about the ASA Safety Guidelines is that it was written with the end user in mind. This is not aimed at engineers but rather done in an approachable style with plain language so that the crew in the field have yet another resource for doing the best job possible and working safely as a team. There are many photos illustrating the different sections and the content was carefully chosen to ensure it covered shotcrete specific safety issues. It is a very user-friendly compilation that should be required reading for all new members of the shotcrete team, as well as more seasoned shotcrete veterans and foremen.

As ASA moves forward in implementing our Strategic Plan we find that different committees will at times be working together to achieve the objectives we've identified as important to ASA. Both Education and Safety Committees recognize that safety must be a part of the initial, as well as ongoing, training of shotcrete crew members. Shouldn't you make use of something that has been already been compiled, and use it as a jumping off point for the new hires as well as an opportunity for dialogue with more experienced employees? Do members of your team know when to take used items out of service before failure occurs? Does your company have parameters that are clearly defined for the crew, which empowers nonmanagement personnel to regularly check for wear in the areas in the placement system that experience the greatest amount of pressure as well as the largest amount of wear?

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Lihe (John) Zhang | LZhang Consulting & Testing Ltd.

Safety is an ever-evolving area with innovations coming for items as mundane as hard hats to high tech smart helmets that allow you to have heads-up display projected on to the eye.

As we move forward in the shotcrete industry, we need to hear more from our members about the issues that are of interest or concern. We are currently working on a Spanish language version of the Guidelines and a dry-mix presentation similar to the recently balloted wet-mix safety presentation. The impact of our changing world can have a dramatic effect on jobsite safety. How will you deal with the legalization of recreational marijuana and its impact on drug testing? How will this affect safety within our industry? I urge you to become involved and send us questions, concerns, or problems that you would like to see as topics for our ASA Safety Committee to address and include in future articles in *Shotcrete* magazine. Our meetings are open to our members, please attend and participate. The more we work together, the stronger our voice for safety in the shotcrete world!

3-D Concrete Printing? We've Been Doing That for over 100 YEARS!

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

First, a few updates on ASA activities. We enjoyed having great attendance and participation at our Fall Committee Meetings held Saturday, October 13, 2018, in Las Vegas, NV, immediately before The ACI Concrete Convention and Exposition – Fall 2018. Thanks to all our volunteer members who actively participate and get the work done through our committees. Please look in our Association News column for more details on our committee actions.

ASA/ACI Shotcrete Nozzleman Certifications are still strong. We're currently running about 30% ahead of last year's record year for number of sessions and individuals certified. The sharp increase in sessions is keeping Alice McComas, ASA's Senior Programs Coordinator, and our team of 20 ASA/ACI-approved examiners very busy.

Demand for our 1-hour seminars has increased, supporting our goal for outreach and education. In your shotcrete business, you may encounter engineers, architects, and owners who would benefit from an on-site seminar about the state-of-the-art in shotcrete. Sustaining Corporate Members can request up to two seminars per year, while Corporate Members can request one seminar per year.

WHAT ABOUT 3-D PRINTING?

So, what's all the excitement about three-dimensional (3-D) printing? I've watched with interest the evolution of 3-D concrete printing—sometimes called "additive manufacturing." I've recently seen articles proclaiming, "Three-dimensional printing may be one of the most disruptive technologies of the 21st century" and "The 3-D concrete printing market is projected to experience exponential growth in the next few years." The American Concrete Institute (ACI) just created a technical committee ACI 564, 3-D Printing with Cementitious Materials, whose mission is to develop and report information on 3-D printing and additive manufacturing with inorganic cementitious materials.

In perhaps one of the largest 3-D concrete printing research efforts, the U.S. Army Corps of Engineers Construction Engineering Research Laboratory (CERL) in Champaign, IL, has a program called "Automated Construction of Expeditionary Structures" (ACES). The CERL successfully three-dimensionally printed a 512 ft^2 (48 m^2) concrete structure. The Program Manager, Michael Case, said "ACES provides a capability to print custom-designed expeditionary structures on-demand, in the field, using locally available materials. ACES will allow the Army to print buildings and other required infrastructure, such as barriers, culverts, and obstacles, on location." Further, he said, "The ACES team designed, built, and validated an additive, three-dimensional concrete printing technology that is a real game changer." "Unlike previous efforts, ACES can use up to 3/8 in. aggregate in the concrete that is used. In addition, the ACES project paid particular attention to methods of reinforcing printed concrete, both horizontally and vertically." CERL has also worked with NASA to develop a dry material delivery batching system that was used for the 3-D printing.

But wait—isn't that what we've been doing for over 100 years? When compared to 3-D printing, shotcrete inherently allows:

- **Use of locally sourced concrete materials**
  For decades, quality dry-mix shotcrete simply used locally sourced sand and cement. Prebagged concrete materials can also be used for enhanced concrete properties and can be easily transported. Wet-mix can use site-batched materials or local ready mixed if available.
- **Relatively small portable equipment**
  A single dry-mix gun and hose are much smaller than the smallest 3-D building printer that needs a relatively large framework to move the printhead. Even a small inline concrete pump is smaller and more mobile than 3-D building printers and their supporting equipment.
- **Concrete placement with minimal to no formwork**
  Though 3-D printing may use no formwork, shotcrete can use a minimal, movable form to define the inside surface. Shotcrete can also use a relatively inexpensive stay-in-place form that requires no external form.
- **Relatively small construction crews**
  Yes, we do need human workers—the nozzleman, finishers, gun or pump operators, and laborers for cleanup, but still this is a relatively small crew. This is exemplified by the small mobile shotcrete crews that shoot pools every day across the country. Conversely, I expect the 3-D printing operation requires setup crews, an operator, and material supply/batching crew. Is it really less labor intensive?

- **Use of conventional reinforced concrete designs** Shotcrete is concrete. We can build concrete structures using conventional (and widely available) steel reinforcement and accessories. On the other hand, 3-D printing has difficulty using conventional reinforcement, and fully encasing blockouts or penetrations for windows, doors, etc.
- **Reliable performance in harsh environmental conditions** Hundreds of thousands (maybe millions) of yd^3 (m^3) of concrete have used shotcrete placement. In blistering heat and freezing weather with proper attention to detail, shotcrete has performed. Will highly mechanical 3-D printers be able to run reliably in these environments?

So why hasn't shotcrete been considered as a time-proven component of 3-D printing? When compared to current 3-D printing, we can accomplish in hours what the 3-D printers accomplish in days. Perhaps it's because we don't have the electronic computer-driven "smart" systems that many equate to "modern technology." Maybe it's because we depend on a human operator to control the nozzle and the nozzleman isn't "automated." Or is it simply that the shotcrete process just wasn't on the researcher's radar? I suspect all these are somewhat to blame.

Through ASA, we as an industry are continuing to expand our outreach to many different segments of the concrete construction market. And though sometimes it seems to take longer than desired, we are making significant progress in gaining recognition and acceptance of shotcrete. We must continue to reach out to engineers, architects, owners, and students to grow our image and prove that shotcrete is a creative, cost-effective, and well-proven method for placing concrete.

Evaluation and adoption of technology is important in any industry. In shotcrete, we have been a leader in adopting sophisticated concrete materials. We regularly use silica fume, hydration control, rapid-set accelerators, alternative cements, and nanoparticles in our mixtures. We've seen the development and use of robotic equipment. As we look to the future, perhaps we will see more automated placement equipment using real-time laser scanning, and even systems to augment the nozzleman's physical strength and endurance. Shotcrete has over a century of proven performance. On that foundation of experience, we have continuously evolved our materials, equipment, and techniques to produce better results for the concrete structures we create. Shotcrete is the 3-D printing of the past…and the future!

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ACI Shotcrete Nozzleman Certification

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Martes, 22 de enero de 2019
ASA Educación (vía húmeda y vía seca)
Las Vegas Convention Center
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Jueves, 24 de enero de 2019
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Shotcrete Use in the Gold King Mine Rehabilitation

By Christoph Goss

The Gold King Mine Level 7 Portal is located at elevation 11,438 ft (3486 m) on the North Fork of Cement Creek, approximately 8 miles (13 km) north of Silverton, CO. From the mid-1890s until the start of World War I, the Gold King was a major producer of gold, silver, lead, zinc, and copper. During that time, it had two aerial trams, boarding house, shop, and a dedicated mill in the valley below. The mine itself consists of seven underground levels connected by a vertical shaft. The only levels that connect to the surface are Level 1 at elevation 12,160 ft (5516 m) and Level 7. Level 7 served as the main haulage and drain level during the mine's most productive years. In the 1980s, a second horizontal opening (adit) was driven into Level 7 to allow mine rehabilitation and mineral exploration, but this effort was abandoned after a few years. The Gold King Mine regained "fame" in 2015 when an uncontrolled release of mine drainage made national news. While much has been publicized about the release, very little has been said about the steps taken to rehabilitate and stabilize the mine since then.

PROJECT CHALLENGES

Many of the challenges on this project centered around access. The nearby town of Silverton is reachable by only two roads, both of which cross high mountain passes. From Silverton, an unpaved county road leads to the abandoned town site of Gladstone. From Gladstone, a narrow unpaved county road leads to the site—a waste dump and portals on a south-facing mountainside slope with a steep (approximately 60%) grade. The site is accessible only during non-snow months of the year, typically late June through early October. Even during those months, the road width and sharp curves severely limit the size and type of equipment that can access the site.

Figure 1 shows the portal area shortly after the 2015 release. The jointed, strongly altered rock hung precipitously over the open channel where timber sets had once stood. Looking into the old workings, one could see failed rock bolts, rusty mine straps, and a high "cathedral" in the back (roof). Given the instability of the ground and the short time before winter would arrive, it was critical to design a rehabilitation that was flexible, resistant to mine water, and used "off the shelf" material. A system of shotcrete and rock bolts was quickly selected. The underground contractor, Harrison Western out of Lakewood, CO, mobilized to the site a few weeks later. They laid back the slopes around the portal and installed temporary split set rock bolts along with welded wire fabric. They continued the work into the underground, scaling and bolting their way past the cathedral.

INITIAL STABILIZATION OF THE PORTAL

The next phase of work was shotcrete around the portal. Harrison Western chose to use the dry-mix process. The material was provided in supersacks by Thiessen Team. The mixture consisted of 650 lb (295 kg) Type II/V cement, 100 lb (45 kg) fly ash, 65 lb (29 kg) silica fume, sand, pea gravel, and accelerator. Some bags came with polypropylene fibers at 12 lb/yd^3 (7 kg/m^3). Given the high altitude of the site, an 825 ft^3/min (23 m^3/min) air compressor was needed.

Fig. 1: Portal before rehabilitation

Fig. 2: Portal area excavated and initial support in place

Fig. 3: View into cathedral behind portal

The shotcrete application went very well thanks to skilled miners with significant shotcrete experience. The crew hand nozzled and used a manlift to access the slope. The final support consisted of an initial shotcrete layer 2 in. (50 mm) thick, followed by No. 8 Dywidag resin bolts, and a second layer of shotcrete 4 in. (100 mm) thick.

The initial design for the underground support was the same shotcrete and bolting used at the portal. Based on requests by the client, the final underground support in the first 64 ft (20 m) was changed to fully lagged steel sets backfilled with cellular concrete. To allow safe construction of the steel sets, 2 in. of shotcrete was applied to the upper ribs and back to reinforce the bolts and mesh. This is shown in Fig. 2, 3, and 4. Note the 30 ft (9 m) high cathedral back in Fig. 3. For comparison, the original dimensions of the adit were approximately 10 x 10 ft (3 x 3 m).

SUPPLEMENTARY STABILIZATION

After the initial stabilization in 2015, Harrison Western remobilized in 2016 to complete the work. This included the steel

Fig. 4: Installing steel sets under initial shotcrete support

Fig. 5: Shotcrete placement in high back

sets and backfill. Concurrently, the team evaluated ground conditions further in the mine. Approximately 100 ft (30 m) into the mine, another high back cathedral 27 ft (8 m) high was discovered. Failed mine straps and rock bolts were visible around it. To avoid a new collapse in this area, it was decided to fully support the mine to just past this point. Advance was difficult due to the presence of sludge and debris 5 ft (1.5 m) thick on the floor. The material consisted of sand, gravel, cobble sized rock blocks, old pipes and cables, and orange metal precipitate with a pudding-like consistency. Harrison Western mucked out this material, scaled the ground, and installed No. 8 Dywidag resin bolts with welded wire fabric. Next, they placed 4 in. of shotcrete in two lifts. This time they elected to use the wet-mix process. Alpine Mobile Crete (AMC) from Durango, CO, mobilized a volumetric mixer truck to the mine portal. During the initial shotcrete placement, AMC adjusted the mixture design until they had a mixture that pumped well and stuck to the back and ribs without requiring an accelerator. The final mixture included 790 lb (360 kg) Type II/V cement, 165 lb (75 kg) fly ash, 72 lb (33 kg) silica fume, sand, and pea gravel.

Figure 5 shows the shotcrete placement in the second high back area. Figure 6 shows the initial layer of shotcrete

looking in while Fig. 7 shows the final layer looking out. In Fig. 8 one can see the final shotcrete in the second high back cathedral area along with wood/concrete cofferdams to hold back the sludge and debris. Also visible in the figures is the hose from the bypass pump that pumped water from the mine pool to the treatment plant, keeping the work area dry. Figure 9 shows the portal area at the completion of the project. Thanks to the skilled nozzlemen who used a good mixture and appropriate equipment, the shotcrete placement went very well, meeting all design specifications.

Fig. 6: Initial layer of permanent shotcrete support

Fig. 7: Final layer of permanent shotcrete in place

Fig. 8: Final shotcrete in place at high back

CONCLUSIONS

The use of shotcrete, both dry and wet mix, was a critical component of the successful rehabilitation of the Gold King Mine. It allowed for a rapid response in a remote alpine area where varied types and amounts of support were required. Now that this ground support and other components of the rehabilitation are complete, the mine has been stabilized and all parties can focus on long-term solutions. The Gold King Mine is now part of the EPA's Bonita Peak Superfund site. More information about the project can be obtained from EPA. For more on the history of the mine, see the new book published by the San Juan County Historical Society, *The King of the Spill: The Gold King Mine* by David L. Thayer and Douglas R. Thayer.

Christoph Goss *received his BS in civil engineering and his PhD in mining engineering, both from the Colorado School of Mines, Golden, CO. He is a Principal with Deere & Ault Consultants Inc. in Longmont, CO. His practice focuses mostly on tunneling, underground construction, and mine rehabilitation. He has been involved with shotcrete since 1996 and the ASA shotcrete nozzleman program since 2003. Goss is a licensed professional engineer in Colorado.*

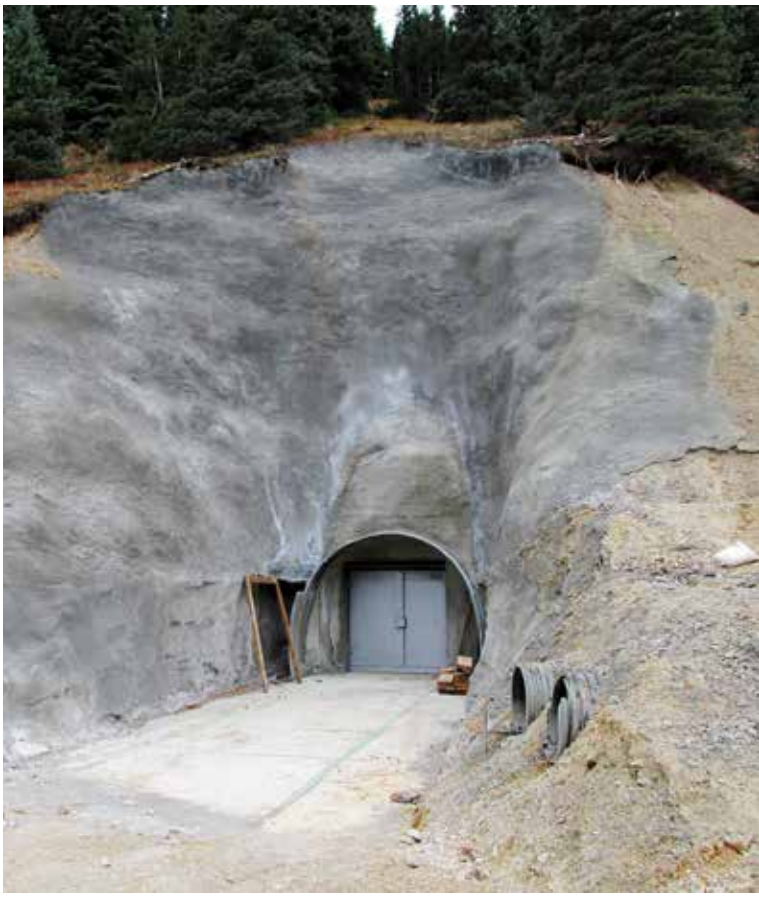

Fig. 9: Portal at completion of project

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Towards Automated Concrete Spraying

By Lauro Lacerda and Marjo Koivisto

Operating a remotely manipulated shotcrete placing system is one of the most demanding tasks in underground mining and tunnel construction. Experienced and skilled operators are becoming more difficult to find, and as a result the quality of the shotcrete application can vary significantly from one operator to another. Equipment manufacturers have been increasingly asked to develop their products so the impact of the operator on the final result is minimized, and productivity, along with safety, increased. The SmartSpray System by Normet is a first step towards developing a shotcrete machine capable of fully automated shotcrete placement.

Traditional control of a spraying boom means that every boom position and nozzle orientation is separately controlled by the operator to achieve the desired shotcrete placement. The in-place shotcrete quality and even longevity of the machine can vary greatly between operators. The need for improved performance prompted Normet to design and build a fully automated spraying system. Normet's Spraymec family of shotcrete sprayers is currently available with SpraySmart System as an option. This version includes two features to assist the operator—coordinated and point-to-point control modes built on top of the standard boom control system—allowing the machine to be operated in either a semi-automated or traditional control configuration.

STATE-OF-THE-ART SHOTCRETE

Recent developments in shotcrete equipment incorporated into Normet sprayers include low-pulsation concrete pumping, constant flow accelerator dosing systems, and high-voltage power systems. These advancements combined with operator training through simulators and other means promote best shotcreting practices and optimum hardened shotcrete characteristics.

There are two categories of sprayers with many configurations offered. Five sprayer models are designed for mining and six sprayers for tunneling. Several compact Normet equipment models are designed specifically for use in smaller cross sections, while many models are larger to handle larger mining and tunneling headings.

SMARTSPRAY 1—FIRST STEP TOWARDS AUTOMATION

Normet launched its first version of the SmartSpray 1 system in June 2017. SmartSpray 1 is an extension of the NorSmart system, which provides seamless control and diagnostics for

Fig. 1: Sprayers in action: (a) tunnel portal spraying with Spraymec 8100 VC; (b) equipment suitable for small, medium, and large headings; and (c) delivery and shotcrete application in mining projects around the world

all machine functions. These systems combined, allow the machine operator to use computer assistance to control the concrete spraying boom and nozzle with either a coordinated control mode or a point-to-point control mode.

In coordinated control mode, the operator controls only the spraying nozzle; boom functions are automatically controlled to stay in alignment with the nozzle position. Thus, only a single joystick is needed to perform basic concrete spraying movements. Spraying direction can be maintained automatically during the movements if desired using an automatic nozzle control feature, which simplifies the spraying task for human operators.

When using point-to-point mode, the operator defines a line between two points. After activation, the spray nozzle automatically follows this line. If the nozzle angle is locked, it is automatically retained in position against the tunnel profile. The operator only has to move the boom to the next position needed for spraying. Nozzle position can be fine-tuned, and controls overridden manually if needed. This functionality is useful for spraying large smooth surfaces.

With the redundant nature of movement positions for shotcrete booms, to assist with boom control, the Smart-Spray system allows the middle point of the boom to be moved in three axes by the operator using one of the control

levers while pressing an activation button. Position of the boom can be controlled to avoid collisions or to prevent the boom from being driven to impractical positions. Operator-controlled movements of the middle point do not alter movement of the shotcrete nozzle. A second feature allows middle joints (two joints in the boom) to be made rigid using an on/off switch. These joints remain in the position during coordinated movement of the nozzle, which is especially useful in narrow tunnels.

Also included with the Normet SmartSpray 1 system is a coordinated frame where the control works can be reoriented by pressing a button. This new orientation is set to sync with the current orientation of the upper part of the boom. Essentially this only changes interpretation of the control lever signals, which define the movement speed of the nozzle. It also includes an automatic back-and-forth rotation and tilting of the shotcrete nozzle. Choosing between on/off or proportional steering of nozzle turn and tilt are similar to those in direct manual control state.

SMARTSPRAY 2—CURRENTLY IN DEVELOPMENT AND TESTING

When speaking about "robotic spraying," worries concerning incorrect thickness and inconsistent quality of sprayed concrete arise. These issues have been considered from the beginning of the SmartSpray development process.

Normet customers have asked for a system where the nozzle is kept within a certain range of distance from the wall to keep fluctuations of nozzle distance from affecting the final quality of the shotcrete. At this stage in development, however, it was still expected that the operator keeps responsibility for other spraying parameters so that the shotcrete quality in place does not fully rely on equipment and technology. We have also had many requests for development of a system to spray a required thickness of concrete, more or less automatically. Development work for this SmartSpray 2 System, with easy profiling of an area to be sprayed, is in the testing phase.

Fig. 2: SmartSpray 1 system being tested at Normet's R&D facilities in Finland

Operator experience and knowledge of proper shotcrete techniques is essential to quality placement. Normet shotcrete placing equipment is being developed and refined to provide more automation and ease of use to assist the operator in doing a quality job throughout the work day.

SMARTSPRAY 3—THE NEXT BIG STEP

Normet is working on more elaborate software and measurement systems to provide "semi-automated" spraying equipment with thickness control. Normet strives to be a leader in concrete spraying automation. Its ultimate goal, though farther in the future, is development of a fully automated concrete spraying system. Normet's progress so far shows the company is heading in the right direction and this is an achievable goal. By use of unique scanning features in Normet's sprayers, the company foresees a fully automated concrete spraying system complete with accurate thickness control and reporting. Normet's customers will directly benefit from this fully automated system through improved productivity, quality of application, and optimal concrete material usage.

Detailed information on the complete Normet spray concrete equipment line is available at **www.normet.com/process/concrete-spraying**.

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Marjo Koivisto *received her bachelor's degree in vehicle design from Lahti Institute of Design, Finland, and is working towards her Master of Arts degree in collaborative and industrial design and minor in international design business management from Aalto University, Finland. For the past few years, she has been working at Normet as a Designer, designing everything from communications and customer experience to user interfaces and concept vehicles.*

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Shotcreting the East Side Access Program

Architect/Engineer: New York Metropolitan Transportation Authority Capital Construction

By Frank E. Townsend III

Prior to 9/11, all structural wall and tunnel concrete applications in New York, NY, used the form-and-pour concrete placement method. During this time, the dry-mix shotcrete process was being used in marine and bridge repair projects by Eastco Shotcrete throughout the region. The wet-mix shotcrete process was also being used in underground applications, primarily for initial smoothing of tunnel surfaces as a substrate for the sheet waterproof membranes. With support from George Yoggy and Bill Drakeley, Superior Gunite was brought to New York City (NYC) to help on a contract for the World Trade Center Reconstruction. The site was heavily congested with contractors and access from cranes was difficult due to the limited space. This project was extremely successful as Tutor Perini used Superior Gunite to stayform and shoot all the walls, hence eliminating carpenters, formwork, and crane time. The project came in under time and budget. From here, NYC was introduced to the wet-mix shotcrete process as an alternative to form-and-pour methods. Following this project, Superior Gunite had several other projects for the NYC Port Authority at the World Trade Center site assisting six different contractors with shotcrete placement in time-sensitive and difficult forming situations.

CM9 and CM19 Contracts

Superior Gunite was brought in to help on the Metropolitan Transportation Agency's (MTA) East Side Access project working on the four "well-ways" in the excavation contracts CM9 and CM19. The East Side Access project brings the Long Island Railroad into Grand Central Terminal and included dozens of separate construction projects. This project also adopted the term "pneumatically applied concrete" (PAC) in lieu of "shotcrete" to differentiate structural shotcrete placement in underground work from MTA's existing "shotcrete" specification that was geared exclusively towards smoothening shotcrete. PAC is shotcrete and complies with ACI's definition of shotcrete as concrete placed by a high velocity pneumatic projection from a nozzle. Though the term "pneumatically applied concrete" has been around for over 100 years and generically included the shotcrete process, the intent of MTA's PAC specification was to specifically include only the modern shotcrete placement materials, equipment, and techniques that meet the requirements for structural liner applications and to clearly distinguish it from smoothening shotcrete. PAC was used on the well-ways, which were inclined tunnels in rock and designed to house the access escalators. These well-ways were performed in a fraction of the time and cost of forming and placing these elements. After the well-ways were completed, word spread throughout the NYC construction community that the shotcrete process provided major efficiency and cost savings to the East Side Access program.

CQ39 and CQ32 Contracts

Following the well-ways, Superior Gunite was awarded the CQ39 project to shoot a 125 ft (38 m) long sequentially

Fig. 1: East Side Access overview schematic
(Photo courtesy of Evan Mason, CC BY-SA 3.0)

Fig. 2: CQ39 Tunnel section, prior to cutting out support columns

Fig. 3: Finishing at CQ39, cutting out pencil rod and starting to float

Fig. 4: First layer of shotcrete at CM006 showing scratch finish prior to installation of inside face reinforcing bar

excavated (SEM) tunnel between two 85 ft (26 m) deep access shafts. The tunnel was situated approximately 55 ft (17 m) below the water table and required freezing of the surrounding soils. A value engineered approach was given to the MTA to shotcrete this liner in lieu of the traditional form-and-pour method. This offered both savings in time and construction cost. Superior Gunite's scope was to expeditiously shoot the structural liner in 5 days, and then to quickly thaw the ground and transfer the load from the above ground structures. The tunnel was a 3 ft (0.9 m) thick structural liner with ring girders to help carry the load from above. Superior Gunite shot 1463 yd^3 (1119 m^3) of concrete in 4.5 days with a good portion of the placement in the overhead position.

Adjacent to CQ39 was CQ32, an 85 ft deep open cut with 5 ft (1.5 m) thick one-sided walls, 124 columns, and 1 to 2 ft (0.3 to 0.6 m) thick interior walls, adding up to 11,000 yd^3 (8400 m^3). The largest challenge on this project was the hydrostatic head on the exterior of the walls from the water table. Controlling the groundwater required constant use of weep pipes to relieve the water and/or pumps.

44TH, 50TH, AND 55TH STREET VENT SHAFTS PROJECT

Superior Gunite was then awarded several deep vent shafts in midtown Manhattan. These were 44th, 50th, and 55th Street vent shafts. These were one-sided exterior walls and, on the 55th Street vent, a large, 5 ft thick, 7000 ft^2 (650 m^2) overhead placement. This overhead was performed in 1 ft thick lifts using layering with prepared surfaces between layers. The exterior walls were 1 to 2 ft thick and totaled about 7000 yd^3 (5400 m^3).

CM006 CONTRACT

The CM006 contract was the largest shotcrete project Superior Gunite performed with a contract value of over $20 million. This was for shotcrete surface smoothening and PAC work on the East Side Access project that included running tunnels, caverns, and cross passages from Queens to the midtown Manhattan station.

Fig. 5: Complete CM006 M-Cavern arches, end wall tunnels, and center walls showing rubber float finish

Fig. 6: Typical CM006 cross passage

At the start of the project, following the approval of nozzlemen and mixture designs, work began with overbreak smoothening. Smoothening layers were applied to the caverns' uneven and over-broken surfaces that had been drilled and blasted. Smoothening was considered complete by the surfaces meeting smoothness criteria, after which the waterproofing installation began. The structural arches in the lower-level caverns were completed in the following sequence: backfill/smoothening, waterproofing installation, outside face reinforcing bar installation, first layer of shotcrete with a rough scratch finish, inside face reinforcing bar installation, and second layer of shotcrete with rubber float finish. Most all overhead shotcrete was performed in layers. The first layer was "scratch" finished and saturated surface-dry (SSD) prior to shooting the subsequent final layer.

CM006 had a number of challenges that called for detailed coordination between the owner, multiple general contractors, and subcontractors. Above CM006 was CM014B, where Superior Gunite performed ceiling beam encasements in preparation for follow on walls. Shotcrete was also performed on exterior walls and additional smoothening. These were smaller dental placements of about 7 to 20 yd^3 (5 to 15 m^3) a shift, totaling about 1000 yd^3 (800 m^3).

Fig. 7: Rod-finished cavern at CM006

Fig. 8: Communications room with fishmouth, interior wall, and arched ceiling at CM006

CM005 CONTRACT

CM005 was much like CM006 as it also included running tunnels, caverns, and most all of it was overhead work. The most challenging portion was at TT1, with a double mat of No. 11 (No. 36M) and No. 9 (No. 29M) reinforcing bars at 6 in. (150 mm) on center and four beam sections (Fig. 9).

Fig. 9: Reinforced beam section in upper level arch of CM005 TT#1 structure

Fig. 10: Upper level arch of TT#1 structure, tunnel, and cross passage interface

Fig. 11: Completed CM005 tunnel section

Due to the lap lengths, stirrups, and reinforcing bars transitioning from the inner to outer mats at the interfaces, the reinforcing layout forced the shotcrete to be placed in one lift. On most other overhead applications, layering of the reinforcing bars within concrete lifts of about 12 in. (300 mm) placements facilitated proper consolidation. A rubber float finish was provided on the 1500 ft^2 (140 m^2) surface area of these placements.

Fig. 12: Finished Access Tunnel 1 with rubber float finish

Fig. 13: Finished Grand Central Terminal 1/2 arch with rod finish; walls were rubber float finish

CM007 CONTRACT

CM007 was the placement of the cavern walls, cross passages, and niches. Systematic patches 3 ft thick by 800 ft^2 (74 m^2), totaling 11,000 yd of concrete, were placed and finished. This allowed the general contractor to expeditiously place precast beams and progress through the two caverns. For this aspect, we drove the concrete trucks directly in from Queens and they rode the track invert directly into the main cavern.

LOGISTICS OF CONCRETE

Concrete service for the entire project was provided from three locations on street level in midtown Manhattan. The material was conveyed via 5 in. (125 mm) of slickline, up to 1500 ft (450 m) with up to 8 yd^3 (6 m^3) in the line before reaching the secondary pump that was located in the underground caverns for the placement of the shotcrete. Due to the volume of material in the slickline and the slower nature of shotcrete placements, the concrete used a retarding admixture to prevent the material from setting up in the slickline. The effect of the retarder was then negated at the nozzle using an accelerator.

Fig. 14: CM007 Cavern walls; this is one of two caverns

Fig. 15: CM007 Cavern walls; 3.5 ft (1.1 m) being placed

LOGISTICS OF WORKERS AND MATERIALS

Access of workers and materials was unique as the material access was 7 miles (11 km) away in Long Island City. At the access point, materials were loaded on to work trains and brought into the project on a designated schedule. This one point of access, along with the use of work trains, put an immediate 24-hour delay from when the materials arrive in the project yard to when they are available at the work location. Supply delays were further increased at peak project production times as availability of space on the working trains was quickly taken by the deliveries of steel, waterproofing, and equipment. As a result, general materials needed to be scheduled to be delivered no less than 72 hours before they were required. Large equipment needed to be delivered a week in advance. The track was shared by several subcontractors and the three general contractors. Coordination was challenging, and congestion significantly added to delays and created management challenges. The workers came in from several access points via rail, stairs down 110 ft (34 m), or construction hoists. This also shortened time available for doing productive work during the shifts. Getting to and from the work locations took up to an hour at times, but generally averaged about 30 minutes.

Shotcrete was used on two-sided walls, running tunnels, cross passages, niches, and as well as the cavern walls and arches. The use of shotcrete significantly aided the NYC East Side Access program, creating major cost and schedule savings by reducing the formwork and adding flexibility to the projects. Superior Gunite has installed over 84,000 yd^3 (64,000 m^3) of shotcrete throughout the program.

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Shotcrete Lining Innovations in the United States

By Andy Thompson and Frank E. Townsend III

Historically, the permanent concrete linings for underground structures have been installed using form-and-pour methods but the use of shotcrete or sprayed concrete for the structural linings is becoming increasingly more common. Although form-and-pour methods are well proven, they do have their downsides, especially where nonuniform shapes are required.

Form-and-pour methods can be used for virtually every combination of shapes and space; however, there are drawbacks to its use, especially when nonuniform cross sections and junctions are required. Designing and installing custom-built formwork is time-consuming and, depending on the project logistics, can cause pinch points in the schedule. As clients strive to manage the scarce capital to be expended to manage existing and build new facilities, designers and constructors are increasingly being challenged to minimize the excavation and lining quantities. This brings new challenges to the use of form-and-pour due to the complex nature of the shapes being designed.

The use of shotcrete or sprayed concrete for the installation of the permanent structural lining for nonuniform openings is a well-established process, but in the last few years the boundaries of its use, especially in the United States, have been stretched. These innovations and the issues that are raised when expanding the range of shotcrete applications will be discussed in this article. Mott MacDonald, in conjunction with Superior Gunite, has been at the forefront of expanding the use of this application method in the underground environment.

FREEFORM CONCRETE

So, what are the benefits of the use of freeform concrete linings, how does it differ from shotcrete final lining (SFL), and what are the potential drawbacks?

Major capital projects in New York City, NY, have adopted the term “freeform concrete” or “pneumatically applied concrete” (PAC) to differentiate structural shotcrete placement in underground work from Metropolitan Transportation Authority’s (MTA) first “shotcrete” specification that was geared exclusively towards smoothening of underground surfaces without structural properties. Though the term “pneumatically applied concrete” has been around for over 100 years and generically includes the shotcrete process, the intent of the MTA PAC specification was to specifically include only the modern shotcrete placement materials, equipment, and techniques required for structural liner applications. PAC uses compressed air for high-velocity placement of structural concrete to achieve full consolidation, compaction, and a uniform distribution of concrete constituents. The end product is portland cement concrete with 3/8 in. (10 mm) nominal coarse aggregate size capable of achieving conventional and high strengths, while maintaining or exceeding required end properties by design. Premixed concrete materials are pumped to the nozzle where air is added at high pressure and flow rate to achieve the required spray pattern and velocity for the concrete application.

But how is PAC different from other SFLs? A typical SFL lining uses lattice girders to support the steel reinforcement and assist in controlling the profile/geometry of the tunnel cross section and is applied in layers to build up the concrete thickness of the final linings. Reinforcement in such applications is usually small bar diameter and well spaced out, as recommended by ACI 506, to minimize the opportunity for shadowing of the shotcrete around the girders and reinforcing bars. It requires a high level of application skill, workmanship, and a rigorous quality control process. It is increasingly being installed using robotic spraying, which therefore limits the finish that can be achieved to a nozzle finish. For example, a typical sequence for SFL may include: 1) installation of lattice girders at 5 ft (1.5 m) centers with a steel reinforcing bar mat placed against the waterproofing membrane at the extrados side of the girders, and partial encasement of the lattice girders; 2) shotcreting of an infill first layer between the lattice girders; 3) shotcreting of a second layer; 4) installation of reinforcing bars on the intrados side of the lining; and 5) installing a final shotcrete layer to provide minimum cover over the reinforcement. The number of shotcrete layer installations would depend on the total design thickness of the final lining. Figure 1 illustrates the installation of SFL.

PAC by contrast is used with the same reinforcing bar design used for a form-and-pour lining; thus, no specific design changes are needed to accommodate its use. It can be used around extremely heavy and congested reinforcement and against polyvinyl chloride (PVC) or spray-applied waterproofing membranes. Shotcrete is applied in layers that act monolithically in the completed concrete section. It can be hand finished to achieve any standard of finish required, including textured architectural finishes. It does,

Fig. 1: SFL installation

Fig. 2: PAC in use

however, require proper equipment, quality materials, an experienced shotcrete contractor, highly skilled ACI-certified shotcrete nozzlemen, and support crews to ensure a safe and high-quality finish is achieved as well as an extremely rigorous quality control process both before application starts and during. Figure 2 shows a PAC application.

Shotcrete excels in tunnel applications where conventional forming methods are difficult logistically and also costly to construct. Where conventional methods use large, heavy, and in most cases steel forms that have limited flexibility in final position, PAC finds its most effective uses. The benefits that the use of PAC brings include no need to engineer, fabricate, install, and remove a form system in a restricted underground space. This results in no forms blocking the tunnel during concrete placement operations. Scaffolding is needed but typically there is a need for scaffolding for the reinforcement installation and in any case, scaffolding is lighter and easier to erect, dismantle, and transport than a form system. PAC can be used with or without waterproofing, be it sheet membrane or spray-applied. Enhanced quality control is required for sheet membrane systems, especially in overhead applications to ensure the membrane is tight against the substrate. Figure 3 shows an example of a PAC-lined structure.

PAC has been successfully used for caverns, wyes, cross passages, vent shafts, air plenums, inclined escalator shafts, tunnel boring machine (TBM) crossovers, and tunnel junctions, all of which are locations that render uniform linear applications vulnerable to customization requirements. In these locations PAC provides a monolithic concrete placement process while allowing the designer and contractor to achieve the needed variations in conforming to the ever-changing conditions of a project which would not otherwise be achievable with a fixed forming system. For a tunnel system as shown in Fig. 4, PAC is an ideal placement method for the many and varied geometries.

While PAC is extremely versatile, it is not a process that can be used in all locations; for example, repetitive uniform

Fig. 3: Typical example of PAC lined structure

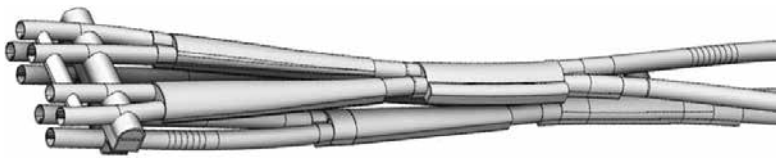

Fig. 4: Complex tunnel network lined using PAC

TBM lining operations are better served using a traditional form-and-pour approach, as the rate of placement of PAC cannot equal that for a formed placement.

The use of PAC requires a rigorous quality control process. For example, when PAC was introduced to the East Side Access Project in NYC, it became clear that additional measures would need to be included in the Quality Control process both to ensure a safe and high-quality installation but also to satisfy the requirements of the New York State Building Code (NYSBC). The NYSBC includes requirements that need to be met to permit shotcrete placement for a structural component. These requirements include using a maximum No. 5 (No. 16M)

Fig. 5: Preconstruction test panels: (a) vertical; and (b) overhead

reinforcing bar, a 6 in. (150 mm) minimum reinforcing bar spacing, and a prohibition on the use of full-contact lap splices. Crucially, however, the NYSBC includes a provision for a waiver to these requirements should the designer be satisfied that full encapsulation of the designed reinforcing bars can be achieved. To satisfy this requirement, the following process was put in place.

In addition to vertical and overhead compressive test panels to confirm the shotcrete mixture design, a full-size preconstruction mockup of the most complicated section of the lining was shot using the approved mixture designs and the shotcrete equipment to be used in the works. Working with the designer, the most heavily congested reinforcing bar sections both vertically and horizontally were identified and installed together with any embedded elements required for the final lining along with the waterproofing system. All shotcrete nozzlemen were required to demonstrate their ability to completely encapsulate the reinforcement and embeds and provide the requisite compaction of concrete required prior to approving the use of PAC in the permanent works. Once the mockup had been shot, sections through the reinforced mockup panel were cored and saw-cut to demonstrate that the encapsulation had been achieved. Figures 5(a) and (b), 6, and 7 demonstrate this process.

Regular testing of the concrete mixture was conducted during production operations. However, limited testing of the production-place shotcrete was performed. The shotcrete process allows full visual inspection of all the concrete being placed. This helps to ensure that shadowing and voids are dealt with as the shotcrete is being placed by an experienced nozzleman. Coring through the finished product was minimized and was typically undertaken in early applications


Fig. 6: Preconstruction field trial PAC mockup and hand spraying of vertical walls


Fig. 7: Encapsulation around reinforcement, embedments, and encasement of water barrier (on right lower side)

only, using “sacrificial” additional reinforcing bars to check the encapsulation.

PAC is typically used with a waterproofing membrane which can either be a PVC or spray-applied membrane. In both cases, a layer of mesh is installed approximately 1 to 2 in. (25 to 50 mm) away from the waterproofing and hung on the waterproofing supplier’s proprietary anchor system. This mesh gives the shotcrete a surface to grip against enabling overhead applications to be undertaken with little difficulty. Where a PVC membrane system is used, all water barriers used as part of the waterproofing sectioning system are equipped with re-groutable hoses to ensure adequate embedment of the water barriers with the shotcrete. After the concrete lining has gained its 28-day compressive strength, grout is injected through the re-groutable hoses to fill any voids between the water

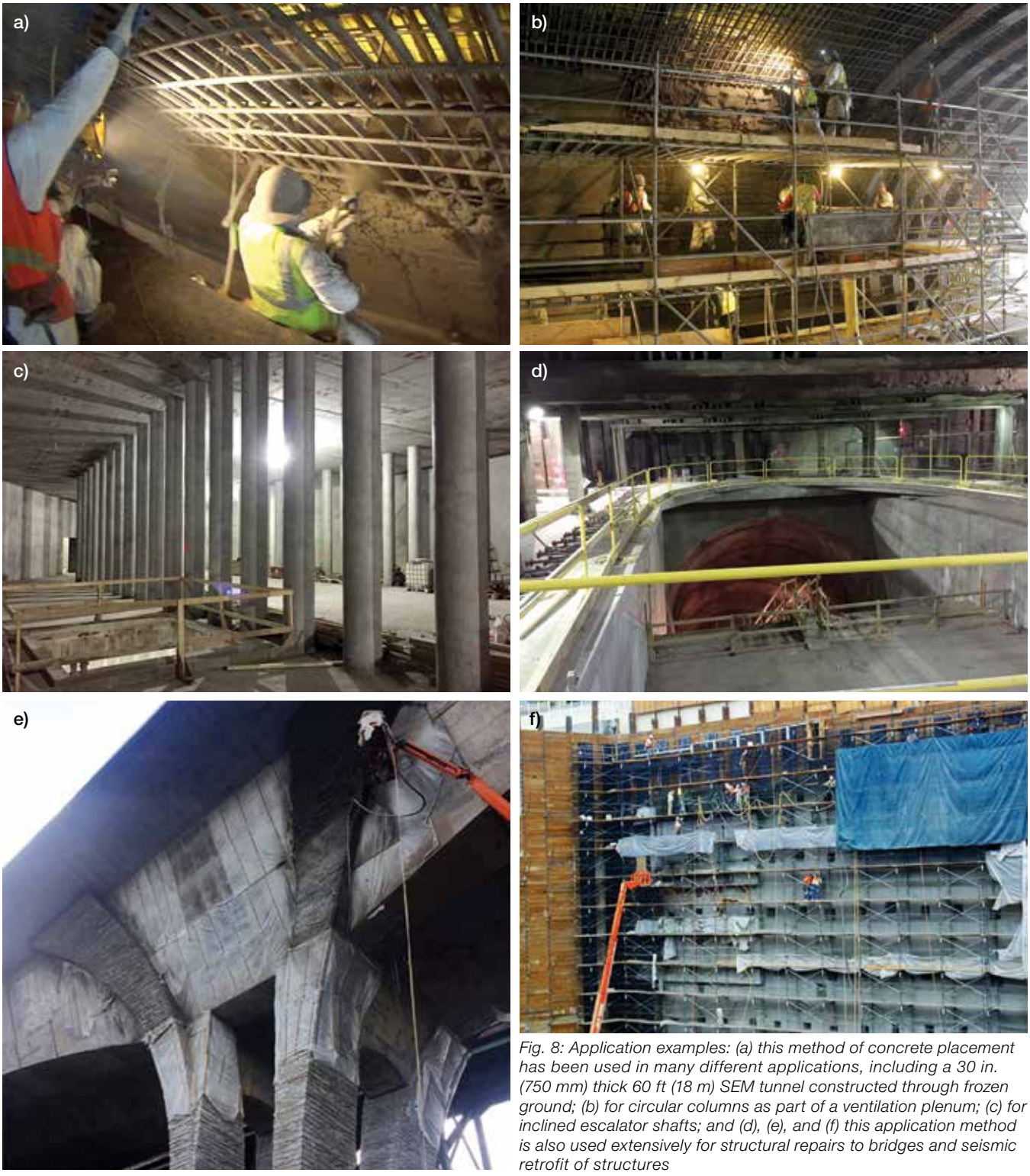

Fig. 8: Application examples: (a) this method of concrete placement has been used in many different applications, including a 30 in. (750 mm) thick 60 ft (18 m) SEM tunnel constructed through frozen ground; (b) for circular columns as part of a ventilation plenum; (c) for inclined escalator shafts; and (d), (e), and (f) this application method is also used extensively for structural repairs to bridges and seismic retrofit of structures

barrier and the PAC final lining. Similar to form-and-pour and SFLs, contact grouting is required when PAC is used to fill any voids between the waterproofing membrane and the concrete final lining. This contact grouting is not limited to roof sections only, but a radial and more frequent distribution of grouting ports and pipes around the crown and above spring line was implemented with injection of low-viscosity cementitious grouts between the final PAC lining and the membrane to ensure a tight contact between the initial and final lining.

CLIENT BENEFITS

Client benefits to using the PAC method are mainly associated with schedule and quality. As no forms are required, there is no need to go through a drawn-out process of design, fabrication, delivery, installation, and removal of forms. As such, the PAC method can be used throughout the duration of the project, enabling the final lining to be installed relatively quickly after excavation. This can enable follow on contracts to enter into these completed sections for access or for completion work earlier than would be the case with a form-and-pour lining. In addition, there are no forms to block access routes through the area to be lined. Scaffolding required to install the control wires and for the shotcrete placement may cause some blockage but is of a more limited duration.

The finished space is not now limited by the need to build and install forms. Continuously changing cross sections can be developed that minimize excavation, lining thickness, and schedule, as the PAC method can be used to match the lining to the space requirements and the challenge is now back with the designer to economize on these elements knowing that PAC is a tool in his or her armory.

With shotcrete, the quality of the finished product is fully visible as the work progresses. There is no waiting until the form is stripped to discover poor consolidation, voids, and honeycombing. If there are isolated problems with the shotcrete placement, these are fixed as the work progresses, thus minimizing the need to go back and undertake remedial works in completed sections of tunnel and thus freeing up the completed structure earlier. In fact, shotcrete is often used to rectify areas where problems have been encountered with the use of formed concrete.

CONCLUSIONS

Form-and-pour concrete will continue to be the prime method of placement of final linings in underground structures. For repetitive lining operations such as lining a TBM tunnel over several thousand feet, this is, in reality, the most practical method of concrete placement. The PAC method offers a viable alternative placement method for nonuniform cross sections, shaft, and other areas where the installation of a form would be problematic. It is certainly not a panacea and requires a rigorous engineered approach to the design of the structures and methods to take advantage of its flexibility and quality benefits. The challenge moving forward is to take advantage of this PAC method to provide efficient and economic designs that can account for the benefits and constraints of the shotcrete placement method.

Andy Thompson *has worked for Mott MacDonald since 1988 and is currently involved with the management of the design phase for the Purple Line in Maryland and the Thimble Shoal Tunnel Project in Chesapeake Bay. Between 2008 to March 2016, he worked on the East Side Access Project in midtown Manhattan serving as Program Executive, responsible for delivering around $5.5 billion of heavy civil and underground elements of the project beneath Grand Central Terminal and Sunnyside Yard in Queens. Previously, Thompson has worked on landmark projects such as Channel Tunnel and the A20 Round Hill Tunnels in the United Kingdom, the Great Belt in Denmark, as well as other underground projects such as Harbor Area Treatment Scheme Stage 1 in Hong Kong, Greater Istanbul Water Supply Project, and Atlanta West CSO project.*

Frank E. Townsend III *is a Vice President for Superior Gunite. He received his bachelor's degree in civil engineering from Worcester Polytechnic Institute, Worcester, MA, and his master's degree from the University of Missouri, Columbia, MO. Townsend served the U.S. Army Corps of Engineers and his diverse military background has led to him being deployed around the world. He is an active member of ACI Committee 506, Shotcreting, and the American Shotcrete Association. He has been Awarded the U.S. Army Corps of Engineers' deFluery Medal and* Engineer News-Record *New York's "Top 20 under 40" design and construction leaders in 2016. He is a member of the Moles and Beavers, which are fraternal organizations of the heavy construction industry.*

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* Model shown with optional features.

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Creating a Foundation for Success: The Use of Lidar in Tunneling Projects

By Carlos Gonzalez

Shotcrete placement requires close attention to safety; when combined with the difficult working conditions of a tunnel, overhead placement requires even greater awareness of potential hazards. As underground and tunneling projects become more common, collaborative partnerships between forward-thinking civil engineers, shotcrete contractors, and technological innovators are becoming more prevalent in an attempt to improve not only the way shotcrete efficiency is measured but also to reduce the risk for workers.

The dangers of underground construction methods are numerous. The whole premise of making tunnels safe often relies on placing workers at risk while the work is carried out. In March 2014, a shotcrete rig operator died while working on London's Crossrail tunnel project. Investigations into the incident led authorities to believe that the wet shotcrete lining collapsed as the worker approached the wall to trim excess concrete. As most experienced operators know, fallout from overhead placement is a potential hazard when working on underground applications that can never be entirely avoided by improvements in both safety and training practices.

COMBINING KNOWLEDGE

3D Laser Mapping (Now part of GeoSLAM) has been working with mining companies for over 20 years, creating solutions that address the challenges of those working in unstable environments. One such technology is LiDAR (Light Detection and Ranging), which visualizes and analyzes surroundings from a distance, using remote sensors to warn of impending dangers. When approached by Jetcrete Oz, an opportunity arose to create a solution with the aim of making the underground application of shotcrete safer, faster, and more efficient. Jetcrete has over 35 years of experience supporting and fortifying shafts and tunnels. With employees regularly working in the dark and difficult environmental conditions of a tunnel, it became a necessity to create an operational management system that would help Jetcrete to more effectively communicate job progress and compliance with application standards.

The majority of mine sites suffer from rockfall and slope instability, leading to the development of industry standard technologies which are now commonplace in many open pit and underground mining operations.

LIGHT AT THE END OF THE TUNNEL

Laser scanning has traditionally been used by civil engineers and surveyors to create three-dimensional (3-D) maps of large and potentially complex environments. Using a pulsed light from a laser, a LiDAR system calculates distance by timing how long it takes for each pulse to reflect back to the scanner. Capable of firing around 1,000,000 pulses per second, the most progressive systems can generate a millimeter-perfect representation of a target area. Once analyzed, this can reveal characteristics and features that can often be difficult or even impossible to see with the naked eye.

In an underground environment, these stations are often the surveyor's instrument of choice when it comes to monitoring movement. Great advancements in above-ground applications have now made LiDAR an even more powerful tool when it comes to measuring and monitoring changing landscapes. Thanks to its ability to map and pinpoint specific geological features, LiDAR is adept at identifying minute changes. It is this attribute that inspired the development of the underground shotcrete monitoring system, ProcessMonitor Live.

DEVELOPMENT FOR THE UNDERGROUND MARKET

While consulting with Jetcrete, it became clear that, as much as the application technology of shotcrete rigs and equipment had advanced, the measuring and reporting processes had not. Many experienced shotcrete contractors have relied on measuring the applied thickness using probes. This method can be as time-consuming and inconsistent as using stamps. Sometimes operators had to return to a shotcreted surface hours after application to check whether the desired thickness had been reached. If it had not, the rig would have to be returned to the deficient location to reapply. In addition to under-application, neither stamps nor probes allow for a rig operator to gauge if the shotcrete has been over-applied, meaning that the potential for wastage is high.

Another important consideration that arose in the initial consultation was safety. From exposure to heavy machinery, potential rockfall and fallout incidents, nozzlemen were

constantly placed in harm's way once they were out of the rig. With this in mind, the 3D Laser Mapping's research and development team considered three key objectives when developing ProcessMonitor Live: safety, time management, and efficiency. This combines the accuracy of LiDAR with advanced real-time data-processing software, allowing Jetcrete to assess each surface prior to application and then measure and monitor the thickness of shotcrete as it is applied.

SAFETY

The health and safety of workers is paramount in any industry, yet in heavy industrial environments such as mining, the hazards are often serious and potentially life-threatening. LiDAR's remote sensing capabilities and ability to automatically assess an environment from a distance allows users to create maps and models of transportation infrastructure or assess the integrity of slopes and cliffs. These capabilities help keep employees at a safe distance, reducing the risk of incidents and fatalities.

ProcessMonitor Live was initially designed to be mounted to a shotcrete rig, allowing the operator to provide inspections at each stage of the application process from the safety of the vehicle. The remote nature of the system also helps to complete initial risk assessments with the assurance for clients that additional safety measures will be taken while working on site.

TIME MANAGEMENT

Laser Mapping's research and development team used a software algorithm with the potential to almost instantly detect change between each scan of the surface. The laser scanning system was connected to a tablet, which the operator used to capture a color-coded image showing the profile of the target surface in real time. Each time a layer of shotcrete was applied, the operator could then repeat the scanning process and visualize any under-sprayed areas before the rig moved on. With the ability to scan immediately after application and with each scan taking around a minute to perform, the rig operator was able to improve the accuracy of the process as well as shortening the time to cover the area correctly.

EFFICIENCY

Material wastage is difficult to quantify when applying shotcrete, particularly when shotcrete tunnel linings can run into thousands of square feet. A wastage tolerance of as little as one percent can have huge cost implications for both the principal contractor and shotcrete contractor. ProcessMonitor Live can measure the applied thickness of shotcrete down to the millimeter, helping to reduce waste.

Measuring and monitoring potential overspray can also help to prevent dangerous instances of fallout, a common occurrence when working in tunnels. Underspraying can have equally large safety ramifications if areas prone to rockfall are not adequately protected. The digital data collected by the scanner and software allows ProcessMonitor Live users to ensure that their shotcrete placements comply with regulatory requirements by providing documented data to prove work has been carried out to specified requirements.

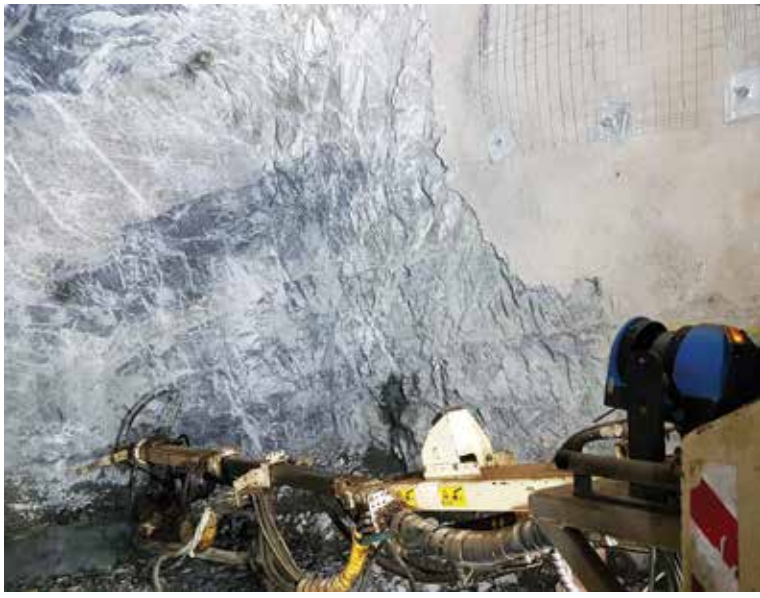

Fig. 1: Monitoring equipment on a shotcrete rig

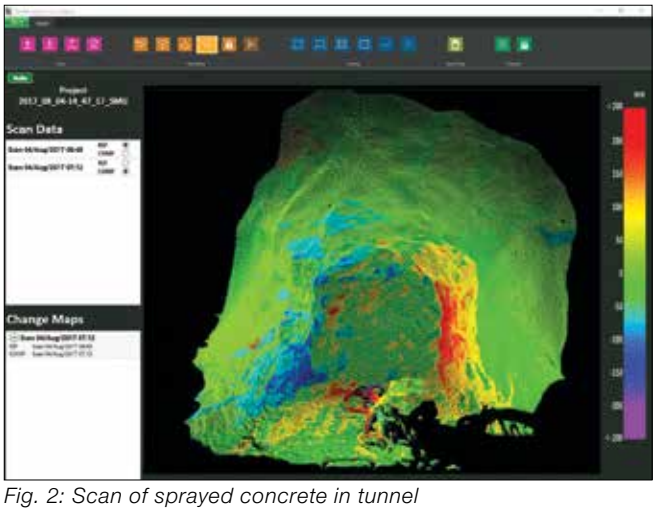

Fig. 2: Scan of sprayed concrete in tunnel

Since joining in 2014, ***Carlos Gonzalez*** *has been the key contact in Australia for 3D Laser Mapping. His experience is in product engineering, geodesy, and surveying in different environments and industries such as oil, gas, and mining. He has held positions as a Survey Manager, Product Engineer, and Senior Surveyor and specializes in monitoring solutions and mining services.*

Simple Still Works

By John Becker

Coastal Gunite Construction recently executed a few phases of a storm sewer rehabilitation in a line running under the Blue Plains Advanced Wastewater Treatment Plant operated by the District of Columbia Water and Sewer Authority. The company was a subcontractor on a much larger contract with PC Construction Company. The crown of the 7 ft (2 m) tall arched concrete pipe was damaged due to biogenic corrosion, which necessitated the removal and replacement of the deteriorated concrete. Shotcrete was the perfect choice for the repair due to the speed of installation, durability of the product, and minimally invasive nature of the work by avoiding excavation and formwork.

For many of people in the industry this is a familiar story, similar repairs have been done for over 100 years. In fact, the gunning machine used on the project was a 50-year-old N-style double chamber dry-mix shotcrete rig with a mixer and conveyor leading to a hopper affixed over the gun itself. This equipment would not look out of place at all in a photograph from a century ago. The shotcrete mixture, batched on site, was a minor tweak of a 3:1 sand-cement concrete mixture, adding silica fume and synthetic fibers. In a world of rapidly changing technology, where many tools and materials are obsolete so quickly, why do some things remain steadfastly useful with only minor modifications and improvements over great stretches of time?

Fig. 1: Finished tunnel crown installation

Fig. 2: N-style gun and mixer rig

Perhaps the best explanation for the stability of the shotcrete process is the amazing results that are achievable with the process at its simplest. Coastal Gunite Construction recently impressed Florida Department Transportation officials on a job outside of Orlando, FL. After negative experiences on a culvert repair project with an engineered spin-cast lining alternative, Lane Construction Corporation, the prime contractor, convinced the engineers to allow another culvert on the project to be repaired using the simple 3:1 sand and cement dry shotcrete mixture still present in the state's standard specifications. The concrete placed was dense, durable, and greatly exceeded the required

compressive strength, and was installed inexpensively and quickly. Swiftly scrabbling the existing culvert allowed an excellent bond with the new material with no signs of separation or cracking after placement and followed by traditional water curing. The dry-mix shotcrete was placed with the same well-proven equipment that was used on the Blue Plains Project a few weeks earlier.

Coastal Gunite Construction still uses N-Style double-chamber guns for the same reason that FDOT still has the 3:1 mixture in its spec book—it is basic, reliable, and provides proven quality results. The gun itself is powered by the same compressed air source that conveys the dry concrete material through the delivery hose and accelerates the material to impact on the substrate at high velocity. The gun is built out of thick steel and a few rubber gaskets, is entirely mechanical, and rarely requires repair. Testament to the N-gun's earned workhorse status is obviously its age. The hours of dry-mix shotcrete that have run through it are uncounted, as its future reliability is just assumed. It would be interesting to know how many different generations of compressors have powered this sturdy and effective device.

The project at the Blue Plains facility was not without challenges and problems, including hydrodemolition equipment issues, tidal flows, tight schedules, and issues surrounding surface preparation testing all contributed to a difficult but ultimately successful project. The site batch dry-mix shotcrete was an oasis and low-stress component amongst other complexities.

Coastal Gunite Construction is very fortunate that the core technology in the shotcrete industry is so strong. Sand, cement, and decades-old equipment work together extraordinarily well for most applications. This proven base capability gives us the opportunity to evaluate and choose improvements, tweak and test new technology. Ultimately it is comforting that these things improve an effective method that when properly designed and installed far outlast all the people involved in the project.

John Becker *is an ACI Certified Nozzleman who for over a decade has worked in many capacities, most recently as Project Manager, for Coastal Gunite Construction Company based in Cambridge, MD. He has been involved with many shotcrete projects large and small including the $15 million Bonner Bridge Rehabilitation Project in Nags Head, NC; the $5 million Old Mill Creek Sewer Rehabilitation Project in St. Louis, MO.; and the $19 million Fort McHenry Tunnel Rehabilitation in Baltimore, MD.*

Fig. 3: Tunnel after hydrodemolition

Fig. 4: Tunnel being shotcreted after surface preparation

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2019 ASA SHOTCRETE CONVENTION & TECHNOLOGY CONFERENCE

Omni Amelia Island Plantation Resort
Fernandina Beach, FL
February 24-26, 2019

This year, ASA will host a 2-day Shotcrete Convention & Technology Conference, bringing the industry a focused opportunity to explore shotcrete applications and innovations as well as future advancements in the industry. ASA Spring Committee Meetings and our annual Outstanding Shotcrete Project Awards Banquet will also be featured events here! Sunday's pre-convention opportunities include ASA's Contractor Qualification Seminar and several fun networking events taking advantage of Amelia Island's exceptional destination venue, including a pre-conference Dessert Reception and Industry Mixer.

Featured Events and Optional Activities:

- Shotcrete Technology Conference presentations
- ASA Spring Committee Meetings (replacing meetings at The ACI Concrete Convention and Exposition – Spring 2019)
- Tabletop Exhibits
- The annual ASA Outstanding Shotcrete Project Awards Banquet at nearby Walker's Landing
- Full-day ASA Contractor Education Seminar
- ASA Golf Outing at Omni's Oak Marsh golf course, designed by Pete Dye
- Deep sea fishing, group tennis clinic, guest programs, and other resort offerings

www.shotcrete.org/convention

SCHEDULE AT A GLANCE

Sunday, February 24, 2019	
8:00 am – 5:00 pm	***Contractor Education Seminar*** *(w/ boxed lunch)*
9:30 am – 2:30 pm	***Deep Sea Fishing*** *(w/ boxed lunch)*
10:00 am – 3:00 pm	***Oak Marsh Golf Outing***
3:00 pm – 4:00 pm	CM – ACI C660 Special Meeting: Brainstorming on the Future of Shotcrete Nozzleman Certification
3:00 pm – 5:00 pm	Exhibitor Registration and Setup
4:00 pm – 5:00 pm	CM – ACI 506-H Pool Subcommittee
7:00 pm – 9:00 pm	**Dessert Reception** and Exhibit Hall open
Monday, February 25, 2019	
6:30 am – 7:30 am	Registration
6:30 am – 8:00 am	Breakfast and Exhibit Hall open
8:00 am – 9:00 am	CM – Education | Underground
9:00 am – 10:00 am	CM – Membership | Pool & Rec
10:00 am – 10:30 am	AM Break
10:00 am – 12:00 pm	***Group Tennis Clinic***
10:30 am – 11:30 am	CM – Marketing | Safety
11:45 am – 12:45 pm	TC – Track 1 (A, B, C)
11:45 am – 1:45 pm	Lunch
1:45 pm – 2:45 pm	TC – Track 2 (A, B, C)
3:00 pm – 4:00 pm	TC – Track 3 (A, B, C)
4:30 pm	Exhibit Hall closed for the evening
5:30 pm – 6:30 pm	Reception
6:30 pm – 8:30 pm	**Buffet Dinner**
Tuesday, February 26, 2019	
6:30 am – 7:30 am	Registration
6:30 am – 8:00 am	Breakfast and Exhibit Hall open
8:00 am – 9:00 am	TC – Track 4 (A, B, C)
9:15 am – 10:15 am	TC – Track 5 (A, B, C)
10:15 am – 10:45 am	AM Break
10:45 am – 11:45 am	TC – Track 6 (A, B, C)
12:00 pm – 1:00 pm	TC – Track 7 (encore presentations*)
12:00 pm – 1:00 pm	CM – CQ
12:00 pm – 2:00 pm	Lunch
2:00 pm – 4:00 pm	CM – BOD
3:00 pm – 4:30 pm	Exhibit Hall closed | Exhibitor Move-Out
5:45 pm – 6:00 pm	***Bus departure to Walker's Landing***
6:00 pm – 10:00 pm	***Reception and Awards Banquet***

CM = Committee Meetings
TC = Technology Conference presentations
Bold/italic = optional events (not included with registration)
*Top two attendee-selected presentations repeated based on attendee request

TECHNOLOGY CONFERENCE

Speaker		Presentation
Mason Guarino	1A	The Shotcrete Pool Business
Marc Jolin/Antoine Gagnon/Pierre Siccardi	1B	The Shotcrete Placement Method: the Past, the Present, and the Future
Axel Nitschke	1C	Guidelines and Resources for Underground Shotcrete Design and Specification
Ryan Oakes	2A	Pool Shotcrete—High Quality Does Not Mean Low Productivity
Oscar Duckworth	2B	Concrete Mixture Design for Shotcreting
Patrick Bridger	2C	Recent Innovations in Robotic Shotcrete Technology
Mason Guarino/Ryan Oakes/Bill Drakeley	3A	How NOT to Shoot a Shotcrete Pool
Dennis Bittner/ Eric Bertrand	3B	Shotcrete Projects Converted from Form-and-Pour
Mario Manser	3C	Behavior of Bi-Component Polymer Fibers under Creep and in Aggressive Environments Regarding Durability Performance
Oscar Duckworth	4A	Advancements in Wet-Mix Nozzle Design
Lloyd Keller	4B	Development and Testing for a Low-Temperature Shotcrete Mixture Using High-Volume Slag
Bill Geers	4C	Fiber-Reinforced Shotcrete 101
Will Clements	5A	Recent Developments in the Science of Shotcrete Materials and Mix Design
Kristin Routh	5B	Wetsuit—Next-Generation Waterproofing Solutions for Shotcrete
Marc Jolin/Antoine Gagnon/Pierre Siccardi	5C	Perspective on Fiber-Reinforced Shotcrete—Current Practice and Future Innovations
Mark Bradford/ Dominic Petrella	6A	Shotcrete Finishing—Dos and Don'ts
Marcus von der Hofen	6B	Tiber Creek Sewer Rehabilitation—Combining Initial Support with Final Support and Lining
Benedikt Lindlar	6C	Testing Wet Shotcrete on Laboratory Scale

All sessions approved by the American Institute of Architects (AIA). ASA is an AIA/CES Registered Provider.

OPTIONAL TICKETED EVENTS

Sunday, February 24, 2019

CONTRACTOR EDUCATION SEMINAR

8:00 AM – 5:00 PM (w/ boxed lunch) | Cumberland C
Fees: $600 per person (includes reference materials + written exam)
$450 per person (seminar only)

One of the mandatory requirements in our new ASA Contractor Qualification Program (CQP) is the attendance of a company representative at a full-day Contractor Education Seminar presented by ASA. The seminar focuses on the many aspects of successful shotcrete contracting and how shotcrete construction compares to more traditional form-and-pour concrete construction. The seminar is geared toward the education of Contractors but may be valuable to Owners, Engineers, Architects, and Suppliers who want to learn more about the details required to consistently construct high-quality, durable concrete structures with shotcrete placement.

Topics covered in the seminar include: Overview of the CQP; Site Planning/Logistics; Diversity of Shotcrete Applications; Concrete Knowledge; Shotcrete Equipment; Shotcrete Knowledge; Shotcrete Testing; Equipment Maintenance; Shotcrete Specific Safety; and Financial Responsibilities.

Attendees seeking Shotcrete Contractor Qualification for their company (one representative per company) will be required to take a written examination at the conclusion of the seminar.

DEEP SEA FISHING – Amelia Angler Outfitters

9:30 AM – 2:30 PM | Meet at hotel, Uber to docks, 15 minutes away
Fee: $200 per person (six-passenger boats)

Superb bottom fishing action can be enjoyed all year long offshore of Amelia Island. Look for some of the best action during the cooler months. "Schultz's Fish Market" is a manmade reef located just 5 miles offshore of the southern tip of Amelia Island, offering excellent red snapper, gag grouper, cobia, and black sea bass fishing year-round. Numerous sunken wrecks, lime rock ledges, hard bottoms, and manmade wrecks are also located within 5 to 20 miles offshore. Fishing techniques include fishing right on the bottom from an anchored or drifting boat with fresh squid, cut bait, live baits, cigar minnows, or "Boston" mackerel. Our clients hold their own rods and enjoy the excitement of a large reef dweller trying to yank their fishing rod right out of their hands! When schools of striking fish are present, our mates will set out a "Flat Line" bait or two, allowing our charter guests to have the opportunity of catching a fast swimming pelagic species as well! Included are king mackerel, cobia, dolphin, barracuda, amberjack, and more! The six-passenger fishing charters for a 4-hour excursion includes all bait, tackle, license, cleaning of your catch, boxed lunch, water, and a cooler on board to BYOB.

OAK MARSH GOLF OUTING

10:00 AM – 3:00 PM (lunch on your own) | $49 club rental fee
Fees: $145 per person (includes small prize given at Monday's dinner)

The Oak Marsh Golf Course is one of the truly classic Pete Dye-designed golf courses in the world. At par 72, this 6500-yard course has 14 holes with water hazards and numerous bulk-headed greens. A variety of bunkers are placed throughout the course to add to the challenge, and a natural approach has been maintained as well with the use of coquina shell cart paths, native plant life, and preserved habitats for the local wildlife. Oak Marsh played host to the 1991 PGA Section Championship and 1992 Society of Seniors Championship. In addition, numerous resort tournaments are played here. Included in Golf Digest's prestigious list of the "Top 75 Resort Courses in the U.S.," Oak Marsh also was selected by Travel & Leisure Golf as one of "Florida's 50 Finest Courses."

Monday, February 25, 2019

GROUP TENNIS CLINIC – Cliff Drysdale Tennis Program

10:00 AM – 12:00 PM
Fee: $95 per person

Tennis Clinics are great social events and provide a welcoming atmosphere for everyone to connect with one another. The format will consist of 2 hours total, made up of both instructional and informal playing time. The program includes balls, rackets, towels, and non-alcoholic beverages. The courts are set beneath a canopy of majestic live oaks and feature 23 Har-Tru® fast-dry clay courts, a tennis pro shop, and a health & fitness center.

Tuesday, February 26, 2019

OUTSTANDING SHOTCRETE PROJECT AWARDS BANQUET

6:00 PM – 10:00 PM | Walker's Landing
Fee: $150 per person

The American Shotcrete Association's annual Outstanding Shotcrete Project Awards Banquet has been a highlight event for the industry for more than a decade. Formerly held in conjuction with World of Concrete in Las Vegas, we are excited to host this year's celebration at nearby Walker's Landing on Amelia Island Plantation! Guests can enjoy a sunset view of the Intracoastal Waterway from the deck surrounding this octagonal-shaped facility. Always a capstone event for our industry and Association, we invite you to come celebrate with us!

CONVENTION HIGHLIGHTS

Networking—The exhibit hall is the central meeting spot for the convention. Registration, exhibits, breakfast, lunch, and breaks will be located here—all included with your registration. Tabletop exhibits will surround the room, giving attendees the opportunity to meet exhibitors, colleagues, and other leaders in the industry! New this year, the exhibit hall will also be the venue for our Sunday evening Dessert Reception and Industry Mixer. This informal reception will be an opportunity to meet new people at designated tables for various market segments such as pool, underground, repair and rehabilitation, and more to network with industry professionals in similar markets.

ASA Logoware—ASA baseball caps will be available for purchase! Order forms will also be available at the ASA Registration table to order your ASA polos, shirts, and jackets. This is a limited-time opportunity to place your orders for ASA apparel!

Sponsors and Exhibitors—Sponsorship for the convention provides exceptional promotional opportunities at the convention and Banquet venues, ASA's booth at World of Concrete, on the ASA website, in *Shotcrete* magazine, and on social media forums! Sponsors can also secure a tabletop exhibit at the convention with priority placement given to Gold Sponsors. Non-exhibiting sponsors may distribute materials from the ASA Registration table as space allows. A complimentary Banquet seat is also included with Gold sponsorships this year. Sponsorship for the ASA Convention demonstrates your support for the mission of the Association, allowing us to provide knowledge resources, qualification, certification, education, and leadership to increase the acceptance, quality, and safe practices of the shotcrete process for the industry. For full Prospectus details, visit **www.shotcrete.org/sponsorship**.

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DETAILS AND RESERVATIONS

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ASA has negotiated extremely favorable rates with the Omni for your convenience. By staying at our Host Resort, you will be closest to all the action while helping your Association meet our commitment to Omni to obtain these rates.

ROOM RATES (PER NIGHT)

Oceanfront Hotel Run of House Deluxe Room — $189 (+ $10 reduced Resort Fee)

Oceanfront One Bedroom Villa — $229 (+ $10 reduced Resort Fee)

Oceanfront Two Bedroom Villa — $369 (+ $10 reduced Resort Fee)

All rooms are subject to an additional State & Occupancy tax of 12%. Resort Fee of $10 per night includes WiFi access in-room and numerous on-resort WiFi hot spots, including all ASA meeting rooms.

RESERVATIONS

Book by February 1, 2019. To reserve by phone, please call the hotel at (904) 261-6161 and ask for the ASA Shotcrete Convention rates. All reservations are on first-come, first-served basis. Check-in time is 4 p.m.; check-out time is 11 a.m. If you arrive earlier, or need to stay on site after checkout, the resort will securely store luggage until you need it.

RESORT FEATURES

3.5 miles of beach; full-service luxury spa, salon and spa boutique; indoor and outdoor pools; fully-equipped fitness center with an indoor lap pool; 36 holes of championship golf; family and youth recreation; kids playground; hiking and nature trails; award-winning recreation department; beach rentals including chairs, umbrellas, and cabanas; Cliff Drysdale Tennis program and 23 Har-Tru® tennis courts; Nature Center and nature tours; biking, fishing, kayaking, and paddle boarding; guided Segway Tours and Island Hopper rentals from Amelia's Wheels; shopping Village.

SHOTCRETE CONVENTION & TECHNOLOGY CONFERENCE

Convention and Student Registrations includes: Sunday evening Dessert Reception and Industry Mixer; all Breakfasts, Lunches, and Breaks (Monday and Tuesday); Monday evening casual Buffet Dinner; all Committee Meetings and Technology Presentations (Monday and Tuesday).

Guest Registration includes: Sunday evening Dessert Reception and Industry Mixer; Breakfasts (Monday and Tuesday); and Monday evening casual Buffet Dinner. Guest registration does NOT include attendence of Committee Meetings or Technology Conference presentations.

Convention Registration Early-Bird Bonus: Register by January 2, 2019, to be entered for a drawing for (1) complimentary full-page color ad ($1920 value) in the Spring 2019 issue of *Shotcrete* magazine OR a Golf Round for a foursome at Silverado Resort & Spa in Napa, CA.

Registration Form available online until February 18, 2019. Limited onsite registration will be available at the Omni.
Online form may be used for one Attendee and one Guest: www.shotcrete.org/convention.

Cancellation Policy: ASA will refund the registration fees for any cancellations received by Friday, February 1, 2019, minus a $100 cancellation fee (Golf Outing subject to an additional cancellation fee of $50). NO registration refunds can be given for cancellations after February 1, 2019.

Convention/Conference Registration	Member Rate	Nonmember	+ Late Fee (after Jan. 18)
Full Package Attendee	$450	$525	+ $100
Full Package Guest/Spouse	$200	$200	—
Full Package Student	$200	$200	+ $100
Optional Ticketed Events (flat rates)	**Attendee Fee per perseon**		**Day of Event**
Convention registration **required** for the following:			
Pre-Convention Contractor Education Seminar (w/ exam)	$600		Sunday
Pre-Convention Contractor Education Seminar (w/o exam)	$450		Sunday
Oak Marsh Golf Outing	$145		Sunday
Deep Sea Fishing (lunch included)	$200		Sunday
Group Tennis Clinic (2 hours)	$95		Monday
Awards Banquet	$150		Tuesday

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Can Supplemental Consolidation Extend the Limits of Shotcrete Placement?

By Oscar Duckworth

In many major metropolitan regions of the United States, shotcrete methods are being used daily to place concrete within elements incorporating large, highly congested reinforcement layouts. In the past, many thought that only form-and-pour methods could be used for these dense layouts. The increased use of shotcrete for these applications is primarily driven by the cost and labor savings that inherently result from shotcrete's efficiencies. Because shotcrete's compaction and consolidation qualities are directly attributed to high velocity, lower velocity that can occur in tightly congested reinforcement configurations being shot today can prove insufficient to provide adequate compaction.

For years, experienced shotcrete crews have used a hybrid of high-velocity placement with supplemental consolidation methods. The supplemental mechanical vibration techniques help consolidate the concrete and allow full encasement of congested reinforcement elements. Success with the hybrid placement requires careful attention to detail and experience by the shotcrete crews.

Current shotcrete technical documents, ACI 506.2-13, "Specification for Shotcrete;" ACI 506R-16, "Guide to Shotcrete;" and ACI CP-60, "Craftsman Workbook for ACI Certification of Shotcrete Nozzleman," do not recognize the use of mechanical vibration during shotcrete placement. Lack of published guidance can lead to confusion for engineers, specifiers, and on-site inspectors if a vibrator is operated in conjunction with shotcrete placement.

Fig. 1: Mockup panels with congested reinforcement patterns may require alternative methods to attain adequate consolidation

Is the shotcrete industry comfortable with this hybrid placement process? Can the untrained misuse of mechanical vibration spell trouble ahead?

> "*shotcrete — concrete placed by a high velocity pneumatic projection from a nozzle.*"
> from ACI Concrete Terminology – CT-18

By definition, the shotcrete process is entirely dependent on high velocity. The velocity and impact force provide the energy required to achieve compaction and consolidation. A skilled crew using proper nozzling techniques can achieve full encasement within fairly dense reinforcement configurations. However, some congested reinforcement patterns may interrupt the flow of material and reduce the velocity before impact. This may reduce the ability to fully encase the reinforcing steel.

Whether cast or shot, the use of larger bars and increased reinforcement congestion presents distinct challenges to attaining full consolidation of concrete during placement. If congestion prohibits the use of internal vibrators with form-and-pour placement, alternative consolidation methods or designs must be considered. This includes use of external mechanical vibration, redesign of the reinforcement, or use of a self-consolidating concrete mixture. With shotcrete placement, such options do not exist.

Currently in structures with congested reinforcement, preconstruction testing (mockups) are used to validate the concrete materials, delivery equipment, and if the shotcrete crew can satisfactorily encase the structural reinforcement (Fig. 1).

Professional nozzlemen who routinely shoot complex mockup panels can immediately identify the exact location of areas within the panel that will be difficult to achieve encasement. Highly experienced shotcrete crews place concrete in these difficult areas through a combination of high-quality shotcrete placement techniques and supplemental consolidation.

TO UNDERSTAND WHY SUPPLEMENTAL CONSOLIDATION MAY BE NECESSARY—THINK LIKE A NOZZLEMAN

For the shotcrete nozzleman, as reinforcement congestion increases, the complexity of placement increases. As complexity increases, so does the potential for consolidation quality to be compromised. It is important to understand that nozzlemen must function within certain natural limitations of the shotcrete process. Nozzlemen must use impact energy derived from velocity as the only means to consolidate the material.

As obstacles between the nozzle tip and the receiving surface increase, the nozzle stream is affected in two distinct ways. Initially, because the nozzle stream cannot be directed into all the shadow areas behind reinforcing bars due to its impeded path, some bars may not receive material at the proper velocity or angle. Larger bars, in conjunction with more restrictive reinforcement patterns, tend to decrease the likelihood that velocity alone can successfully encase and consolidate all the material adequately. Voids can occur within shadow areas behind bars that are within the shadow of other bars. Second, the mixture proportions tend to become segregated by the high-velocity nozzle stream's interference among congested reinforcing bar layouts. Higher quantities of loose, unconsolidated material, or rebounded materials—rather than well consolidated materials—can become embedded, especially within areas that cannot be effectively blown clear with the blow pipe.

Experienced nozzlemen who direct the nozzle stream skillfully, have proper placement equipment, and use well-chosen concrete mixtures can overcome much of shotcrete's natural limitations. But beyond these, nozzlemen have few additional tools to counteract these limitations. In most instances, the nozzleman is the ONLY person that can make a visual observation of whether acceptable consolidation is occurring during placement. Unfortunately, it is difficult to quantify the degree of congestion that may or may not be successfully encased due to the natural limitations to the process (Fig. 2).

WHAT IS SUPPLEMENTAL CONSOLIDATION?

In heavily congested reinforcing layouts, high-quality shotcrete placement techniques alone may not always assure adequate encasement. Thus, supplemental consolidation should be considered as a method of supplying additional consolidation energy for proper placement techniques. Mechanical consolidation using properly sized concrete vibrators have been incorporated with form-and-pour methods for more than 75 years. However, use with the shotcrete process is not widely known or documented.

Freshly placed shotcrete is highly susceptible to disruption from movements. Experienced placement crews incorporating mechanical vibration in conjunction with shotcrete placement techniques must carefully balance the mechanical energy required to consolidate the material, but not displace it. By comparison, form-and-pour methods use

Fig. 2(a) and (b): Mockup panels with congested to extremely congested reinforcement patterns

mechanical vibration as the primary means of consolidation because rigid formwork withstands the material pressures during vibration. With shotcrete—because there are no restraining forms—mechanical vibration, if used improperly, can (and will) interfere with in-place quality. Vibration can unintentionally disturb freshly placed material to the point that delaminations, internal cracks, sags, and fallouts can occur. When vibrators are used with shotcrete, experience, timing, and properly selected equipment will be the determining factor in the success of supplemental consolidation.

UNDERSTANDING MECHANICAL VIBRATION

Concrete vibrators used for form-and-pour methods have not changed significantly for decades. Vibrators use a rotating counterweight encased within a steel body to produce powerful oscillations. As the vibrator is immersed in the concrete, a momentary fluidized puddle of highly agitated material occurs within a small area surrounding the vibrator known as the radius of action. Within the vibrator's radius of action, strong agitation changes the material adjacent to the vibrator to temporarily act in a more viscous, fluidized state, allowing the material to simultaneously release trapped air, consolidate tightly, and potentially segregate.

Manufacturers offer various lengths, exterior diameters, horsepower ratings, and oscillation frequencies to match their intended purpose. Because concrete is a mixture with many components of various weights, vibration can segregate the material as the oscillations cause heavier aggregates to fall and the lighter paste to rise. Heavier high-powered vibrators have a wide radius of action and work well for large elements and coarse mixtures but can quickly segregate material if used improperly. Small pencil vibrators, usually about 1 in. (25 mm) in diameter, are less likely to segregate materials, but have an effective radius of action of just a few inches and may lack the necessary energy to consolidate much more than the smallest element.

The vibrator's oscillation speed or frequency is important to the proper choice of a vibrator. Most common vibrators that plug into 120 or 240VAC household current can only rotate at about 3600 rotations per minute due to the limitations of the available alternating currents' 60-cycles-per-second rate. This low-frequency oscillation speed tends to consolidate concrete material well but unintentionally shakes the mixture's large

aggregates downward excessively, causing segregation. As the frequency of the oscillations increase, large aggregates are less (or not at all) affected, so the material's movement is more uniform, diminishing the risk of segregation. This behavior is comparable to the behavior of dental, jewelry, or industrial ultrasonic cleaners, which vibrate a cleaning solvent at very high frequencies. High-frequency oscillations effectively dislodge stains or contaminants but will not shake even the smallest items. Because of the benefits of high-frequency oscillation, many "high-cycle" direct-current or battery-powered vibrators are available and are designed to function at 10,000 rpm or higher.

APPLYING MECHANICAL VIBRATION TECHNIQUES TO SHOTCRETE

With shotcrete, what is the best method to accomplish supplemental consolidation using a vibrator? Because vibration can unintentionally disturb rather than consolidate in-place material, the vibrator's size, frequency, and methodology become far more critical than with other concrete applications. Smaller pencil-style vibrators, which operate at very high frequencies, tend to work best.

Because freshly placed shotcrete can be easily damaged by vibration, the material must be as tightly placed as possible through proper nozzling techniques and the vibrator operated *only* as a means to assist, rather than act as the primary means of consolidation. Consolidation of poorly placed material or low-velocity placement methods using vibration as the primary means of consolidation should not be considered.

Supplemental consolidation requires that the material be carefully placed with vibration only used to help consolidate any remaining smaller voids or shadow areas behind obstacles. Skilled operators focus the vibrator's activity only within these areas, working carefully to avoid movement of the in-place material outside the vibrator's radius of action. If operated carelessly, vibrators will damage in-place work. Because material being vibrated is not retained within formwork, over-vibration **will** cause the fluidized material to flow downward and outward, which can create cracks or delaminations; reduce internal cohesion; or break the bond between the shotcrete, the reinforcement, or the underlying material.

USE TIMING AND VISUAL INDICATORS

The vibrator operator must follow the nozzle closely, move quickly, and continually monitor both the shotcrete's upper bench surface and the areas immediately below the vibrator's radius of action. The operator should be able to recognize the visual indicators indicative of proper shotcrete vibration techniques. The upper surface should become smoother without dropping excessively. The area below the vibrator should flow outward *slightly* without bulging. If vibration is causing excessive movement, or displacing material away from the immediate work area, the vibrator is too large, or the material is being over-vibrated. Work should be stopped, and the problem must be corrected before continuing.

The use of a vibrator as supplementary consolidation of shotcrete can be an extremely valuable tool to counteract the natural limitations of the shotcrete process in congested structural concrete—but only if experienced personnel and properly chosen vibration equipment is paired with high-quality nozzling practices.

Can supplemental consolidation redefine the limits of where shotcrete placement can successfully provide well-consolidated concrete with fully encased reinforcing steel? It already has. Perhaps a future definition for shotcrete is:

> *shotcrete—concrete or mortar projected at high velocity where a combination of impact and supplemental consolidation, when needed, achieve compaction.*

Supplemental consolidation checklist:

- When in doubt whether an element can be successfully shot, ask the nozzleman. Occasionally, the nozzleman is the ONLY person capable of making a visual observation of whether supplemental consolidation may be necessary;
- Gather knowledge on the proper use of a vibrator before purchasing or using a vibrator with shotcrete;
- Choose a vibrator that is best suited for use with the shotcrete process. Small pencil-type vibrators with a frequency range of 10,000 rpm or above work best;
- Use vibration for supplemental consolidation of properly placed shotcrete—not as the primary means of consolidation for low-velocity placement or poorly placed shotcrete;
- Vibrator operator: learn to recognize the timing and visual indicators of proper supplemental consolidation. Follow the nozzleman closely and avoid over-vibration; and
- Nozzleman: learn to identify the visual indicators of proper supplemental vibration techniques. If material sags or becomes visibly damaged from vibration, internal damage from cracks or delaminations are likely; cut it out and replace the entire damaged section rather than simply repairing its surface with a trowel.

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

Hose and Fitting Wear

Critical Safety Issues in Shotcreting

By Sean Madole

In May of 2016, our company, Madole Construction, participated in the rehabilitation of the historic Lincoln Hall Dormitory at the University of Nevada in Reno, NV. The dormitory was constructed in 1896. Lincoln Hall is one of the oldest buildings on the University of Nevada's campus and was continuously occupied from 1896 through 2015. Part of the structural retrofit for the building included placing structural shotcrete walls around the perimeter of the basement and the two lower floors of the building.

We had several new crew members as we started the project and decided it would be an excellent time to bring in an outside trainer to refresh everyone on shotcrete principles and safety. During the training, the criticality of checking wear parts in a shotcrete system for damage or excessive wear was thoroughly discussed. I am acutely aware of danger involving worn hose and parts because my Dad was injured on a jobsite in 1970 by a failed concrete pump reducer. Over the course of my childhood, he spent 3 years on crutches and had over 17 surgeries because of that injury. It should be noted he was not a part of the concrete pumping or placing operations and was working about 80 ft (24 m) away from the pump.

After several hours of a classroom safety session, we went outside as a group to visually inspect the hoses and fittings on our concrete pumping system. When checking the pipe and fittings we had been using we found a 3 to 2 in. (75 to 50 mm) reducer that had excessive wear. That started a conversation among the group: When does a part have enough wear to be replaced? Our consensus was, at the point a part is worn 0.25 in. (6 mm), it should be replaced. On the reducer in question, we handed the tape measure to each person on the crew and got several different measurements ranging from 3/16 to 5/16 in. (5 to 8 mm).

After the class, my Dad and I had several conversations about coming up with a more reliable way to measure the wear on the steel parts in a pump system. Even if a crew member religiously checked a part with a tape measure there is a good chance they could make a mistake and install an

Fig. 1(a) and (b): Gauge to measure wear levels

unsafe part in the system. So, to try and make evaluating wear as foolproof as possible, we developed a hose wear indicator from a piece of aluminum round stock. The concept for the indicator was simply building it as the reverse of a case gauge used in handloading ammunition. A round aluminum stock piece was machined in a lathe with a taper to just have the end fit inside a new 2 in. fitting. As the part wears, the gauge will slide deeper to accurately measure the wear. One side of the taper rabbeted to provide marks showed how much wear was present. We added green lines to show acceptable wear levels and a red line for excessive wear. The tapered gauge is a more reliable indicator of wear, easier to use, and can quickly measure the pipe in more than one direction.

Sean Madole *is the President of Madole Construction Co. Inc. based in Reno, NV. Madole Construction is an AB Licensed contractor in Nevada and California, performing foundation repairs and specialty contracting. Madole is an ACI Certified Nozzleman and performs daily oversight for operations and management. He is a 1994 graduate of the United States Air Force Academy.*

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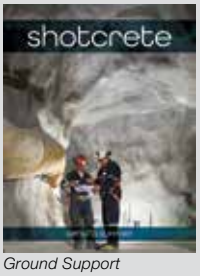

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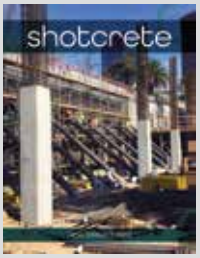

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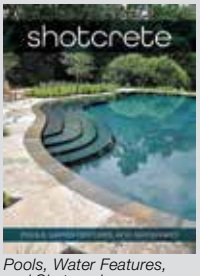

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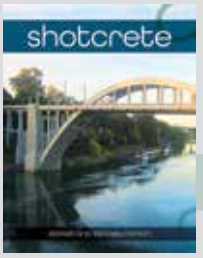

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Chemistry and Heat Treatment

The Recipe for Steel Success

By Andy Kultgen

If you stop and take a look around your shop at your equipment and tools, and maybe the walls and beams of the building itself, you are bound to see dozens or hundreds of individual metal components. Given the tough, rugged environment of the construction industry, most of those metal components are steel or iron. The tasks we use those components for may vary quite widely, even though they may be very similar materials. Some materials may need to be strong, tough, and flexible, like the frame of your truck. Others may need to be rigid and very hard, to resist wearing out, like the races of a wheel bearing, or the cylinder walls of a hydraulic cylinder or material cylinder of a wet-mix shotcrete pump. Other components may need to be incredibly tough and resistant to cracking, like the head of a hammer. All those components can be made from very similar recipes of steel, but the difference lies in minute changes in the amounts of carbon and other alloying elements, and the heat treatment.

INTO THE CRUCIBLE

Steel refers to a specific range of recipes, called chemistries, of iron alloys. What sets this group of materials apart from other iron alloys is the amount of carbon present in the metal. Steel generally ranges from almost zero carbon up to about 2% carbon, in what are called high-carbon steels. The presence of trace elements can have an enormous effect on the properties of the steel. The properties of steels are closely related to the crystalline structure the steel takes when cooled from molten to solid. Just as water has a crystalline structure when it freezes, so does steel. The crystalline structure is influenced by the chemistry and how quickly you cool and solidify the steel. Many steels for general use are primarily iron and carbon. Other steels, known as alloy steels, have additions of alloying elements.

Common alloying elements are manganese, nickel, chromium, molybdenum, and vanadium; however, there are many more possibilities. These elements, in the right amounts, increase desirable properties, such as toughness, strength, or corrosion resistance. Some elements, such as sulfur and phosphorus, are limited to a maximum amount, as they generally weaken steel. Many standard chemistries of steel are defined by various specifying bodies. They list the acceptable ranges for various elements and the known physical properties for steels with that chemistry. You may have heard of these specified chemistries, or grades, of steels before. In the United States, they are dictated by SAE and ASTM International and have names like 1018, 4140, or 316. The 4100 series of steels have chromium and molybdenum additions, so are commonly called Chromoly steel. The 316 stainless steel resists corrosion because of the addition of chromium and nickel.

Fig. 1: Chemistry sampling: (a) taking a sample—a furnace operator takes a sample of molten metal from the furnace. He will pour the metal into a water-cooled mold to quickly make a sample for the quality control laboratory; and (b) spectrometer—a technician places the metal sample cylinder, or button, on the sample stage of the spectrometer. This machine will analyze the chemistry of the metal in just seconds, allowing the technician to approve the chemistry of the sample or inform the furnace operator how much alloying elements to add to this melt (batch) of metal

(Photos courtesy of Alliant Castings)

Grade	Allowable limits, % by mass													
	Carbon		Manganese		Phosphorus	Sulfur	Silicon		Nickel		Chromium		Molybdenum	
	Min.	Max.	Min.	Max.	Max.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
4140	0.38	0.43	0.75	1.00	0.04	0.04	0.15	0.35	—	—	0.80	1.10	0.15	0.25

Fig. 2: SAE chemistry specification—an example of a chemistry specification for a certain grade of material. In this case it is SAE 4140 alloy steel, a common alloy steel, often called Chromoly steel

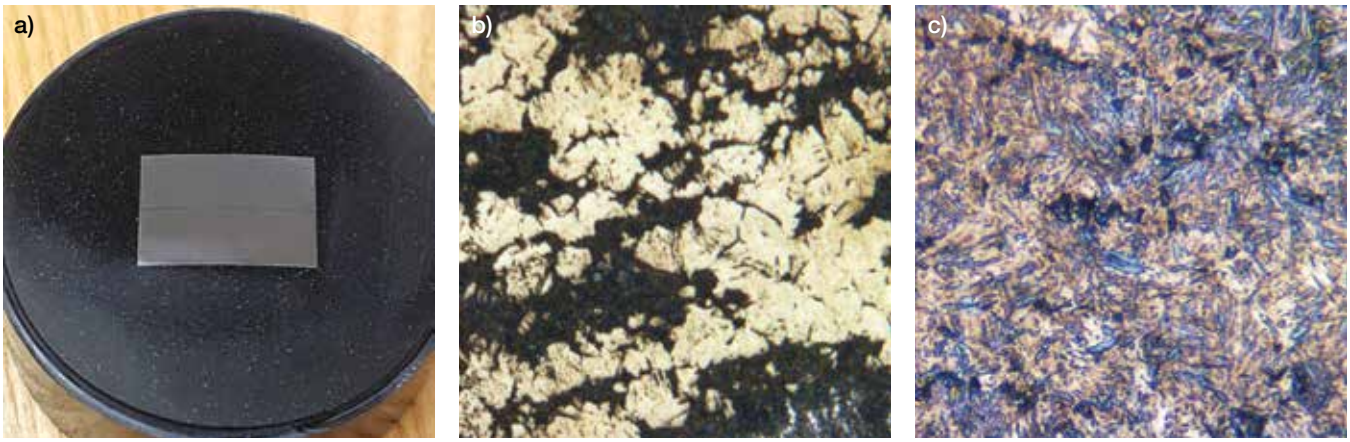

Fig. 3: Metal structure: (a) sample mount—a small sample of steel is encased in phenolic resin to hold it securely. To examine the steel crystalline structure, the sample is etched with a nitric acid solution to dissolve one type of crystalline structure and expose another. The sample cylinder in the photo is 2 in. (50 mm) in diameter. This steel sample was heat treated with localized heating and quenching, so there is both martensite, ferrite, and pearlite present. Both accompanying microstructure photos were taken from this sample; (b) perlite/ferrite—a mixture of ferrite (the light areas) and pearlite (the dark areas); and (c) martensite—tan areas. Martensite crystals grow in branching plates, resembling frost on a window

HEAT TREATMENT THEORY

A single chemistry of steel can form several different states depending on how it is heated and cooled. The different states can be distinguished under a microscope; they have distinct crystalline structures in different quantities. These different crystalline structures lend different physical properties to the steel. To heat treat a steel, the material is heated up above its critical temperature, but below the melting temperature, where the material's structure is called austenite. Cooling the material slowly will result in a mixture of structures called pearlite and ferrite; this is known as annealing or normalizing, depending on the exact parameters. Cooling quickly results in a mixture called martensite and is known as quenching. Quenching is typically done by immersing the component in a water or oil bath. Pearlite tends to be softer and more ductile, so the steel will bend and deform instead of breaking but will not be as strong. Martensite is harder and more brittle; steel in this state will be harder and stronger but will fracture more easily.

Typically, a material will be tempered after quenching. Tempering involves heating the quenched steel to a temperature below the critical temperature. This relieves stresses in the martensite, reducing the likelihood of cracks growing through the material, but does not change the martensite back into austenite. The result is a martensitic steel that is still strong and hard, but less prone to cracking. Each chemistry of steel has an Isothermal Transformation diagram that manufacturers can use to know how quickly to cool the steel to achieve the desired crystalline structures.

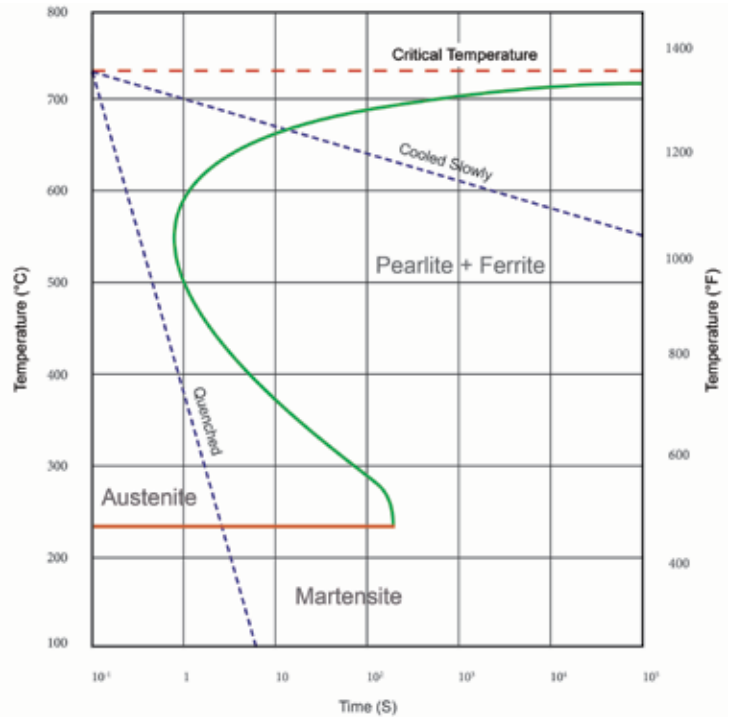

Fig. 4: TTT diagram—this Isothermal Transformation diagram can be used to determine how quickly to cool a steel or other metal when heat treating. The steep line shows a metal that was quenched, cooled from over 1300°F (700°C) to room temperature in a matter of seconds, and would be in a primarily martensite structure. The less steep line shows a metal that was cooled from the same temperature slowly, over several hours. This metal would be in a mixture of pearlite and ferrite structures

There are more states of crystalline structure for steel and iron alloys than covered in this article and more advanced methods of heat treating, many of which are employed by contemporary pumping equipment suppliers. For wet-mix concrete pumping, high hardness results in better wear characteristics, but too high of hardness results in a brittle component that cannot tolerate rough handling, such as being hit by a hammer or dropped on the bed of a truck.

WHAT IF I WANT WEAR RESISTANT AND TOUGH?

There are many cases where a component should have a hard surface to resist wear but should be tough as well. Martensite is hard and resistant to wear but is brittle and prone to cracking. A pearlite and ferrite mixture is ductile and resistant to cracking but isn't very hard and will wear quickly. The types and quantities of each crystal structure present are defined by the chemistry of the steel and how quickly it is cooled. To get differing material qualities in different areas of a component, you need to either vary the chemistry or the heat treatment within the component.

TARGETED AREA HEAT TREATMENT

If a component is a shape that allows part of it to be quenched while the rest is allowed to cool slowly, it can be heated up and quenched in just one area. Add tempering afterward and you have the process often used for hand tools, power tool bits, and a wide variety of other components where you need one end to be hard, to keep an edge or point, and the rest of the part to be tough and durable.

TARGETED AREA CHEMISTRY

If the component cannot be quenched in only the area that should be hardened, another option is to change the chemistry in that area. The amount of martensite is generally related to the amount of carbon in the steel. A component made of a steel with low amounts of carbon throughout, but with high levels of carbon just on the surface, could be quenched and tempered to produce a part with good toughness and ductility through most of the thickness, but high hardness right at the surface. This process is called case hardening. By heating a component above the critical temperature where it changes to an austenite structure and exposing it to a high-carbon environment, carbon molecules will soak into the steel. The higher the carbon amount in the environment and the longer the steel is exposed will result in more carbon soaking deeper into the steel. This process can be done with nitrogen as well as carbon; they are known as nitriding and carburizing, respectively.

HEAT TREATMENT PRACTICE

There are several ways to heat treat components to be used for concrete pumping—the requirement is just that the steel be heated above the critical temperature and then cooled at the right rate to develop the desired crystalline structure. A common practice is to batch heat treat. In batch heat treating, the material is placed into an oven and heated to the desired temperature. Heat treating ovens are commonly powered by fossil fuels, usually natural gas. If an annealed part is desired, the heat for the oven is turned off and the load is allowed to cool very slowly inside the oven. If a

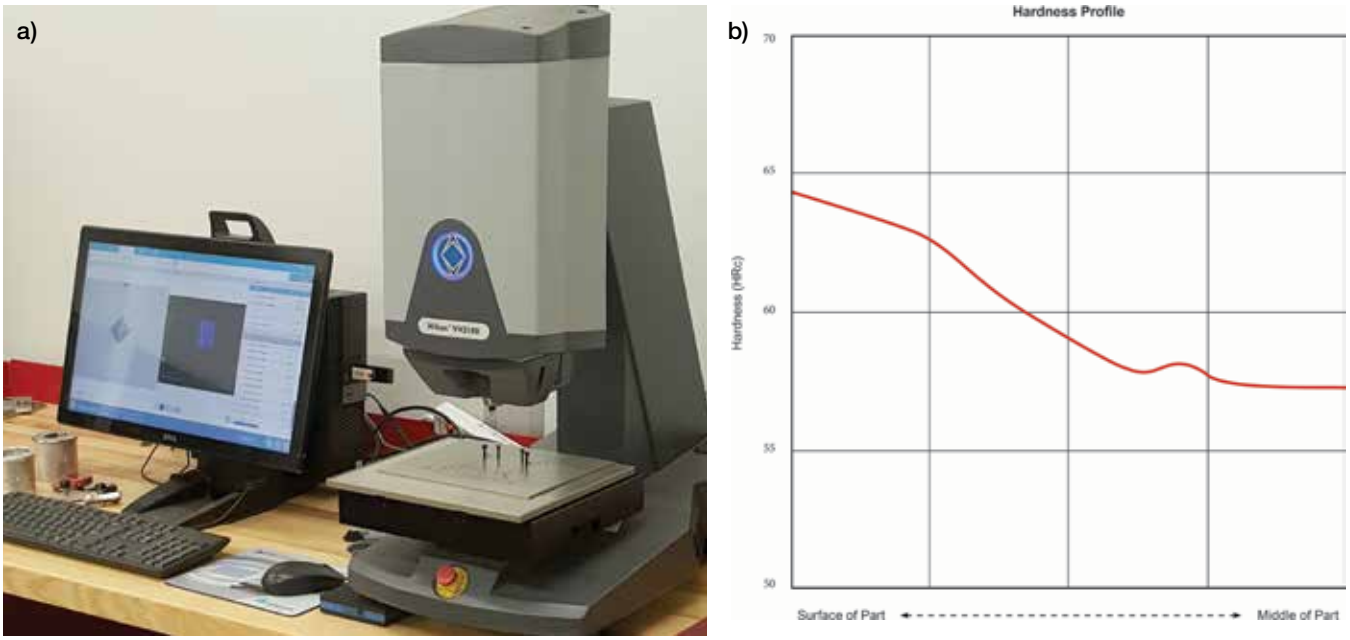

Fig. 5: Hardness check: (a) microhardness—this machine can measure the hardness of samples in very small increments. This allows technicians to very closely monitor the results of heat treatment, especially in cases of case-hardening or targeted heating and quenching; and (b) hardness gradient—this is a plot of hardness values of a cross section of a steel part. The plot begins at the surface of the part. You can see this part was case-hardened, resulting in a very hard surface layer and decreasing hardness throughout the middle of the part. This part is used in concrete pumping and has a very high surface hardness to resist abrasion

hardened part is the goal, the load is removed from the oven and quenched into a water or oil bath.

This process can be used from continuous processing as well, by feeding a continuous flow of materials into the oven, allowing the material enough time to come up to temperature, and then feeding the material into a quench tank.

In some applications, continuous processing can take advantage of a directed heating method called induction. Induction applies electricity to coils to produce magnetic fields, which rapidly switch polarity. Electrically conductive materials that are close to the fluctuating magnetic fields will have electric current induced within them. The material's resistance to the flow of electricity causes the material to heat up. Because the magnetic field only affects electrically conductive materials, the energy is focused on heating the metal object and is not wasted heating other things. Once the material reaches the critical temperature, it can be quenched to create the hardened structure.

A common method of carburizing and nitriding is gas carburizing/gas nitriding. Parts are heated in a sealed oven with a controlled atmosphere rich in either carbon or nitrogen. Commonly used gases are carbon monoxide for carburizing and ammonia for nitriding, but several other options exist. Once the parts have soaked for long enough, they may be removed from the oven and quenched and tempered as desired to reach the right hardness and toughness levels.

Fig. 6: Heat-treat oven—a load of castings is pulled out of the batch heat treating oven. This alloy is quenched with forced air, not a water or oil bath. They are positioned below powerful fans, which will blow air over the castings, cooling them rapidly. The pieces of reinforcing bars are used to keep the castings from contacting one another, which would result in uneven heating and cooling
(Photo courtesy of Alliant Castings)

This summary of materials and heat treatment for steel barely scratches the surface of the fields of metallurgy and material science. Ancient people created iron tools thousands of years ago, figuring out how to make material that fit their needs by trial and error. Now, these concepts are taught to engineering students early in their careers, and engineers and material scientists can do things that couldn't be imagined a few decades ago with a wide variety of materials. Next time you are holding a wrench that says Tempered and Vanadium, you know that the steel chemistry included vanadium to increase the strength and hardness and it was tempered after quenching to make a hard part that is resistant to wear but has a decreased likelihood of cracking. Suddenly that plain old wrench doesn't seem so plain anymore.

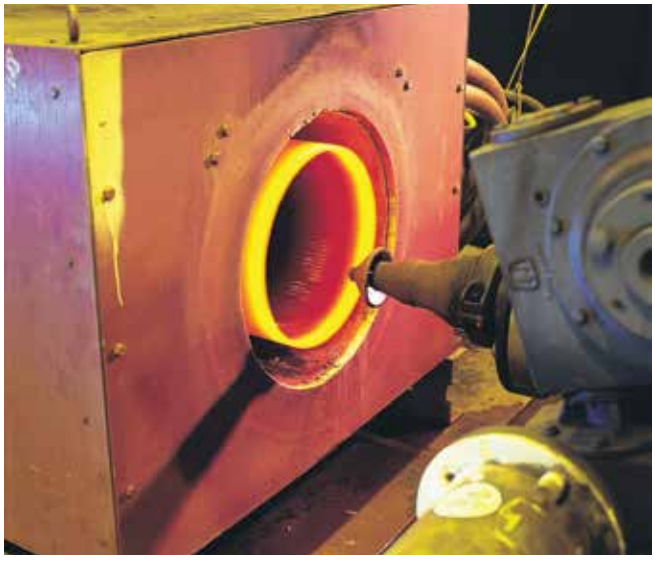

Fig. 7: Induction pipe—a steel pipe emerges from the stationary induction heating coil. The pipe travels quickly through the water-cooled coil, which is protected inside the orange box. Having been heated to over 1600°F (875°C), the pipe immediately passes over a smaller pipe, called a lance, seen in the center-right. Water floods out of the lance, quenching the pipe, resulting in a very hard pipe that is effective at resisting abrasion

Andy Kultgen *is an Engineer at Construction Forms, Inc., based in Port Washington, WI. Since 2011, he has been involved in research and development as well as technical and field engineering for the concrete pumping and mining industries. He has worked on customized products and layout plans for concrete pumping on several record-setting projects in the United States and internationally. Kultgen received his BS specializing in machinery systems engineering from the University of Wisconsin, Madison, WI. He is active in ASA and ACI, and is focused on furthering research in wet-mix nozzle performance and developing improved nozzle designs, as well as encouraging safe practices in the concrete pumping industry.*

The True Cost of an Injury

By Jason Myers

When an injury occurs, management will often look at the cost of the injury only as the cost of the insurance statement. The reality is that the cost of the injury is much greater. It is easy to identify these direct costs, but the ongoing and indirect costs need to be taken into consideration and are many times higher than the direct costs, depending on the business and the different circumstances of the accident. Preventing workplace injuries not only keeps employees safe, but it also hedges against significant unexpected losses. This article presents the importance of safety from a cost point of view and is based on a presentation given to Dees Hennessey's employees. It is crucial for employees to understand the importance of safety beyond the point of view of keeping each other safe, which is of prime importance, but also in making sure that their company stays in business and they have continued employment.

DIRECT COSTS

Some of the obvious direct costs are medical bills, doctor visits, medicine, and physical therapy. However, some of the direct costs are less noticeable, such as lost time, disability compensation, and legal expenses. The obvious direct costs are easily quantifiable but the less noticeable directs costs are the costs that lead to insurance companies requiring a larger reserve fund to handle the possible expenses. Insurance companies often look at their insurance payouts to be around 60% of the premiums that they charge, and insurance companies, just like all companies, are in business to make a profit. Thus, insurance companies will make sure that they are being covered based upon your past performance—whether good or bad.

INDIRECT COSTS

The total cost of an accident is like an iceberg. We often see the above the water portion of the iceberg (direct costs) but do not realize the size of the iceberg below the water (indirect costs). The indirect costs are the costs that are the not easily calculable but can lead to a factor of three to ten times the direct cost of an accident. Some examples of indirect costs for a company include lost production, accident investigation costs, OSHA fines, structure or equipment damage, retraining costs, loss of morale and productivity, loss of business and goodwill, loss of work by key personnel, and modified work duty costs. To limit the direct costs, companies will frequently have a person come back to work with modified job responsibilities to limit the amount of lost time from the injury. This can end up being a very large expense by having a very qualified employee sitting around performing less productive work around the jobsite for a couple of weeks.

MINIMIZING DIRECT AND INDIRECT COSTS

The way to limit the costs of injuries is managing the crisis and minimizing the direct and indirect costs. The direct costs are usually out of the contractor's hands but there are ways to limit the exposure. One successful way we have found is using a safety service company that has trained personnel who are on call to come out to the jobsite on a moment's notice and assess an injury, perform first aid if needed or provide counsel if a trip to the clinic is needed. The safety service company will also make return visits to the jobsite if additional care is needed. Their goal is to provide quick and effective care but get the employee back to work as soon as possible. This is in sharp contrast to a clinic providing the same care and then simply scheduling a follow up visit for a week or two later. The most effective way to limit the costs of injuries is to minimize the indirect costs. This includes finding ways for the employee on modified duty to still provide a productive role on the crew, such as holding a stop sign for a couple of days rather than a shovel, cross training crew members so others can step in quickly and effectively, or having all paperwork filled out and being very proactive with OSHA to help out if an investigation is performed. Managing the costs, especially the indirect costs, are essential to minimizing the impact of any injury.

Now the good news. According to the National Safety Council, for every $1 companies invest in safety prevention, they receive a $2 to $6 return. This shows that with smart investments in the needed types of safety training and equipment, there is a great return on the investment. The first three steps that most companies focus on to reduce injury risks are through administrative controls, engineering controls, and personal protective equipment (PPE). However, sometimes the most effective way to reduce the accident rate is through a culture change. If the field employees view any changes as another paper to fill out or another item they have to wear, then the safety changes will not be effective, and will quickly be seen as the latest fad. If safety becomes part of the culture and the field employees view their role in safety as part of the normal corporate culture, then the real savings can be seen.

El verdadero costo de un accidente

Por Jason Myers

Cuando ocurre un accidente, la empresa a menudo considera que el costo del accidente es solo el costo de los gastos del seguro. La realidad es que el costo de un accidente es mucho mayor. Es fácil identificar estos costos directos, pero los costos indirectos deben tomarse en consideración y son muchas veces mayores que los costos directos, según el tipo de negocio y las circunstancias del accidente. La prevención de accidentes en el lugar de trabajo no solo mantiene a los empleados seguros, sino que también protege contra pérdidas significativas inesperadas. Este artículo presenta la importancia de la seguridad desde un punto de vista económico y se basa en una presentación dada a los empleados de Dees Hennessey. Es crucial que los empleados comprendan la importancia de la seguridad más allá del punto de vista de mantenerse seguros entre sí, lo cual es de suma importancia, pero también para asegurarse de que su empresa permanezca en el negocio y continúen con su empleo.

COSTOS DIRECTOS

Hay algunos costos directos que son muy obvios como las facturas médicas, visitas al médico, medicamentos y terapia física. Sin embargo, hay algunos costos directos que son menos notables, como el tiempo perdido, la compensación por discapacidad y los gastos legales. Los costos directos obvios son fácilmente cuantificables, pero los costos directos menos notables son los costos que llevan a las compañías de seguros a requerir un fondo de reserva mayor para manejar los posibles gastos. Las compañías de seguros a menudo consideran que los pagos de sus seguros representan alrededor del 60% de las primas que cobran, y las compañías de seguros, al igual que todas las compañías, están en el negocio para obtener ganancias. Por lo tanto, las compañías de seguros se asegurarán de que estén cubiertas en función del desempeño de sus clientes, ya sea bueno o malo.

COSTOS INDIRECTOS

El costo total de un accidente es como un iceberg. A menudo vemos la porción del iceberg sobre el agua (costos directos) pero no nos damos cuenta del tamaño del iceberg debajo del agua (costos indirectos). Los costos indirectos son los costos que no pueden calcularse fácilmente, pero pueden llevar a un factor de tres a diez veces el costo directo de un accidente. Algunos ejemplos de costos indirectos para una compañía incluyen pérdida de producción, costos de investigación de accidentes, pago de multas de OSHA, daños a la estructura o equipos, costos de reentrenamiento al personal, pérdida de ganancias y productividad, pérdida de negocios, pérdida de trabajo por parte del personal clave e incremento en los costos del trabajo que está realizando. Para limitar los costos directos por tiempo perdido debido al accidente, las empresas a menudo hacen que una persona trabaje con diferentes responsabilidades para cubrir la posición por la lesión. Esto puede terminar siendo un gasto muy grande al tener un empleado muy calificado haciendo un trabajo menos productivo durante un par de semanas.

MINIMIZANDO LOS COSTOS DIRECTOS E INDIRECTOS

La forma de limitar los costos de los accidentes es manejar la crisis y minimizar los costos directos e indirectos. Los costos directos generalmente están fuera del alcance del contratista, pero hay maneras de limitarlos. Una manera exitosa que hemos encontrado es utilizar una compañía de servicios de seguridad que tenga personal capacitado que esté de guardia para acudir al lugar de trabajo en cualquier momento y evaluar un accidente, realizar primeros auxilios si son necesarios, brindar asesoramiento e ir al hospital si se requiere. La compañía de servicios de seguridad también realizará visitas al sitio de trabajo si se necesita atención adicional. Su objetivo es brindar atención rápida y efectiva, pero hacer que el empleado vuelva al trabajo lo antes posible. Esto está en contraste con una clínica que brinda la misma atención y luego simplemente programa una visita de seguimiento para una o dos semanas más tarde. La forma más efectiva de limitar los costos de los accidentes es minimizar los costos indirectos. Esto incluye encontrar formas en las que el trabajador que está cubriendo al trabajador accidentado, pueda realizar un papel productivo en la cuadrilla (por ejemplo, sostener una señal de alto por un par de días en lugar de una pala), capacitar al personal de la cuadrilla para que otros puedan intervenir rápidamente y efectivamente, llenar la documentación y ser proactivo en la investigación del accidente con OSHA. El manejo de los costos, especialmente los costos indirectos, es esencial para minimizar el impacto de cualquier accidente.

Ahora las buenas noticias. Según el Consejo de Seguridad Nacional, por cada $1 que las compañías invierten en la prevención de accidentes, reciben de $2 a $6 en retorno. Esto demuestra que, con inversiones inteligentes en capacitación y equipos, existe un gran retorno de la inversión. Los primeros tres pasos en los que se centran la mayoría de las empresas para reducir los riesgos de accidentes son a través de controles administrativos, controles de ingeniería y equipo de protección personal (EPP). Sin embargo, a veces la forma más efectiva de reducir la tasa de accidentes es a través de un cambio cultural. Si los trabajadores ven cualquier cambio en seguridad como otro papel para llenar u otro elemento que deben usar, entonces los cambios de seguridad no serán efectivos y se verán rápidamente como la última moda. Si los cambios de seguridad son parte de la cultura y los empleados ven su papel en la seguridad, entonces se pueden ver los ahorros reales.

CONCLUSIONS

In the end, safety does pay. The primary goal is to get employees home every day to their families, but a safe jobsite can also make a company more profitable. Any injury is a tragic event and must be taken very seriously to make sure that it does not happen again. When an injury does occur, the employee must be properly but effectively treated. Injuries are expensive but must be managed properly to minimize their impact. If not managed properly, accidents and the resultant costs can destroy a company. Safety is the right thing to do for your employees. It is also the smart thing to do for your company's bottom line.

Table 1: Injury Cost Calculation

Direct Cost of Injury	Assume a light to moderate injury	$30,000
Indirect Cost of Injury	Assume a very conservative 2x effect	$60,000
True Cost of the Injury	—	$90,000
Profit Margin of Company	—	10%
Revenue Required to Offset Injury	—	$900,000

Jason Myers *received his bachelor's degree in civil engineering from California Polytechnic State University, San Luis Obispo, CA, and his MBA with an emphasis in project management from Golden Gate University, San Francisco, CA. Myers started his professional career working for an earth retention subcontractor where he learned the importance of budgeting, scheduling, and client relationships. Also, during this time he was introduced to the use of shotcrete and its applications. After working for a General Contractor for a couple of years he realized that he enjoyed the tighter knit of working for a subcontractor and the ability to construct multiple projects on a tighter timeframe. Myers also enjoys the process of handling most of the procedures that go into constructing a project rather than seeing only a small portion of the process. Myers joined Dees Hennessey in 2004 and has been a part owner of the company since 2007. He currently serves as the Vice President of Operations as well as the Safety Director.*

CONCLUSIONES

Al final la seguridad sí paga. El objetivo principal es regresar a los trabajadores a sus hogares todos los días, sanos y salvos, pero un lugar de trabajo seguro también puede hacer que una empresa sea más rentable. Cualquier accidente es un evento trágico y debe tomarse las medidas necesarias para asegurarse de que no vuelva a suceder. Cuando ocurre un accidente, el trabajador debe ser tratado de manera adecuada pero efectiva. Las lesiones son costosas, pero deben manejarse adecuadamente para minimizar su impacto. Si no se manejan adecuadamente, los accidentes y sus costos resultantes pueden quebrar a una empresa. La seguridad es lo correcto para todos. También es lo más inteligente que puede hacer para los resultados de su empresa.

Tabla 1: cálculo del costo del accidente

Costos directos del accidente	Supongamos una lesión leve a moderada	$30,000
Costos indirectos del accidente	Supongamos un porcentaje muy conservador 2x	$60,000
Costos reales del accidente	—	$90,000
Margen de utilidad de la compañía	—	10%
Ingresos requeridos para compensar lesiones	—	$900,000

Jason Myers *recibió su licenciatura en ingeniería civil de la Universidad Politécnica Estatal de California en San Luis Obispo, California, y su maestría en administración de empresas con énfasis en gestión de proyectos de la Universidad Golden Gate, San Francisco, California. Myers comenzó su carrera profesional trabajando para un subcontratista de Estabilización de suelos donde aprendió la importancia del presupuesto, la programación y las relaciones con los clientes. Además, durante este tiempo aprendió del uso de concreto lanzado y sus aplicaciones. Después de trabajar para un contratista general durante un par de años, se dio cuenta de que disfrutaba el trabajo más estrecho de trabajar para un subcontratista y la capacidad de construir múltiples proyectos en un plazo más corto. Myers también disfruta el proceso de manejar la mayoría de los procedimientos que se utilizan para construir un proyecto, en lugar de ver solo una pequeña parte del proceso. Myers se unió a Dees Hennessey en 2004 y ha sido uno de los dueños de la compañía desde 2007. Actualmente se desempeña como Vicepresidente de Operaciones y Director de Seguridad.*

SHOTCRETE FAQs

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

Question: *Shotcrete is very rarely used in Belize. I am building a new home and purchased a shotcrete machine to apply exterior finishes to houses, and most importantly to my new pool. A very good contractor here (who has built many hand-plastered pools) has told me that we cannot use shotcrete in Belize because of the type of sand that we have. Is this true? Can the consistency of the sand make it impossible to use shotcrete?*

Answer: Shotcrete is a placement method for concrete. If the sand can be used for concrete, it should be acceptable for shotcrete placement. To some extent, the type of shotcrete equipment may make a difference. If shooting wet-mix shotcrete, the concrete mixture must be able to be pumped. For pumpability, we do recommend a smooth gradation of the fine aggregate. If shooting dry-mix shotcrete, the sand gradation has much less effect, and you should be able to shoot most any sand in your concrete mixture.

Question: *I am looking through Chapter 20 of ACI 350-06, "Code Requirements for Environmental Engineering Concrete Structures and Commentary," and I don't see any suggested methods for repair—only that the structure (or any repair) must meet specified criteria (strength, load testing, etc.) for serviceability. I am trying to find some reference allowing shotcrete to be used to reestablish the thickness of an existing structure that has inadequate cover over reinforcement. Can you provide any guidance?*

Answer: The ACI 350 Code doesn't really cover repair in detail because it is more about new environmental structures. Shotcrete is concrete; it provides excellent bond to properly prepared concrete substrates and it inherently creates a composite section with the existing concrete that acts monolithically. The supplemental shotcrete could be considered an additional layer of concrete that acts monolithically and thus provides the needed concrete cover. Reference-wise, you could refer to the article "Shotcrete Placed in Multiple Layers does NOT Create Cold Joints" in the *Shotcrete* magazine archive, as it discusses the bond issue between layers (**Shotcrete.org/ArchiveSearch**). There are research papers that discuss a 200 psi (1.4 MPa) bond shear stress is needed for a bonded concrete overlay to act monolithically, and that bond pulloff (tensile) test results should be multiplied by 2 or 3 to represent the bond shear capacity. Because we typically well exceed a 145 psi (1.0 MPa) tensile bond pulloff strength, properly applied shotcrete will easily exceed the 200 psi requirement for the bond to act monolithically.

An additional factor in providing additional cover with shotcrete is that shotcrete has very cement-rich paste, along with low permeability, and thus provides a better alkaline environment to combat corrosion of embedded reinforcement, so is effectively giving even better cover than normal form-and-pour concrete.

Question: *Surely you are aware of the recent OSHA regulations regarding Respirable Crystalline Silica (RCS). Does ASA have any information about typical levels of RCS generated during indoor shotcreting? Do you have any recommendations for an apparatus to test levels to ensure safety of our workers and OSHA compliance?*

Answer: ASA has closely followed the development of the new OSHA rules for a couple of years before they were put into effect. You can find several articles in *Shotcrete* magazine that specifically address the rules in consideration of shotcrete application. In the Summer 2016 issue, an article,

"OSHA's New Crystalline Silica Rule–Potential Impact on Shotcrete Operations" (**Shotcrete.org/ArchiveSearch**), addressed many of the concerns. Unfortunately, with the wide variety of shooting conditions, there are no generic values. The reason for this is that the levels can vary significantly due to a variety of factors, including:

1. The materials used—this includes comparing wet-mix to dry-mix and the variations in variability of concrete mixture design ingredients (for example, silica fume, fly ash, and accelerator).
2. Equipment
   a. Dry-mix gun type (rotary or chamber), using a predampener or not (type of wet-mix pump likely doesn't make much difference)
   b. Size of air compressor (more air might result in more dust)
   c. Delivery line and hose (1.5 in. [40 mm] hose versus 2 in. [50 mm]) can change volume of flow, and then level of acceleration and nozzle stream dispersion as a function of air volume)
   d. Nozzle type can significantly affect the material stream
3. Shooting location (inside or enclosed, or open air)

With so many variables it is difficult, if not impossible, to get any reliable "generic" number for shotcrete as a whole. Many of our shotcrete contractors are using air quality consulting firms or testing labs who have the monitoring equipment. You may want to note that silica fume is amorphous silica, not crystalline, so it is not hazardous. Most exposure to crystalline silica is through sawing, cutting, or grinding of hardened concrete. We expect that most shotcrete contractors will need to establish a reliable, accurate level by on-site testing because shotcrete is not directly covered in Table 1 of the OSHA rule.

Question: *I'm not satisfied with my subtrades blowout procedures for the shotcrete lines. I'm not an expert in this; however, the way they are doing it does not look safe. I've tried to Google and reach out to other shotcrete companies but have not had any luck. They use a hopper that concrete is pumped into and is disbursed through lines that are moved manually; this step is normal. But when they have a blockage or cleaning the line when done, they have two workers sit on the end. They use compressed air. There must be a better way to clean and clear a blockage than having human bodies as weights. Please give me some guidance.*

Answer: ASA's "Safety Guidelines for Shotcrete" specifically addresses hose blockages. Use of compressed air to clear blockages or for cleaning the lines is not recommended. The Guidelines state:

> "With the variety of shotcrete material delivery systems available, and their placement on individual job sites, the Contractor should establish site-specific safety procedures applicable to the specific delivery systems and site conditions for blockage removal. Any field procedures for clearing blockages should not use compressed air as means to remove or dislodge blockages."

Using water to clear blockages or the delivery lines when finishing shooting is the recommended procedure. However, if compressed air is used, the hose end must be securely fastened with a substantial fastening system that can routinely and safely handle the forces created if the concrete is discharged explosively. Shotcrete contractors have developed cleanout bins that clamp the hose end into a heavy steel tank and collect the waste concrete from the line for disposal. Others have created clamps that firmly hold the end of the hose to a loader bucket or other heavy piece of equipment, thus depending on the weight of the equipment to hold the hose end. Simply having two people sitting on the hose end is not safe and can result in injury to crew members. Even when holding the hose end with a clamping system on heavy equipment, clearing the line can cause an explosive discharge of concrete with material flying in a wide path from the hose. Unless planned for and contained, the material stream can hit adjacent workers, facilities, equipment, and vehicles.

BASF LAUNCHES SERIES OF "ON-THE-JOB" APPLICATION VIDEOS

BASF released application videos for 39 Master Builders Solutions brand products, including joint sealants, wall coatings, sealers, and primers. All videos are 2 minutes or less and provide contractors with an easy way to view application techniques with a smartphone while on the jobsite.

"We created these videos based on our customers' feedback," said Christopher Perego, Industry Sector Manager for BASF. "Contractors are under a lot of pressure to deliver projects on time, on budget, and at a high level of quality. These videos allow them to quickly view best practices when on a jobsite, to help ensure a successful application."

The videos complement the product technical data guide by visually illustrating proper techniques. The complete series of videos can be accessed at **www.master-builders-solutions.basf.us/en-us/about-us/news/on-the-job-application-videos**. For more information, call (800) 526-1072 or visit **www.basf.com**.

CTS CEMENT AND CONCURE SYSTEMS PARTNER TO ENHANCE PERFORMANCE FOR CONCRETE FLOOR SLAB DESIGNS

CTS Cement Manufacturing Corp. announced a partnership with Concure Systems to enhance performance in moisture protection and Komponent® shrinkage-compensating jointless floor slabs.

For jobs that specify moisture-sensitive floor coverings or seamless flooring systems, the partnership combines integral moisture mitigation; 90 to 95% fewer joints; and dimensional stability that prevents shrinkage cracking, spalling, and edge curling.

Integrating these two technologies allows users to minimize or eliminate control joints and saw-cutting, prevent joint-related flooring failures, and eliminate topical moisture remediation systems. This solution can eliminate delamination concerns for moisture-sensitive floor coverings or resinous floor systems and prevent reflective cracking and costly joint failures—all while improving operational efficiencies and overall aesthetics.

For more information, call CTS Cement at (800) 929-3030 or visit **www.ctscement.com**, or Concure Systems at (480) 820-7171 or visit **www.concuresystems.com**.

QUIKSPRAY U-BLEND MIXER

Quikspray® has created a new lid for its U-Blend™ Mixer to help reduce dust on jobsites. With the new crystalline silica dust concerns, this lid will help minimize contaminates in sensitive environments. A vacuum port can be added to further eliminate dust.

The U-Blend Mixers are capable of mixing epoxy grouts; heavily bodied materials; regrouting mortar joints; and also spraying fireproofing, waterproofing, EIFS, artificial rock work, stucco, and other commercial coatings. Equipment is available in electric, pneumatic, and hydraulic. For more information, call (419) 732-2611 or visit **https://quikspray.com**.

BLASTCRETE EQUIPMENT'S REFRACTORY PADDLE MIXER

Blastcrete Equipment's Refractory Paddle Mixer provides fast mix times while working with mixtures that include aggregates up to 0.5 in. (13 mm) thick. The hydraulic machine mixes as much as 500 lb (230 kg) of refractory castable in 1.5 to 2 minutes and performs well in form-and-pour applications and other projects involving precast shapes, mortars, and grouts.

The Refractory Paddle Mixer's oversized, heavy-duty, chain-and-sprocket drive system can provide years of use in harsh conditions. It also features a pair of easily accessible levers to control the hydraulic dump and operate the system in both forward and reverse.

Users can pair the 1900 lb (860 kg) machine with a variety of electric power options for safe indoor use. Users can select between three electric motors—a 10-horsepower (7.5-kilowatt) electric motor with starter disconnect, a 240- or a 480-volt, 60-hertz motor, or a 380-volt, 50-hertz motor. In addition, users can choose to power the Paddle Mixer with a 14-horsepower Kohler gas engine.

The 4 ft (1.2 m) wide Refractory Paddle Mixer's trailer features a single axle for easy towing, or it can be skid-mounted.

Users can use the Paddle Mixer with Blastcrete's Dust-Away system, which consists of a bulk bag design that attaches to the mixer to contain dust as the mixer fills.

For larger refractory jobs, Blastcrete also offers a 1000 lb (450 kg) refractory paddle mixer-pump, the RMX-5000, and a Refractory Pan Mixer that can mix as much as 2200 lb (1000 kg) in less than 2 minutes.

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

SHOTCRETE CALENDAR

DECEMBER 2-5, 2018	**ASTM International Committee C09, Concrete and Concrete Aggregates** Washington Hilton | Washington, DC **www.astm.org**
DECEMBER 3-7, 2018	**AEMA's 2018 Annual Meeting, Exposition, and Short Courses** Washington Hilton | Washington, DC **www.miningamerica.org**
JANUARY 22, 2019	**ASA Shotcrete Nozzleman Education** at WOC English OR Spanish class Las Vegas Convention Center | Las Vegas, NV **www.shotcrete.org/WOC**
JANUARY 22, 2019	**ASA General Membership Meeting and (New) Shotcrete Reception** at WOC Las Vegas Convention Center | Las Vegas, NV **www.shotcrete.org/WOC**
JANUARY 22-25, 2019	**World of Concrete** Las Vegas Convention Center | Las Vegas, NV **www.worldofconcrete.com**
JANUARY 23, 2019	**Concreto Lanzado Problemas y sus Causas y Métodos de Reparación** Las Vegas Convention Center | Las Vegas, NV **www.shotcrete.org/WOC**
JANUARY 23, 2019	**ASA Contractor Education Course** at WOC Las Vegas Convention Center | Las Vegas, NV **www.shotcrete.org/WOC**
JANUARY 24, 2019	**Advanced Shotcrete: Innovative Techniques for Architectural & Structural Projects** Las Vegas Convention Center | Las Vegas, NV **www.worldofconcrete.com**
JANUARY 23-24, 2019	**ACI Wet-Mix Certification** Written Exam – Wednesday | Performance Exam – Thursday Hydro-Arch | Henderson, NV **www.shotcrete.org/WOC**

JANUARY 29-31, 2019	**The Pool & Spa Show 2019 (NESPA)** Atlantic City Convention Center | Atlantic City, NJ **www.thepoolspashow.com**
FEBRUARY 24, 2019	**ASA Contractor Education Seminar at the Shotcrete Convention** Omni Amelia Island Plantation Resort | Fernandina Beach, FL **www.shotcrete.org/convention**
FEBRUARY 24-26, 2019	**ASA 2019 Shotcrete Convention and Technology Conference** Omni Amelia Island Plantation Resort | Fernandina Beach, FL **www.shotcrete.org/convention**
FEBRUARY 25-26, 2019	**ASA Spring 2019 Committee Meetings at the Shotcrete Convention** Omni Amelia Island Plantation Resort | Fernandina Beach, FL **www.shotcrete.org/convention**
FEBRUARY 26, 2019	**ASA Outstanding Shotcrete Project Awards Banquet at the Shotcrete Convention** Walker's Landing | Fernandina Beach, FL **www.shotcrete.org/convention**
MARCH 12-13, 2019	**NY Build 2019 Expo** Javits Center | New York City, NY **www.newyorkbuildexpo.com**
MARCH 24-28, 2019	**The ACI Concrete Convention and Exposition – Spring 2019** Theme: "Nordique Concrete" Québec City Convention Centre and Hilton Quebec Québec City, QC, Canada **www.concrete.org**
APRIL 8-10, 2019	**ICRI Spring Convention** Theme: "Waterproofing with Aesthetics" Omni Hotel & Resorts Jacksonville | Jacksonville, FL **www.icri.org**
MORE INFORMATION	**To see a full list with active links to each event, visit www.shotcrete.org/calendar.**

2019 *SHOTCRETE* MAGAZINE MEDIA KIT NOW AVAILABLE

Grow your business by investing your marketing dollars through advertising in ASA's *Shotcrete* magazine.

Shotcrete magazine is the only international magazine focused exclusively on the shotcrete industry. Our magazine covers all aspects of the shotcrete market and highlights our shotcrete advances and achievements—from recognizing outstanding projects, to reports on shotcrete research, to articles exemplifying the state-of-the-art of shotcrete placement. Each issue of *Shotcrete* magazine has a readership of over 17,000 subscribers in over 100 countries.

2019 themes include:

- Winter – 2018 Awards
- Spring – Repair/Retrofit/Repurposing
- Summer – Dams/Water Structures
- Fall – Inspection/Testing

Your advertisement in *Shotcrete* magazine will reach the decision makers that you need to grow your business while also supporting ASA. The cost to advertise in *Shotcrete* magazine is competitive, with an average savings of 25% or more compared to other leading trade association magazines. For more information, rates, and deadlines, visit **www.shotcrete.org/media/pdf/ASAMediaKit.pdf**. Questions and insertion orders can be sent to Lacey Stachel, ASA Editorial and Marketing Manager, at lacey.stachel@shotcrete.org or (248) 848-3736.

ASA AT WORLD OF CONCRETE 2019

World of Concrete (WOC) 2019 will be held January 22-25, 2019, at the Las Vegas Convention Center, Las Vegas, NV. A longtime co-sponsor of this industry event, ASA will be exhibiting at South Hall #S11038 and hosting several events and seminars. Register now using ASA's Source Code: **A17** for $25 exhibits-only admission, lowest price available at **www.compusystems.com/servlet/ar?evt_uid=181&PromoCode=A17**.

Join ASA for its annual Membership Meeting to hear updates on Association activities and new appointments on January 22 at 4:30 p.m. Attendees are encouraged to stay afterward to network with industry professionals and enjoy hors d'oeuvres and beverages at the ASA-hosted reception (NEW). Your exhibits-only pass will gain you admittance into this event.

ASA Shotcrete Nozzleman Education Class | WOC Registration Code: English–**ASATU**; Spanish–**ASASTU**

ASA's Shotcrete Nozzleman Education Class will be available on January 22 at WOC in both English and Spanish. This 7-hour program is a requirement for all nozzlemen who wish to pursue certification as an ACI Shotcrete Nozzleman through ASA. It also provides a great overview of the shotcrete process for owners, contractors, and project managers. Registration includes the required CP60 "Craftsman Workbook for ACI Certification of Shotcrete Nozzleman" (available in English or Spanish) and a complimentary 1-year ASA Nozzleman membership. Attendees registering for this course will also be required to sign up for an Exhibits-Only Pass. Please note this class alone will not result in certification.

ACI Wet-Mix Certification

Individuals who have 500 hours of shooting experience may pursue certification, however, 25 hours of shooting experience will allow individuals to pursue a nozzleman-in-training designation. Both a written exam and performance exam(s) are required. Written exams will be offered at the Las Vegas Convention Center on Wednesday, January 23, 2019. ASA is working in conjunction with Hydro Arch, Henderson, NV, to provide an opportunity on January 24 to those who wish to complete their ACI Wet-Mix Certification or shoot their performance panels for re-certification. Those certifying for the first time are required to attend the ASA Education class. Spots are limited—so secure a spot by sending in your full payment and work experience forms directly to Hydro Arch as soon as possible, but no later than January 3, 2019. Contact Hydro Arch directly at (702) 280-9332.

Shotcrete Problems, Their Causes and How to Repair Them (presented in Spanish) | WOC Registration Code: **CICLWE**

Concreto Lanzado Problemas y sus Causas y Métodos de Reparación | WOC Course Code: **CICLWE**

The College of Civil Engineers of de León brings one of the best international instructors of shotcrete to teach this course. Learn to identify the origin of the problems, their causes, and how to repair them in both dry-mix and wet-mix shotcrete applications. This class will be beneficial for the shotcrete nozzlemen as well as those involved in the inspection, quality control, application, and finishing of shotcrete.

El colegio de ingenieros civiles de león trae a uno de los mejores instructores internacionales de concreto lanzado a para impartir el curso con la finalidad de aprender a identificar el origen de los problemas y sus causas en el concreto lanzado, tanto vía seca como vía húmeda, y como repararlo, está dirigido a lanzadores de concreto y personas relacionadas con la inspección, control de calidad, aplicación, acabado del concreto lanzado.

Attendees will learn how to identify common problems of shotcrete—summarized in five main causes: Design problems; Planning problems; Problems with materials (type of cement, mixture design, quantity of materials); Problems during application and finishing; and Problems during the service life of the concrete (and best options for repairing).

En el curso se tratarán los orígenes de los problemas del concreto lanzado, como identificarlos y poder llegar a su causa raíz la cual se puede resumir en cinco causas principals: Problemas de diseño; Problemas de planeación; Problemas con los materiales; Problemas durante la colocación y acabado; y Problemas durante la vida de servicio.

The book *Shotcrete Problems and Their Causes* (written in Spanish) is included with the course registration fee.

El libro *Problemas y sus Causas en el Concreto Lanzado* (en español) está incluido con tu inscripción.

ASA Shotcrete Contractor Education | WOC Registration Code: ASAWEX (with reference materials and exam); ASAWE (seminar only, no materials or exam)

This seminar is intended for the existing shotcrete contractor pursuing ASA Shotcrete Contractor Qualification. However, concrete contractors interested in learning more of the details and requirements for quality shotcrete placement of structural concrete will also find the seminar highly beneficial. Although a concrete contractor may be thoroughly experienced in form-and-pour concrete construction, shotcrete has fundamentally different equipment, material selection, crew responsibilities, application techniques, testing, curing, and protection that need to be considered for producing high-quality and durable shotcrete. This course provides "best practices" for the shotcrete contractor looking to grow and increase productivity and quality in their shotcrete applications.

This seminar provides a thorough knowledge of shotcrete placement for concrete construction, including logistics (site and project), environmental requirements, safety, crew requirements, shotcreting equipment, concrete mixture design, QA/QC, surface preparation, formwork, reinforcements, embedments, placement, finishing, curing, and protection.

References ACI/ASTM documents provided with the seminar include:

- ACI 506.2-13, "Specification for Shotcrete;"
- ACI 506R-16, "Guide to Shotcrete;" and
- Seven ASTM/shotcrete-related testing standards compiled in one reference document.

Those qualifying individuals pursuing ASA Contractor Qualification for their company who attend the 7-hour course will need to take a 90-minute written exam at the end of the seminar. More information about the ASA Contractor Qualification Program can be found at **www.shotcrete.org/pages/education-certification/cq-program.htm**.

Advanced Shotcrete: Innovative Techniques for Architectural and Structural Projects | WOC Registration Code: TH150

Marcus von der Hofen and Frank Townsend will present advanced topics and case studies in shotcrete placement for new concrete construction. This seminar will also address building heavily reinforced, thick monolithic concrete sections with multiple layers of shotcrete in addition to a discussion of shotcrete enhanced bond to existing substrates or between newly shotcreted sections. Discussions will cover challenges in shotcreting applications and methods for selecting materials, placing and finishing the wide variety of architectural shotcrete.

For more information on ASA events at WOC, visit **www.shotcrete.org/WOC**.

2019 ASA SHOTCRETE CONVENTION & TECHNOLOGY CONFERENCE

SHOTCRETE CONVENTION & TECHNOLOGY CONFERENCE

February 24-26, 2019 | Fernandina Beach, FL

ASA is proud to host its second Shotcrete Convention & Technology Conference, at the Omni Amelia Island Plantation Resort, in Fernandina Beach, FL, February 24-26, 2019. The 2-day Shotcrete Convention will feature 18 technology conference presentations, providing attendees the opportunity to explore shotcrete applications and innovations as well as future advancements in the industry. Attendees will have an opportunity to vote on two encore deliveries of presentations missed due to conflicts with competing presentations.

ASA Spring Committee Meetings will also be featured at the Shotcrete Convention, replacing the Spring 2019 Committee Meetings at ACI Concrete Convention and Exposition – Spring 2019 in Québec City, QC, Canada. All ASA Committees will be meeting along with the ACI 506-H, Pool Subcommittee, and an ACI C660, Nozzleman Certification Committee, special work session.

The 14th annual Awards Banquet will be the highlight event as we recognize those who help raise the bar to outstanding shotcrete work in the industry. The 2018 Outstanding Shotcrete Project Award winners will be announced and celebrated at nearby Walker's Landing Tuesday evening, February 26.

Networking opportunities will be available during meals, breaks, and exhibit hours included with registration as well as optional fun activities including group golf outing on the Omni's Championship Golf Course, Oak Marsh; deep sea fishing; and group tennis clinic at Omni by Cliff Drysdale Tennis, named the "No. 2 Tennis Resort on Florida's East Coast."

Sunday's pre-convention opportunities include ASA's Contractor Education Seminar and several fun networking events taking advantage of Amelia Island's exceptional destination venue. The conference kicks off with a Sunday evening Dessert Reception and Industry Mixer.

Sponsorships and exhibit opportunities include Gold and Silver Sponsorships with opportunities for complimentary tabletop exhibits as available, or distribution of materials at ASA's registration table if not exhibiting. Gold Sponsors will have priority exhibiting privileges until January 2, 2019. Exhibiting opportunities open to Silver Sponsors after January 2, 2019 as available.

Reservations at The Omni Amelia Island Plantation Resort are now open at **www.omnihotels.com/hotels/amelia-island-plantation/meetings/asa-shotcrete-association**. Please make your reservations as space is limited. For full Shotcrete Convention details and to register, visit **www.shotcrete.org/convention**. You'll also find more details in the four-page insert (see pp. 37-40) in the middle of this issue of *Shotcrete.*

ASA FALL 2018 COMMITTEE MEETINGS

ASA saw a great turn out at the Fall Committee Meetings held in Las Vegas, NV, on October 13, 2018. All meetings were well attended with each committee advancing on its goals and objectives as outlined in ASA's Strategic Plan. Committee Chairs will transition to a quarterly reporting structure to the Executive Committee and Board of Directors on the progress of its work in between face-to-face meetings. Some notable changes in committee work include transition of leadership of two committees. Tait Pirkle will serve as Chair of the Marketing Committee, replacing Joe Hutter, and Mason Guarino will serve as Chair of the Pool and Recreational Shotcrete Committee, replacing Bill Drakeley. Pirkle began his term at the end of the 2018 Shotcrete Convention & Technology Conference and Guarino began his term at the conclusion of the ASA Fall Meetings. Additionally, the Publications Committee, whose original role is now primarily managed by ASA staff was officially disbanded after these meetings. ASA thanks Joe Hutter, Bill Drakeley, and Ted Sofis for their leadership and efforts serving as the respective Chairs for these Committees over these past many years! ASA would not have come this far without your dedication!

SHOTCRETE MAGAZINE TO INCORPORATE SPANISH TRANSLATED ARTICLES

ASA is pleased to announce that starting with this issue (see pp. 54-57) *Shotcrete* magazine will include one article fully translated into Spanish. ASA would like to acknowledge ASA member Raul Bracamontes for his efforts of providing the translations to ASA staff.

ASA STUDENT OUTREACH

ASA offers university students—from engineering or construction management programs—a complimentary Introduction to Shotcrete seminar. Professors or student chapter leaders who are interested in this program should contact ASA staff at info@shotcrete.org or (248) 848-3780 for more information or to schedule a seminar.

THE POOL & SPA SHOW 2019

The Pool & Spa Show 2019 will be held at the Atlantic City Convention Center the Atlantic City, NJ, January 29-31, 2019. ASA Past President Bill Drakeley will be speaking at the session, "Shotcrete Uncovered." Industry experts will take attendees through both the right ways and the wrong ways to prepare, shoot, and finish a shotcrete pool shell. Through a hybrid of in-person training, as it happened multi-media presentations and interaction with real-world concrete cross-sections, this program will provide a thorough understanding of how quality concrete pools get built. For the session details, visit **https://s23.a2zinc.net/clients/nespa/nespa2019/public/SessionDetails.aspx?FromPage=Sessions.aspx&SessionID=480&SessionDateID=21**. For full show details, visit **www.thepoolspashow.com**.

NY BUILD 2019

NY Build 2019 will be held at the Javits Center in New York, NY, March 12-13, 2019. ASA will have two presentations: Advanced Shotcrete, presented by Frank Townsend and Bill Drakeley, ASA Past President; and Architectural Shotcrete, present by Charles Hanskat, ASA Executive Director. Dates and times are TBD. For more information, visit **www.newyorkbuildexpo.com**.

LETTER TO THE EDITOR

The "History of Wire-Wrapped Circular Prestressed Concrete Tanks" published in the Fall 2017 edition of *Shotcrete* magazine generated the following comments from a reader. The authors reviewed and agree the clarifications are valid.

1. Last sentence of the second to last paragraph should read, "Diameters range up to 450 ft (140 m) and with wall heights up to 100 ft (30 m)." The revised numbers represent the largest tank sizes most recently constructed.
2. First sentence of the last paragraph should read "Today, four companies…over 9000 prestressed concrete tanks worldwide over the past 75 years." This will match the information published in ACI 372R-13, "Guide to Design and Construction of Circular Wire-and-Strand-Wrapped Prestressed Concrete Structures."
3. Last sentence of the last paragraph should read "Although equipment and construction techniques… the same design principles initiated by J.M. Crom and the Preload Company in 1941." This will match the information published in ACI 372R-13 and provide the necessary recognition to the merits and innovations J.M. Crom brought to the industry outside his direct involvement Preload.

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CONCRETE INDUSTRY MANAGEMENT ANNOUNCES NEW COHORT FOR EXECUTIVE MBA PROGRAM

The Concrete Industry Management (CIM) program is accepting applications for the next cohort beginning in January 2019 for the MBA degree in CIM, offered through the Jennings A. Jones College of Business at Middle Tennessee State University (MTSU).

Administered in 7-week blocks, the format for the 15-month program includes distance learning, webinars, and two on-campus visits to MTSU. The distinctive partner structure is designed for networking and sharing experiences, while fostering a collaborative learning environment. The $25,000 fee represents the total academic cost of the program per participant, except for books. Applications for the next cohort are due by October 1, 2019.

Professionals participating in the CIM MBA program must have a minimum of 3 years of experience in the concrete industry. Academically, all participants must have at least an undergraduate degree from an accredited institution of higher education. While participants must have at least a bachelor's degree, that degree does not have to be in business.

The MBA program's major themes include globalization, leadership, strategy, and execution. The curriculum takes participants beyond basics to a true understanding of forces that will shape the concrete and construction industry. Course content has been tailored to reflect on the issues important to managers and executives in the concrete industry. Because of the distance learning aspect of the program, candidates pursuing this degree can continue in their full-time employment responsibilities.

To submit an application, visit **www.mtsu.edu/graduate**. For more information, call (615) 904-8060 or visit **www.concretedegree.com**.

VMMB VOLUMETRIC MIXER OPERATOR CERTIFICATION PROGRAM

Cemen Tech, a charter member of the Volumetric Mixer Manufacturers Bureau (VMMB), announced VMMB has created its first Volumetric Mixer Operator Certification Program. The certification program's goal is to increase professionalism of volumetric mixer operators and also provide proof of industry-specific knowledge and competencies in the fields of product knowledge, volumetric mixer safety, machine operations, and customer relations.

According to Jerry Gaubert, VMMB Chairman, "This program can also be used to provide volumetric mixer operators a career path, improve customer service skills, as well as improve a company's image, and the image of the entire volumetric mixer industry."

The Volumetric Mixer Operator Certification Program consists of in-depth and industry-specific topics, each of which is presented in a workbook based on a nationally agreed upon standard of knowledge and skills every professional volumetric mixer operator should know.

Volumetric Mixer Operator Certification is achieved through required experience and completion of an examination. The program was developed by the members of VMMB and is administered by the National Ready Mixed Concrete Association (NRMCA). For more information, visit **http://vmmb.org/certifications.html**.

CPI FOUNDATION AND ENGINEERED RESTORATIONS, INC., SUPPORT TRANSITIONING MILITARY SERVICE MEMBERS

Engineered Restorations, Inc., and the nonprofit CPI Foundation (the Concrete Preservation Institute) announced that they joined forces to prepare active-duty service members for civilian careers in the concrete infrastructure industry.

Participating in 12-week field schools, soon-to-be veterans are trained in classroom curriculum and hands-on

projects repairing concrete landmark structures at Alcatraz Island, CA, and Pearl Harbor, HI. The program helps active-duty participants get ahead of the veteran-to-civilian transition curve and avoid unemployment and underemployment.

"We provide valuable career development opportunities for our deserving service members and train the critically needed workforce for the concrete industry facing a shortage of skilled tradespeople and managers required to build and fix our country's infrastructure," said CPI President and CEO Tanya Komas. "Engineered Restorations' support of CPI is a win-win-win public-private partnership: preparing transitioning service members for rewarding civilian careers; providing workforce for industry; and completing deferred maintenance projects that may not otherwise be completed on National Park Service sites with irreplaceable cultural heritage."

CPI holds three 12-week, full-time sessions per year at both Pearl Harbor and Alcatraz Island. Service members remain on active duty while training, receive hands-on technical and management skills, and can earn professional certifications upon passing examinations. CPI then connects candidates with industry employers, who actively seek to hire qualified individuals in concrete repair, new construction, material production, transportation, business, sales, operations, safety, and other construction-related areas.

"Our partnership with CPI provides us with an exciting and structured means to engage active-duty military candidates who not only have the desire to enter the concrete infrastructure repair industry but also the necessary skills to be a valuable asset to our team from day one," said Engineered Restorations President Don Moore. "It has been our experience that military veterans possess an exceptionally strong work ethic, necessary problem-solving skills, a teamwork mentality, and willingness to do what is needed to get the job done. Concrete restoration requires a skilled touch and specific forethought necessary to avoid costly mistakes, all of which come from a typical day in the life of military personnel."

For more information, visit **www.cpi-foundation.org**.

Is your company an ASA Corporate or Sustaining Corporate Member? Submit your Industry News now for inclusion in the next issue of *Shotcrete* magazine to lacey.stachel@shotcrete.org.

KING Shotcrete Solutions

A Full-Service Solution for Your Shotcrete Needs

For over 30 years, the North American shotcrete industry has recognized the name KING as synonymous with quality and service. This reputation has been earned through years of manufacturing and supplying quality shotcrete mixtures on projects including concrete repair, tunneling, and in underground mines throughout the United States and Canada. Behind every bag of KING Shotcrete, stands a team of respected industry experts who understand shotcrete materials and the shotcrete process itself.

THE KSS TECHNICAL TEAM

Founded in 1986 with a small staff and one production plant, KING Shotcrete Solutions (KSS) is now a leader in the supply of shotcrete equipment and materials across North America. KING's strategy is to invest in the people and technology required to elevate the company from being just a supplier to a technical resource. The KSS Technical Team boasts a staff of more than 20 people—more than 10 of which are licensed professional engineers and have a strong understanding of shotcrete materials and equipment.

Fig. 1: KING's prepackaged shotcrete material is available in small bags weighing 66 lb (30 kg) or bulk bags weighing up to 3300 lb (1500 kg) that are marine-grade and water-resistant, allowing long-distance transportation in harsh climatic conditions

Fig. 2: KING RS-D2 UG is a rapid-hardening shotcrete material for dry-process applications. It greatly enhances shooting characteristics, providing reduced setting times and rapid strength development. This product is ideal for use in ground-support applications for mining, tunneling, and other underground operations

Understanding the intricacies of shotcrete mixture design allows KSS engineers to explain how variations in mixture design affect the plastic and hardened properties of shotcrete. Then, they can respond immediately when jobsite concerns arise. A strong knowledge of shotcrete equipment operation allows KING representatives to educate crews, troubleshoot shotcrete equipment issues, and recommend the most suitable equipment for wet- or dry-mix shotcrete operations.

R&D COMMITMENT

KING's commitment to research and development (R&D) has allowed the company to continuously improve the quality, consistency, and performance of its shotcrete mixtures. This commitment has resulted in several new products, including the RS line of rapid setting/rapid strength gain, shotcrete mixtures that provide numerous benefits, each of which depends on the shotcrete application.

KING RS-D2 Shotcrete provides the compressive strength values 2 to 3 hours after shooting that traditional accelerated shotcrete mixtures achieve after 3 days. The impact on the drill/blast/muck/shotcrete cycle is significant, as are the available cost-savings. Ground control engineers at one Northern Ontario mine specified an 8 to 10 hour waiting period after the application of shotcrete, before production miners could enter a heading to load the next round. After a successful trial of KING RS-D2, the miners were able to re-enter the heading only 3 hours after the shotcrete application. This resulted in the mine increasing production by more than one full round per week, which added significantly to the mine's production quota.

Another significant impact of KING's R&D commitment is the development and improvement of MS-W1 Shotcrete. In 2016, a research project designed to improve the dry- to wet-mix shotcrete process was undertaken. Its mandate was to develop a "wet-mix shotcrete on-demand" solution that would allow contractors to produce their own consistent, pumpable wet-mix shotcrete when they need it, without having to rely on availability of concrete from external, ready mixed suppliers. Partnering with a powdered-admixture supplier, KING's research engineers developed a prepackaged shotcrete material, which could be mixed on site and would only require the addition of water and accelerator.

The new version of MS-W1 could provide consistent, easily pumpable, wet-mix shotcrete with an 8 in. (200 mm) slump. A unique aspect of this product was its slump retention of up to 4 hours, providing civil shotcrete contractors the flexibility to stop and start like dry-mix shotcrete, and giving mining companies the ability to transport the mixture underground over long distances. This feature reduces the cost by optimizing the dosage for each type of application.

CUSTOM MIXTURES TO MEET UNIQUE CHALLENGES

Despite the wide range of readily available, "off the shelf" shotcrete mixtures, KSS understands that there are times when unique properties (either plastic or hardened) are required from shotcrete material. KSS engineers will develop and test custom mixtures that will meet the challenges to any project. A custom mixture can perform across a variety of different dimensions, such as faster set times, higher energy absorption, longer slump retention, lower shrinkage values, and other properties which can be modified through the addition of admixtures, fibers, pozzolanic materials, or different/replaced cement binders.

EXPANDING GEOGRAPHIC REACH

There was a time when production limitations and transportation challenges limited the geographic reach of KSS' products. An increased offering of high-performance products, along with several new production facilities, and more efficient transportation options have allowed KING to ship fully preblended shotcrete mixtures around the world.

Modified, water-resistant packaging systems were developed to protect materials from damage due to extended exposure and long-distance shipping. A recent overseas shotcrete supply contract that required the production of over 20,000 tonnes of prepackaged shotcrete material, was executed from the Boisbriand, QC, Canada production facility. This plant is close to many international shipping ports and has become the production plant of preference for export shotcrete shipments. This project was completed on time (during the busy season), despite limited lead-time. The material was loaded at The Port of Montreal, into the hull of a large ocean vessel, for shipment to a mine in Asia.

WHO IS KSE?

For many years, KING has operated a shotcrete/concrete equipment supply division (formerly known as Minequip, now known as King Shotcrete Equipment Canada) from its location in the Ontario mining region. The growth of this division, precipitated mostly by the demands of the North American mining markets, led the KING management team to investigate the option of creating a similar business that could service the equipment needs of its U.S. customer base.

A new location was established in Allentown, PA, which is known throughout North America as the birthplace of the modern-day shotcrete machine. Headed by Patrick Bridger, a former President of Allentown Shotcrete Technology, Inc., King Shotcrete Equipment Inc. (KSE) has grown to be a leading supplier of shotcrete and concrete, mixing and placing equipment throughout the U.S.

In this market, KSE is proud to be recognized as a distributor of equipment brands such as Aliva, Fiori, Normet, Putzmeister, Reed, and Terramin. In addition, KSE is also a full-stocking supplier of wear-parts, hoses, pipe, and other consumable components required by the shotcrete industry.

Employees have come to KING from all areas of the shotcrete industry. The core strength of the group is derived from a diverse cross-section of the market where employees bring varied experience from the fields of contracting, equipment supply and maintenance, as well as engineering. KSS understands all aspects of the shotcrete process and is proud to be part of the growing shotcrete industry!

Fig. 3: Over 20,000 tonnes of prepackaged shotcrete material was produced and released from KING's Boisbriand, QC, Canada, production facility. The material was loaded into the hull of a large ocean vessel for shipment

Fig. 4: KING Shotcrete mixtures are used to rehabilitate concrete structures. A project example of this is how MS-D1 was used for underside slab repairs on the Souligny Interchange in Montreal, QC, Canada

KING SHOTCRETE SOLUTIONS

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Neptune Coatings

A Member of The Harco Group

As the construction market continues to evolve, the push for tighter budgets and restricted schedules has made shotcrete a viable choice in lieu of form-and-pour applications to significantly reduce overall costs. Unfortunately, most of the traditional waterproofing products were not suitable for this application because of failures due to the impact pressure on the products during shotcrete application.

Neptune Coatings developed WetSuit®, "Disruptive Waterproofing Solutions," which reduces the potential of failure at seams and laps like traditional sheet systems. Neptune Coatings continues to work to gain certifications for its systems in the shotcrete market.

Fig. 1: Patented WetSuit spray equipment

WetSuit is a polymer-modified bitumen membrane that is cold fluid-applied. A zero-VOC, seamless and self-flashing monolithic membrane that is applied to horizontal, vertical, and blindside surfaces with superior adhesion, it provides a true waterproofing solution (less than 0.1 U.S. Perms/in.).

WetSuit 2 Part, the flagship product, is a two-component, instant-set water-based coating that is spray-applied using Neptune Coating proprietary equipment. It can be 80% cured in 3 seconds, providing the ability to build at any mil thickness in a single pass. With the capability of going over green concrete (using a specific primer) coupled with a high-production rate of about 1500 ft^2/h (140 m^2/h), the 2 Part system can shave days off a project.

WetSuit 1 Part is a self-leveling, single-component coating that can be sprayed, rolled, or brush-applied. With no need to reinforce, WetSuit can be applied in both vertical and horizontal substrates in a single pass and will be fully adhered and self-flashing, even in 90-degree angles.

In addition, WetSuit is available as a trowel grade and fiber-rated trowel for detailing. Undercover and primer are used for penetrations and surface preparation.

WetSuit's self-extinguishing Class A fire rating—combined with severe hail resistance, high-velocity wind uplift, more than 2000% elongation, UV stability, and the ability to resist ponding water—makes it not only faster but also stronger.

Neptune Coatings offers full warranty packages of up to 20 years for every application.

WetSuit is applied only by trained and certified applicators who have been gone through an extensive training

Fig. 2: WetSuit over a shotcrete created irrigation control system

Fig. 3: WetSuit application for below grade at T-Mobile Arena

Fig. 4: WetSuit system behind shotcrete and blindside application

Fig. 5: Soil retention also under blindside application

program with the company's proprietary spray equipment at its facility. Neptune Coatings' products and spraying equipment hold U.S. patents.

Neptune Coatings is interested in projects of any size and scope. Its global footprint allows the company the ability to assist in projects anywhere they are situated. Neptune Coatings is also looking to grow its applicator base. If you are interested in becoming a certified WetSuit applicator, please contact Neptune Coatings.

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american shotcrete association | asa

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ASA's recognized outreach and leadership in the shotcrete industry are driven by members sharing the interest of advancing the use of shotcrete

Shoot for new heights and become an ASA CORPORATE OR SUSTAINING CORPORATE MEMBER

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- STAY CURRENT on the latest shotcrete industry trends, strategies, challenges, and opportunities
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- Gain EXPOSURE through a variety of tools available to corporate members, such as a listing in the ASA Buyers Guide––enhanced for Sustaining Corporate Members
- INFLUENCE ASA's direction in serving members and growing the industry
- SAVE significantly on ASA products and services

Elevate 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

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

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