shotcrete
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MAGAZINE
VOLUME 22, NUMBER 4 • FALL 2020
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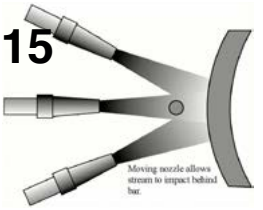
FEATURES

Y Not Try a Double Nozzle System

By Derek Pay



Position Statement #3 ASA Underground Committee

Encapsulation of Reinforcement in Tunnel Shotcrete Final Linings

Position Statement #4 ASA Underground Committee

Mechanical Application of Shotcrete in Underground Construction

The Value of VR Training for Today's Shotcrete Nozzlemen

By Matthew Wallace

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

American Shotcrete Association
25 Century Blvd, Ste 505
Nashville, TN 37214
Phone: 248.963.0210
E-mail: info@shotcrete.org
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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).

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Challenging Year, but Promising Future

By Ryan Poole

As we look back on 2020, many interesting and important things have happened to, and in, our Association. Primarily, after nearly two decades of operation using an ACI-affiliated association management service, ASA's growth and expansion necessitated a move to a firm whose management style and approach to association management were more in line with ASA's goals and ambitions. Our new association management firm, Virtual Inc, came on board just as the first impacts of the COVID-19 pandemic were beginning to be seen and felt. For the most part the changeover has gone smoothly due to the commitment, time, and efforts of ASA and Virtual staff.

Pivoting to an online format for both our Spring and Fall committee meetings in response to COVID-19 was also a big change for our Association. The fact that it came off relatively smoothly, was well attended, and accepted by the membership is again due mainly to the efforts of ASA staff. We trust that the lessons learned here will continue to benefit the Association as we accommodate the changing ways people work and the continued growth of our Association.

As a new year begins, I expect that the enhancements and efficiencies of working with the new association management firm will continue to support and extend the work of our Association to fulfill our mission - "provide knowledge resources, qualification, certification, education, and leadership to increase the acceptance, quality, and safe practices of the shotcrete

process." One of the new opportunities is The Art of Shotcrete, a new photo competition launched this Fall on Instagram by the Marketing Committee. The photo competition encourages shotcrete professionals to tag ASA in their photos to bring awareness to our industry. The top three photos each quarter are featured in Shotcrete magazine. Our first group of winners are featured in this issue. We hope this provides visual recognition of the great things that can be achieved with shotcrete!

Moving forward I am encouraged by the interest and level of participation in the ASA Qualified Contractor program. As can be seen on the website, we have several contractors who have completed the qualification program and are now ASA Qualified Contractors. There are an equal number of contractors that are in various stages in the qualification application process. As ASA Contractor Qualification becomes more prevalent, the value of qualification will increase exponentially, as we have seen with nozzleman certification. The Contractor Qualification program will continue to be an important initiative for ASA with the goal being that every shotcrete contractor member becomes a Qualified Contractor. I would like to encourage all of ASA's member shotcrete contractors who have not yet taken advantage of this program to review the professional benefits it will offer you and begin your qualification application as soon as possible. ASA is streamlining the online application to ease the overall submittal and review process. As a side benefit to those applying, the revised format lets you summarize much of your company's information in a package you can use in your bid submittals moving forward.

Also, the interest in the ASA Shotcrete Inspector Education and the corresponding ACI Shotcrete Inspector Certification program is growing. The demand for our inspector education, even during COVID restrictions, shows the distinct need for enhancing owner's, contractor's, and inspector's knowledge of shotcrete. We have every indication that it will continue to grow into the future. This spread of quality shotcrete knowledge can only benefit the operations of shotcrete contractors as shotcrete placement is recognized in codes and specifications. Shotcrete contractors, General Contractors, and Owners who complete the ASA Shotcrete Inspector Education program learn how to identify quality shotcrete placement on their projects. The accompanying ACI Shotcrete Inspector Certification formalizes the knowledge base required for shotcrete inspection. The ASA education and ACI certification hopefully reduces the need for shotcrete contractors to "educate" inspectors on their projects about quality shotcrete, as the inspector should readily recognize when shotcrete placement is performed well.

Again, as we close out a most interesting year, I believe all of us have learned many things, some good some bad, but we must always remember that all knowledge is useful, as long as it is remembered. The lessons, opportunities, and challenges presented to us in 2020, can positively influence all our futures.

Pool and Recreational Shotcrete Committee

By Mason Guarino, Chair

As many of us are aware, 2020 was a year for the history books. As the year started out with optimism for the future, the economy was staying steady and it looked to be a typical growth year in the swimming pool industry. Many were probably projecting 5%-15% growth or just being comfortable with filling their quota and getting that work done well. Coming into mid-January some strange sickness was sweeping through China and caused many of us to reflect on other diseases and sicknesses that appeared in the past, fortunately most of us were not affected by them. By mid-February, it was time to prepare to attend World of Concrete, by then the spread of the sickness was causing some to question their attendance but in the end most that had planned to go attended. ASA held their Annual Outstanding Shotcrete Project Awards Banquet during World of Concrete, one of our last face-to-face events before this sickness became a real threat. Ryan Oakes and Anna Ploghoft of Revolution Gunite won the award for Outstanding Pool and Recreational project utilizing mountain climbing techniques to create a small mountainous swimming pool. Shortly after everyone returned home from Las Vegas, the sickness was introduced to the world as the Corona virus and within a month it started to gain more news traction and then there was no toilet paper a month later.

With the panic hitting the nation in late March and the banning on all non-essential work, many in the pool industry were fearful and and started to question: How will this affect my business? How will this effect my employees? Will we be ok? Am I going to get sick? Once the initial business panic settled down, the realization that somehow it became apparent that the swimming pool and recreational shotcrete construction industry was essential, so we got our masks on and went back to work in one way or another. Business as usual looked very different. Group meetings stopped, group classes stopped, seminars stopped, and many that could work from home, did. Then came the chaos. What once was a concern of potentially business loss and layoffs quickly turned into an overwhelming windfall. When the thought of just traveling or vacationing becoming horrifying, the safe alternative was to build your own pool and everyone that had the means to build called every single pool company they could. Leads went up by 500% and the ability to call a lead back in a reasonable amount of time became overwhelming.

In the spring, the Pool Committee had their typical goals to complete a few tasks and position papers to strengthen the group and provide support to the rest of the pool industry. As we are all in the pool industry, instead of having some time here and there to dedicate to ASA, all of a sudden all of our time was taken up with swimming pool or shotcrete construction. Many of us who are typically working on running the business, managing meetings, and keeping the company moving efficiently were

suddenly needing to get back into the field because the company required all hands on deck to help get things done, myself included. Much of it was just getting into the field to be another helpful knowledgeable body to try to shave some time off every job we could just to get to the next one. Needless to say, the Committee did not accomplish much in terms of the ASA work. Many are still inundated and will be for some time. The Pool Committee met last November, unfortunately many of us did not have adequate time to prepare and had to call into the remote meeting from the field. Nonetheless, we were all optimistic to work on getting back on track and understanding that normalcy will return at some point. The ASA Pool and Recreation Committee is always trying to support the shotcrete swimming pool industry. All are welcome to join in on the meetings and since the upcoming meetings will still be remote, hopefully this makes participating easier. Keep an eye on the ASA calendar for the upcoming meetings and always feel free to reach out to ASA with either technical shotcrete support or questions you may have.

ASA is your resource to help speak with engineers and architects,in addition to providing education and certification to support your team. ASA now has a shotcrete inspectors training seminar available. This class not only supports the ACI Shotcrete Inspector Certification program for concrete inspection companies, but is beneficial for all swimming pool companies who want to understand the shotcrete process more, particularly what makes shotcrete good vs bad.

Sustaining Corporate Members

Thank you, Sustaining Corporate Members, for your investment in the industry! ASA Sustaining Corporate Members show true dedication to ASA's vision to see "structures built or repaired with the shotcrete process accepted as equal or superior to cast concrete." These industry leaders are recognized for their exemplary level of support for the Association in a variety of ways.

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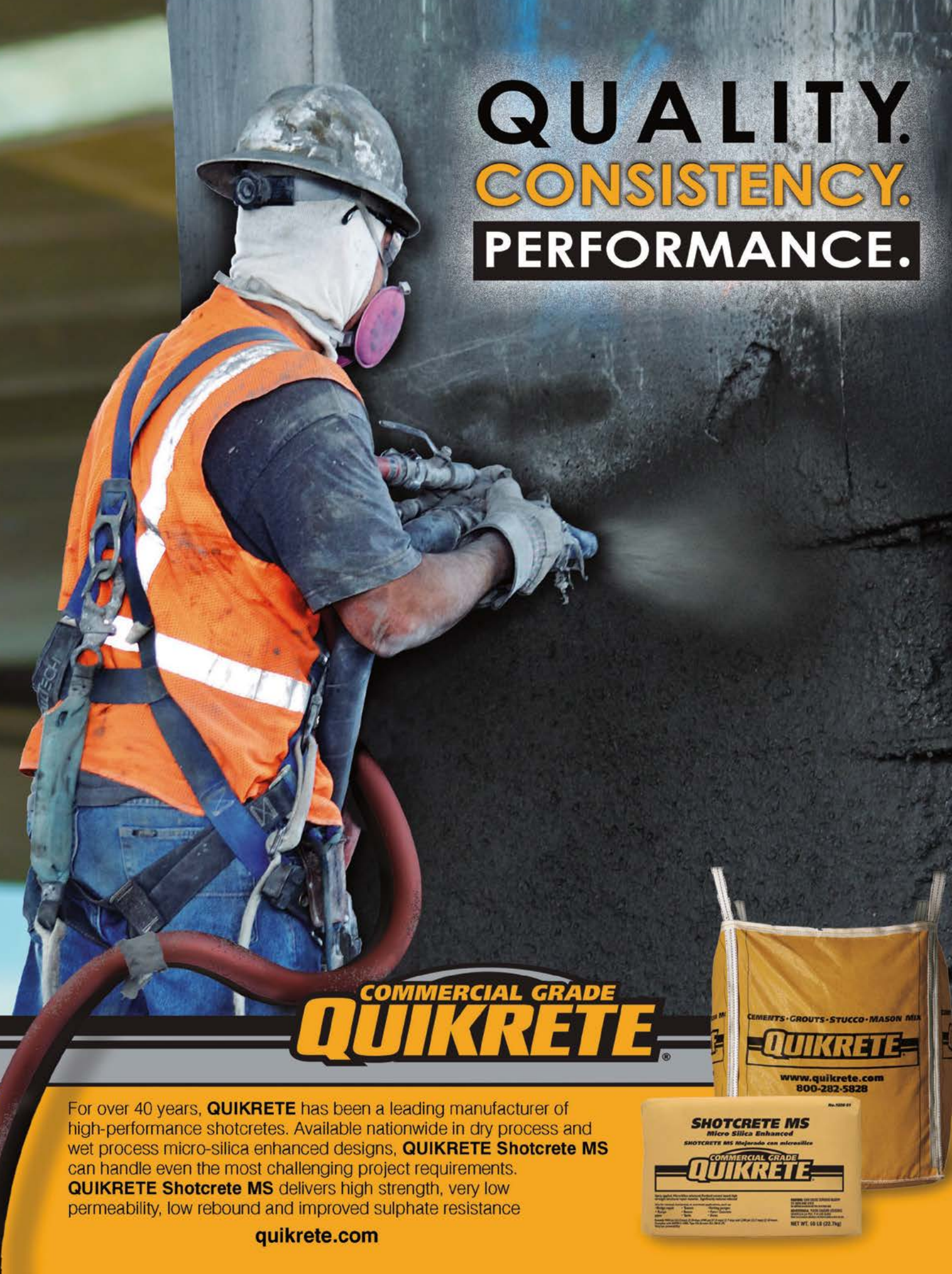

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Quality

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

In my role as Executive Director, I periodically sit back and try to take a strategic overview of where we are as the shotcrete industry in today's construction market, and where can we be in the future? Then I consider - how do we best leverage the reputation, commitment, and involvement of our members to move the industry forward? Unfortunately, I do not have a crystal ball to provide all the answers. But in my decades of experience in the concrete construction world I believe maintaining and even more constantly improving quality is a primary requirement to advance our shotcrete industry.

One definition of quality is "*the standard of something as measured against other things of a similar kind; the degree of excellence of something*." So how does this relate to shotcrete?

For decades, shotcrete placement had been the technology that always needed to prove its ability to build concrete structures as compared against the standard of form-and-pour. Though for over 50 years we have had ACI technical documents that clearly defined shotcrete materials, equipment and application techniques, most engineers and architects were not knowledgeable about shotcrete. There were always concrete contractors who had "expertise" in form-and-pour, so project specifiers knew they could get their designs built. This made it easy for many specifiers to stick with what they knew and not include shotcrete on their projects. Thus, shotcrete quality was, and still is, measured against form-and-pour.

How do we get shotcrete the recognition it deserves as equal or even higher quality than form-and-pour?

For over 20 years ASA has moved the industry forward by increasing:

- Knowledge about inherent benefits of the shotcrete process.
- Field performance of structures built with shotcrete placement.
- Education and certification so field crews know what is needed for quality placement.
- Diversity of structures that can use shotcrete placement.
- Interacting with standards developing organizations like ACI and ASTM to have codes and standards that properly address quality shotcrete placement.

Though form-and-pour concrete work is often less than perfect, most specifiers accept "that's just part of concrete construction." Shotcrete placement, however, is often required to meet a higher standard because it is different. When there are problems in shotcreted structures, it is often blamed on shotcrete as a process, not the lack of experience or inattention to detail by the field crews or contractor. In part, this was also a result of low accountability in the shotcrete industry. Standards, proper education and training were not readily embraced by those in the field. Many contractors simply added shotcrete to their offerings but did not adhere to the resources available. This gave shotcrete a "bad reputation" in many market segments and regions.

We have made great strides in acceptance by engineers and architects in the last two decades of ASA's existence. Many specifiers have recognized the efficiency and flexibility of shotcrete, and they trust that the materials, equipment, and placement techniques we routinely use create high strength, low permeability, durable concrete structures. However, what drives acceptance to an even larger degree is the confidence engineers and architects who specify shotcrete have in our ability to consistently place **high-quality concrete.** Confidence that their designs can be fully and properly built with quality shotcrete is crucial.

The pandemic has brought sharp increases in some of our shotcrete markets. The pool industry is reported to have seen an overall 30% increase in demand and backlogs, in some cases over a year. Highway infrastructure repair was accelerated when traffic levels were decreased from the "work from home" changes in the workforce. With these sharp increases, demand for skilled shotcrete crew is higher than ever.

I have concerns that some contractors may increase production to meet the demand and have difficulty in maintaining the quality. ASA members recognize the necessity for quality in all our shotcrete work to advance the industry. Unfortunately, other companies may not have the appreciation for how poor-quality placement resulting from prioritizing production over quality can hurt us as an industry. With careful attention to details, higher production can be achieved with quality placement, but it takes a conscious effort by all those involved in the shotcrete work.

With our gains in acceptance, we must also accept that we have a responsibility. A responsibility as shotcrete companies, crew members, equipment and material suppliers, researchers, educators, and in many ways, us as an Association, to maintain and ultimately strive to increase the quality of shotcrete placement. Engineers writing codes and standards, specifiers including shotcrete in their specifications and owners asking for shotcrete on their projects have placed their trust in our ability to consistently place quality concrete. We must keep quality as a priority, for we can lose our reputation again in a heartbeat. If their trust is lost, we lose decades of work by ASA and our members in building acceptance. Further, once lost, rebuilding that reputation and trust of shotcrete placement can take decades. We must press on and not let the pressure of demand allow us to cut corners which will have more far-reaching consequences than just the current production schedule. Let's remember lessons learned from the past and continue to strive for greater quality in our shotcrete placement.

Y Not Try a Double Nozzle System

By Derek Pay

Although many shotcrete workers "claim" to be capable of placing massive amounts of concrete in a daily shift, or shooting with the pump turned "wide open," in reality, the nozzleman tends to ultimately be the limiting factor on production speed and daily placement volume. Plain and simple they get tired. Shooting too fast diminishes accuracy and overall quality.

Fig. 1: Delivery line "Y" Splitter

Fig. 2: Ground support shotcrete placement benefited from the two nozzles

Could there be a better way? Y not consider double nozzling? In other words, two nozzlemen operating from the same pump and placement system. In many situations, simply adding a "Y" and a second nozzle to the line increases the amount of yardage output, increases work production, decreases the amount of time spent on the job, and most importantly, decreases the amount of physical strain on the nozzleman.

What is double nozzling? Adding a second line to the concrete pump (Fig. 1), enabling a second nozzleman to simultaneously place material in a different location of the project. Double nozzling is very job specific and works best when you require high volumes placement (Fig. 2) on either large or small projects (Fig. 3 and 4).

There are hidden advantages to running a double nozzle. It allows the pump volume to function at a much higher rate, cutting in half the stroke duration and thrust from concrete flow a nozzleman feels. Greatly reducing a portion of the physical exertion required by the nozzleman, allows the nozzleman to accurately place more yardage in a shorter amount of time (Fig. 5).

For example, assume a 9 yd^3 (7 m^3) delivery each hour, with a yardage total of 72 yd^3 (55 m^3). When adding staging, wash down, traffic, and pump clean out, the majority of us would end our day after eight or nine hours (every crew may vary depending on job requirements). By adding a second nozzle, that same job requiring 72 yd^3 with 9 yd^3 loads every 30 min would be finished on average in half the time thus facilitating a higher placement of total yardage per day.

Another hidden advantage is the dramatic decrease in required pressure when using a properly configured Y pipe set up. The back pressure on the pump is decreased, which in turn can increase the longevity of the pump. On a single nozzle, and a common shotcrete pump, we know that the more we increase the volume, the higher the material cylinder pressure will rise. On a job that requires a pump distance of 250 ft (76 m) using a rubber hose, at a 3 1/2 ft (90 mm) slump, depending on mix design, can require that material cylinder pressure to reach above 3200-3400 lb/in^2 (22 – 23 MPa). The increased pressure creates much higher wear rates and may also increase the risk of failure. However, by adding a properly configured second nozzle system to the line, the material cylinder pressure will dramatically decrease often by 1000-1200 lb/in^2 (7 – 8 MPa), even as your volume of shotcrete output is doubled.


Fig. 3: Project with Separate Sections Shot Simultaneously; Fig. 4: Two Wet-Mix Nozzles – One Pump: Fig. 5: More Flexibility with Two Nozzles

Keep in mind that by adding a second line, the amount of air needed to sufficiently supply a nozzle and a blow pipe increases. A 185 ft³/min (5 m³/min) air compressor is not enough to sufficiently supply enough air to two nozzles and two blowpipes. However, there are many ways to acquire sufficient air. Running a separate air compressor for each nozzle will work, but it increases the amount of equipment needed on site. Increasing the size of both the compressor and air hose for the majority of the run, then splitting the last length of hose, reducing it down to 3/4 in. (19 mm) for the nozzle and blow pipe, will also work, while limiting the amount of equipment needed to supply sufficient air to both systems. A 375 ft³/min (10.6 m³/min) air compressor or higher is required to sufficiently supply the proper amount of air for two nozzles and two blow pipes.

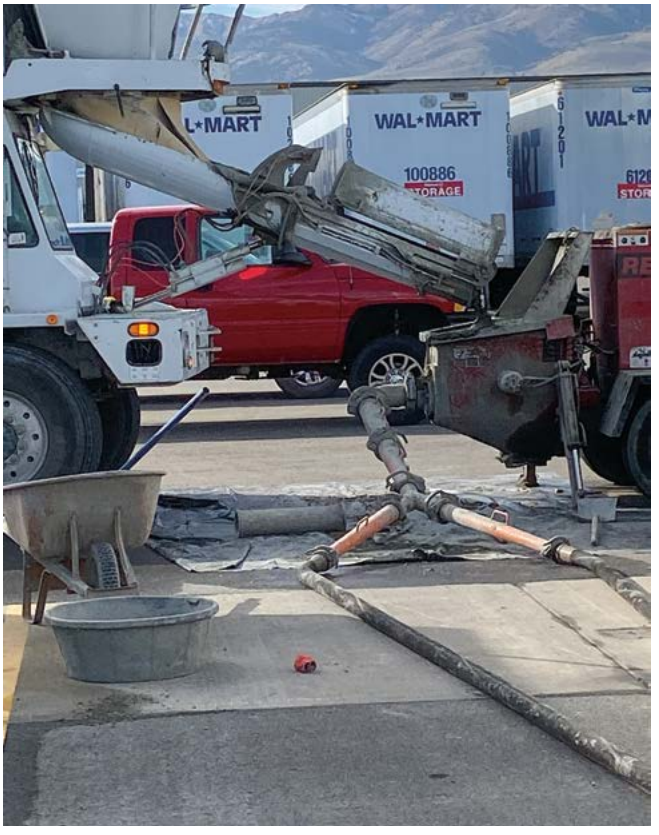

Fig. 6: Delivery Line Splitter on Reducer from Pump

SAFETY CONSIDERATIONS

It is important to remember that when double nozzling, you have added a second line which will require more to manage. That said, safety should always be the number one concern.

There are specific requirements to accomplish double nozzling, safely and efficiently:

1. Running a double nozzle is only for advanced certified nozzlemen. Nozzlemen who are still in the Nozzleman In Training (NIT) program or a nozzleman with limited experience should not be allowed to hold the nozzle.
2. There must be a full understanding of plugs. These include knowing how to brace for them, proper techniques to safely withstand them, how to unplug them, and understanding the feel of the short skip of a pump stroke which generally means that there is a potential blockage coming through the hose headed for the nozzle. Know that a plug can happen at any time and catch us unawares, since the volume is at a much higher rate. If one line of the double nozzle plugs, the other side gets the full volume of shotcrete coming through the hose. Knowing how to prepare and brace for that is key to the success of double nozzling, keeping the nozzleman and everyone else around safe.

3. The remote operator should be an experienced pump and/or nozzle operator, whose job is primarily to receive communication from either of the two nozzlemen and be always ready to stop and reverse the pump in case plugs in the line occur.
4. If using a radio remote control, it must have volume increase/decrease capabilities. Many times, depending on the job, one nozzle may need to produce at a lower volume to properly encapsulate rebar and stack the shotcrete. Having this function will allow you to communicate with either nozzlemen as they are placing the shotcrete.
5. The "Y" should always be placed at the end of the reducer coming out the pump, with the "Y" having a 3 in. (75 mm) diameter opening on all three ends (Fig. 6). After the "Y" is placed, both 3 in. to 2 in. (50 mm) reducers are to be placed with an EQUAL distance of hose on both lines to the nozzle. Splitting the hose with a hard pipe "Y" at the last section of hose is not recommended and will greatly increase the potential for plugs creating a hardship for the crew and the shotcrete system. Having an unequal amount of hose on each line will significantly reduce the pressure in one nozzle line, not allowing the double nozzle to function properly. Equal hose means equal output pressure.

Finally, use common sense with all safety practices, considering jobsite-specific conditions. Running two hoses can greatly increase the amount of yardage placed but can also double the number of shotcrete issues that can occur. Using common sense can really help avoid safety issues.

Double nozzling is a great way to accomplish a job. It is very job specific and is a great tool to have as a business owner. It increases production and longevity of the shotcrete equipment. Most importantly, it reduces the physical strain on a nozzleman, affording greater endurance throughout their nozzling careers.

Derek Pay *is Owner of Oceanside Construction in Salt Lake City, UT. He received his BA from the University of Utah, Salt Lake City, UT, and has been in the shotcrete industry for over 15 years. He is a certified nozzleman in vertical and overhead techniques and currently installs shotcrete throughout the Intermountain west.*

american shotcrete association

Encapsulation of Reinforcement in Tunnel Shotcrete Final Linings

INTRODUCTION

Using shotcrete for the placement of concrete for tunnel final linings is becoming more common. In the past the use of shotcrete final linings was typically limited to non-public or emergency egress areas, however, shotcrete is being used more and more in public areas. The use of shotcrete is typically an attractive alternative to form-and-pour final lining installation where formwork costs are high or technically challenging, pose a scheduling issue, or where labor rates are very high. Typical examples for successful use of shotcrete final linings are complex lining geometries, intersecting or merging tunnels, widenings, short tunnels without sufficient repeating utilization of the forms, or underground systems where formwork would block passing traffic.

However, installing final lining shotcrete has numerous challenges. Some of them are addressed in ASA's position statements about spraying shotcrete overhead [8] or on sheet waterproofing membranes. Improper application of shotcrete can create areas of lower density, resulting in higher permeability and potentially an increased rate of corrosion. If reinforcing steel bar or wire mesh reinforcement is used, proper encapsulation of the reinforcement is one of the key elements for a successful and high-quality shotcrete final lining installation.

Advances in concrete admixtures and metered alkali-free accelerator have helped reduce the issues mentioned above. Using higher slump mixes while maintaining a 0.40 w/cm ratio helps increase the material velocity as well as allowing proper injection of the accelerator. The use of silica fume and migrating corrosion inhibitors along with waterproof membranes has helped increase the density of the liner, and provides improved corrosion resistance on both sides of the shotcrete shell. Reports and guidelines developed by the American Concrete Institute's Shotcreting Committee (ACI 506) [3,4,5,6,7] provide valuable resources in this regard. Also, shotcrete is now fully recognized as a method for concrete placement in ACI 318 [2]. ACI 318 states "Shotcrete is considered to behave and has properties similar to concrete unless otherwise noted." So, it is expected that the use of shotcrete in-place of form-and-pour for tunnel final linings will increase in the future. This position statement provides guidance and recommendations for the proper encapsulation of embedded reinforcement in tunnel shotcrete final linings. Most of the guidance provided is based on the referenced documents of the ACI Technical Committee 506 that is charged with creating and maintaining consensus documents on shotcreting [3,4,5,6,7].

ENCAPSULATION OF REINFORCEMENT

Proper encapsulation of reinforcement provides the structural integrity of the lining. The encapsulation is necessary for stress transfer between the concrete and the reinforcing bar, and the durability of the structure. Proper placement and encapsulation also prevent voids or low density areas, that could accumulate water and increase the permeability of the lining. Therefore, the encapsulation of reinforcement is very important and requires special attention.

The shotcrete nozzleman conducting the work shall be ACI-certified in the shotcrete process (wet-mix or dry-mix) and orientation that the lining requires (typically both vertical and overhead). The nozzleman should also have shotcreted on at least 2 to 3 comparable projects. Past experience is particularly important before participating on projects including complex reinforcement configurations.

The encapsulation of reinforcement in form-and-pour concrete is usually achieved by internal vibration resulting in compaction of the liquid concrete. For shotcrete, the proper consolidation and encapsulation is more challenging. The successful use of shotcrete for tunnel final linings depends on the installation process and workmanship of the nozzleman and the shotcreting crew. The reinforcement layout, and concrete mixture design used, are also key elements for a successful placement. Using proper materials, appropriate equipment, layout and placement techniques facilitates the use of shotcrete for high quality, heavily reinforced tunnel final linings.

It is essential to highlight that the shotcrete nozzleman needs to know how to correctly apply shotcrete for the entire lining section including wire mesh, reinforcing bars, lattice girders, or underlaying waterproofing layer. Each element requires different application techniques or more careful attention, which in most cases are accomplished by avoid sloughing and fall-outs. Details, such as concentrating on getting the first coat onto the waterproofing and wire mesh layer before applying a thicker layer with reinforcing bars or the backside of the lattice girders, are essential.

Shotcrete provides consolidation and densification by high-velocity impact of fresh concrete material on the receiving surface. The high-velocity impact of shotcrete onto a hardened, previously placed layer of shotcrete, that is roughened and brought to a saturated-surface dry (SSD) condition, provides a strong abrasive blast, which opens the freshly hardened surface, creating immediate exposure of the fresh cementitious material paste [3] inherently creates an excellent bond that allows multiple layers to act as if monolithically cast. In most cases when shooting a lattice girder liner two layers of shotcrete are required. The final layer usually requires more time than the initial layer. The first layer is usually water blasted to remove any loose material left by roughening the layer, and removing any dust or overspray deposited by shotcreting in adjacent areas. The water blasting also tends to open the pores of the harden concrete surface for better bond between the first and second layer.

During the shotcreting process, the high velocity flow of the concrete mixture hitting the reinforcing bars directly in the shotcreting stream may clean the outward facing surface of the reinforcing bar from a slight material build-up of fines and sand from a light overspray. However, this positive effect is highly dependent on proper airflow, material consistency and nozzling technique. In general, concrete mixture designs without larger aggregate have more potential to allow a build-up of improperly compacted material on the face of the reinforcing bar. Significant material build-up on the face of the steel bar increases the size of the spray shadow and should be avoided. Using a rapid-set accelerator may increasing the strength of the overspray, thus hindering the positive effect of the cleaning of the reinforcing bar with the material stream.

Thus, proper experience and craftsmanship of the nozzleman and shotcreting crew, as well as use of a blowpipe, are necessary key elements to achieve successful placement. The key to proper encapsulation of reinforcement is the avoidance of voids, honeycombing, or low density concrete, with special attention to areas of shadowing. The term “shadowing” refers to an area behind the reinforcement that may not be filled in or fully compacted, because the reinforcing bar interrupts the material stream (see Fig. 1). When shotcrete is properly installed, the area in the spray shadow is filled by concrete that flows around the bar, by driving fresh concrete behind and adjacent to the bars due to flowability of the mixture and compaction by the impact (Fig. 3). For proper encapsulation, the shotcrete must have sufficient plasticity and impact velocity. Though shotcrete placement generally is at a 90 degree angle to the receiving surface when encasing large bars, plates or embeds the shotcrete stream may need to be angled to place concrete behind the larger shadow zone (Fig. 2).

DESIGN

The design of structures using shotcrete placement as required by the ACI 318 Code [2] is generally not different

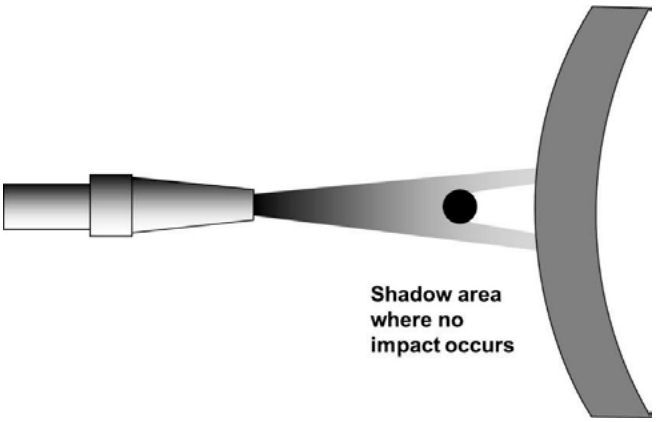

Fig. 1: Shadowing behind reinforcement [3]

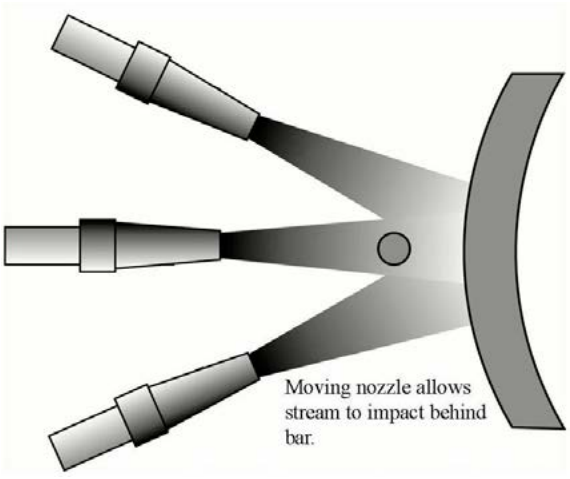

Fig. 2: Encasing large diameter bars. Nozzle slightly angled to force material behind the bar [10]

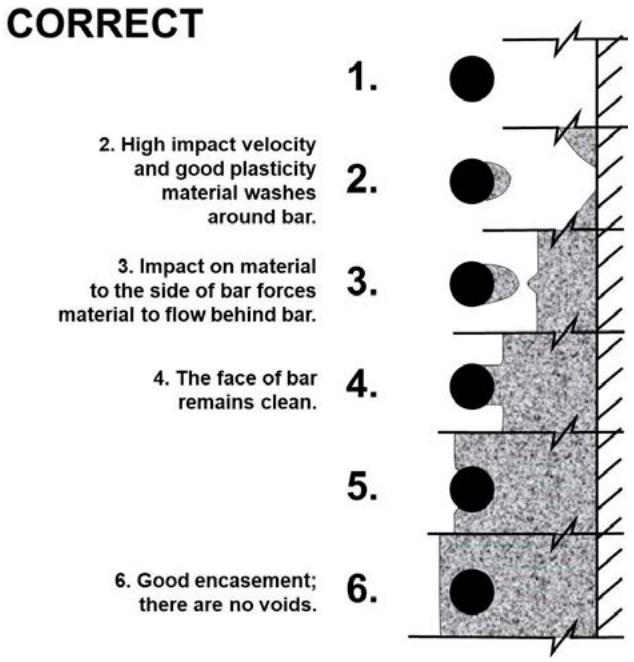

Fig. 3: Correct Encapsulation of Reinforcement [3]

from form-and-pour or other concrete installation methods. Best results are obtained when the reinforcement is designed and positioned to cause the least interference with the placement of shotcrete. The reinforcement should be designed and installed with attention to sizes, spacing, and layout to facilitate the placement of shotcrete. Sufficient clearance around reinforcement is needed to allow the shotcrete material to flow around the reinforcement while allowing the air uses to propel the concrete materials to escape. Insufficient clearance can create trapped air voids. As the reinforcing bar size increases or the spacing decreases, the nozzleman's skill becomes increasingly important to ensure complete encapsulation. Bar lap splices, couplers, number of reinforcement layers, and the depth of section can also interfere with the shotcrete stream or reduce velocity, which further complicates encasement and requires careful attention by the nozzleman [3].

ACI 318 [2] provides specific minimum spacing for reinforcement for members with "parallel non-prestressed reinforcement", which applies for tunnel linings. The clear spacing between bars shall be at least 2-1/2 in. (64 mm) for #3 (#10M) bars and 6db (db = nominal diameter of the bar) for #4 (#13M) or larger bars. If two layers of reinforcement are provided and shotcrete is shot through both layers, the clear spacing between bars in the intrados shall be at least 12db, while the clear spacing between bars in the extrados shall meet the requirement above (at least 2-1/2 in. and 6db). A tighter spacing of reinforcement is permitted if proper reinforcement encapsulation can be successfully demonstrated in pre-construction shotcrete mockup panels. The shotcrete mockups are to be representative of the most complex reinforcement configurations to be encountered. For further guidance regarding the mock-up configuration and shotcrete evaluation refer to ACI 318 [2] and ACI 506 [3,4,5,6].

The special requirements and challenges of spraying shotcrete through multiple layers of reinforcement can generally be avoided if each layer of reinforcement is encapsulated in a separate layer of shotcrete. This means the subsequent layer of reinforcement is installed after the previous layer is already fully encapsulated in shotcrete thus incrementally installing and encapsulating one layer of reinforcing bar at a time, until the full thickness of the lining is achieved.

For non-contact lap splices of reinforcement (a connection of reinforcing steel made by lapping the ends of bars not in direct contact [1]), the clear spacing provided by ACI 318 [2] shall be at least the greater of 6db and 2-1/2 in. between bars for #6 (#19M) and smaller bars. For #7 (#22M) and larger bars, the clear spacing shall be established using a shotcrete mockup panel to demonstrate that the reinforcement is properly encased [2]. ACI 506 [3,4] provides slightly different guidance; non-contact spliced should have a minimum spacing of at least three times the diameter of the largest bar (3db) at the splice, three times the largest aggregate, or 2 in. (50 mm), whichever is least.

Contact lap splices of reinforcement (means of connecting reinforcing bars in which the bars are lapped and in direct contact [1]) create a large obstruction that is more difficult to encase and should be avoided where possible [3]. However, in applications with congested reinforcement, contact lap splices can be advantageous for the installation compared to non-contact splices because they allow for wider shotcrete spray pathways between the reinforcing bars. Per ACI 318 [2] and ACI 506 [4], contact lap splices of reinforcement shall be oriented with the plane of the spliced bars perpendicular to the surface of the shotcrete (parallel to the direction of shooting) to minimize the size of the spray shadow. Also, they should be approved by the licensed design professional based on a shotcrete mockup panel to demonstrate that the reinforcement is properly encased.

Commonly used fabric gauges for welded wire fabric (WWF) are W2 or W1.4 wire [MW9.1 or MW12.8], spaced 4 in. [100 mm], or 6 in. (150 mm) in both directions [3,6]. In no case should the wires be spaced less than 2 in. apart. If WWF is used, they should be lapped at least 1.5 spaces in both directions and be securely fastened [3].

The minimum cover over reinforcement is from the same as form-and-pour concrete and should comply with the job

specification and is usually based on environmental exposures and the service life of the tunnel.

Columns in tunneling are usually not shotcreted because the close spacing between ties, hoops, or spiral reinforcement makes it difficult to achieve adequate encasement of the column longitudinal reinforcement. However, shotcreting of columns is possible with an experienced nozzleman and proper materials.

Following ACI 318 [2], reinforcing bar spacing closer than 3 in. (75 mm) requires approval by the licensed design professional based on shotcrete mockup panels demonstrating that the reinforcement can be encased without voids. Special attention must be given by the designer of the temporary installation and layout of the reinforcing bar cage. Lattice girders or anchors providing support must not only carry the weight of the reinforcement but also fix its location properly during the shotcreting process as well as preventing movement and vibration. Movement and vibration can compromise the encapsulation of the reinforcement, cause sagging of freshly placed shotcrete, create voids, increase permeability to provide pathways for water ingress, and result in reduced strengths and quality.

If using anchors to support the reinforcement cage, shooting overhead work requires closer anchor spacing to minimize the reinforcement movement during placement and help support the weight of the shotcrete. Therefore, the anchor spacing, and reinforcing design require special attention by the designer and by the contractor considering the interface between the waterproofing, reinforcement, and shotcrete installation. For additional guidance on installation of shotcrete overhead and on sheet waterproofing membranes refer to the ASA Underground Position Statements on each topic [8, 9].

Shotcrete, particularly when using the dry-mix process or crushed aggregate in wet-mix, is more abrasive and can cause localized damage to epoxy-coated rebar. This may be a consideration for the designer as discontinuous epoxy-coating an a bar may negatively impact the rate of corrosion. Use of epoxy-coated bars may also reduce the bond of the fresh concrete to the bar, and make it more difficult to fully encapsulate the reinforcement. Preconstruction testing is strongly recommended before using epoxy-coated reinforcement. A preconstruction mockup panel should be shot to determine the effect of the shotcrete process on the coating [3].

REINFORCEMENT INSTALLATION

Movement and vibration of the reinforcing steel can cause a loss of adherence and sagging of the plastic shotcrete, which can create voids and compromise the concrete strength; therefore, the reinforcement must be installed properly and firmly affixed to limit movement during the placement of shotcrete. Rigid reinforcement installation is a key element for high-quality shotcrete final linings.

Compared to form-and-pour, often an additional 75% more tie wire is required to make the reinforcing intersections 100% tied. Intersecting reinforcing bars must be rigidly tied to one another and to anchors or lattice girders with 16 gauge [1.3 mm] diameter) or heavier tie wire and adequately supported to prevent vibration during shotcrete placement. Before shooting the shotcrete, cut off excess tie wire. Large knots of tie wire should be avoided to minimize the buildup of material, which may cause an obstruction and may lead to the development of voids [3,4].

If WWF is used, the mesh should be cut to the proper size and carefully bent to closely follow the contours of the areas receiving shotcrete. Like reinforcing bar, the mesh should be securely tied with 16 gauge or heavier tie wire to preset anchors, lattice girders, or reinforcing bars. Reinforcement should be free from oil, loose rust, mill scale, dust, or other surface deposits that may affect its bond to the shotcrete [3].

SHOTCRETE PLACEMENT

High impact velocity ensures that the fresh shotcrete flows around the reinforcement and ensures proper encapsulation. The key elements to provide proper impact velocity for consolidation and encasement are suitable material consistency, sufficient air flow, and proper placement techniques. Larger diameter reinforcement requires a more flowable mixture for good encasement, and the angle of the material stream may need be slightly adjusted to ensure that the area behind the reinforcement is compacted (see Fig. 2) [3].

For any given shotcrete mixture, experience shows there is an optimum impact velocity. Below the optimum impact velocity, the impact energy is too low to correctly consolidate the in-place concrete, and get adequate wrap of flowable concrete mixture to encase the reinforcing. Impact velocity can be increased by reducing the distance to the receiving surface, or increasing air flow. However, if the impact velocity due to too high an air flow, the surplus energy can increase the amount of rebound or blow the plastic material apart. The standard nozzle distance is 2 to 6 ft (0.6 to 1.8 m) for handheld nozzle placement, depending on the nozzle type, size, and air flow. For mechanically manipulated systems, typically, a higher air flow is used and produces higher material velocity compared to hand-held applications, which may allow for greater distances of the nozzle from the receiving surface.

For congested reinforcement with multiple layers of reinforcement and linings with thicker depth, the nozzleman may need to insert the nozzle tip behind the bars of the intrados layer and the use of longer tips may benefit this process. However, when working closer to receiving surfaces or reinforcement, the air volume and velocity of the shotcrete should be reduced to prevent a blowback of air that can create voids [3].

Before placement of a new layer of shotcrete and encapsulating reinforcement, rebound, overspray, cuttings from adjacent or previous placements, and other deleterious materials that inhibit the development of the bond between previous shotcrete layer and reinforcement must be removed and not be incorporated into the work [3,4].

Close observation of the face of the reinforcement during the application of shotcrete indicates the quality of encapsulation. The front face of the reinforcement shall be kept clean clearly showing the reinforcing deformations during the shotcrete placement to ensure that shotcrete builds up behind the reinforcement to get full encapsulation without creating shadows or voids.

During shotcrete placement, the shotcrete crew shall continuously remove accumulations of rebound and overspray using a compressed air blowpipe, or other suitable devices. When material builds up on the face of the reinforcement, it is an indication that material is not flowing around, and a void is potentially forming behind the reinforcement. The shotcrete placement should be stopped to allow the nozzleman to either adjust the mixture, increase impact velocity, or both. Any buildup of material on the face of the reinforcement must be cleaned off and the area behind the reinforcement opened up before continuing the operation [3].

Proper nozzle manipulation is physically demanding, requires strength, experience, and finesse of the nozzleman. The nozzle technique for placing wet-mix and dry-mix shotcrete is generally similar. Both requiring considerable attention to detail during placement. Wet-mix nozzlemen must manipulate a heavier hose, which is discharging a greater volume of material per unit of time, compared to dry-mix placement. Shotcrete application in larger tunneling cross-sections typically will use wet-mix typically uses mechanical shotcrete manipulators, also referred to as shotcrete robots.

When encapsulating multiple layers of reinforcement at vertical or overhead locations, the application should begin at the bottom, fill corners, areas around anchors, or lattice girders, and from there move upwards. The first layer should, if possible, completely encase the reinforcement adjacent to the back of the form, anchors, or lattice girders and should form “ribs” in the lining. In the following step, after the ribs have initially set, the “bays” between the ribs are filled starting from the bottom. Finishers should be careful not to disturb the freshly placed shotcrete, create cracks or tears, reduce internal cohesion, break the bond between the shotcrete and the reinforcement, or the bond to the previous shotcrete layer. If architecturally acceptable, a “gun” (natural) finish should be considered.

ADMIXTURES

Typical slumps of the wet-mix shotcrete are between 2 and 4 in. (50 to 100 mm) at the nozzle. Admixtures such as accelerators and water reducers added to a shotcrete mixture can change the rheology of the mixture, so the 2 to 4 in. (50 to 100 mm) rule of thumb is not always applicable. For example, slumps from 6 in to 8 in. (150 to 200 mm) may be used effectively when using rapid-set alkali-free accelerator technology, A mixture with a slump less than 2 in. (50 mm) might be difficult to pump and may be too dry to easily flow around reinforcement and properly encapsulate the

reinforcement. Testing should be conducted to determine what combination of admixtures and slump can be shot to achieve desired results [3].

The addition of a rapid-set accelerator admixture to the concrete mixture allows the placement of higher slumps when shooting vertical or overhead applications. However, there can be negative effects when using accelerator for shotcrete final linings. These negative effects may include too early set that compromises compaction, reduction of long-term strength, and potential change of alkalinity negatively affecting the durability of the concrete. These effects must be considered when deciding whether to use an accelerator. In general, the use of accelerator for tunnel final linings should be minimized if possible. Shooting mockups and testing the strength of the shotcrete will determine the best dosage of accelerator for vertical and overhead applications.

QUALITY ASSURANCE AND QUALITY CONTROL

Quality assurance and quality control ensure that items like concrete mixture proportions, shape, thickness, and reinforcement are constructed as designed and meet the specified properties. The quality of the placement of shotcrete and proper encapsulation of reinforcement depends not only on an experienced nozzleman but an experienced contractor and shotcrete crew. Only competent, experienced, and trained craftsmen working as a team and provided with proper equipment and materials will produce high-quality shotcrete final linings.

The contractor and nozzleman should have a demonstrated history of completed, acceptable shotcrete work, similar to that required for the project. The contractor's principals, project managers, and shotcrete field crew should have a successful background in shotcrete, as determined by references and reputation. Job specifications for structural shotcrete should require that the nozzleman is ACI-certified in the shotcrete process and orientation they will be expected to shoot on the project. The nozzlemen should also have completed at least one similar application on a project with similar size and complexity.

The nozzleman is a key person in a shotcrete operation and is responsible for applying the shotcrete. Before the shotcrete is placed, the nozzleman must ensure that all areas to receive shotcrete are clean, sound, and free of loose material, in a saturated surface dry condition, and that anchors, reinforcement, and ground wires are properly placed and spaced.

Pre-construction testing on mock-ups reflecting the reinforcement design (bar size, spacing, and amount) should be conducted. The purpose of pre-construction testing with mockup panels is to confirm that the shotcrete, in general, and placement by nozzlemen and crews who will be on the job, can properly encapsulate the project-specific reinforcement and meet all material and placement requirements. The mockup panel should always be constructed with reinforcement similar to the most heavily reinforced or critical section to be shot. ACI 506 [3,4,5,6] provides detailed information for specification, planning, and execution of pre-construction testing.

On projects with congested reinforced tunnel linings, the nozzleman must be able to demonstrate an ability to satisfactorily perform the required duties and to apply shotcrete as required by the specifications. Although a nozzleman is ACI-certified, the nozzleman may not have sufficient experience to shoot heavily reinforced sections or complex sections. The purpose of mockup panels is to satisfy the specifier that the nozzleman and shotcrete crew, with the materials and equipment to be on the project with meeting the specifiers expectations for the structural quality of the shotcrete placement. Also, mock-ups may serve as an opportunity for the nozzleman to work with the additional crew members and make sure everyone is familiar with the proper shotcrete application required for the specific project conditions.

ACI 506.6T [7] provides guidance to the specifier on visual evaluation of cores taken from mockup panels or in-situ work. It lists quantitative criteria for each category of core quality grading by a Licensed Design Professional (LDP). The cut and cored surfaces of the specimens are carefully examined and evaluated. The cores should be dense and mostly free from laminations, voids, and sand pockets for the evaluation by ACI 506.6T [7]. There are four grading categories of visual evaluation of core quality (very good, good, satisfactory, poor). Each category of quality is discussed and quantified based on two criteria. Each category is not only a function of the imperfections found, but also intimately linked to the complexity and structural demand of the reinforcement layout. Particular attention should be paid to the presence of voids and low density shotcrete behind the reinforcing bars. Factors including the size of the reinforcement, spacing, laps, layers, reinforcement location within a cross-section, and other types of placement should be considered in the evaluation.

RECOMMENDATIONS FOR THE CONTRACTOR

Often, the general contractor has a contractual requirement for coordination between the reinforcement installer and the shotcrete contractor. They may also include additional

coordination with the waterproofing installer. To ensure quality and avoid deficiencies, the interface and coordination required between the different trades and proper handover requirements should be clearly defined, inspected, and documented in detail by the shotcrete contractor. This includes but is not limited to the installation and spacing of reinforcing bars, including splices and the rigidity of the installation to avoid movements and vibration.

The shotcrete nozzlemen should be ACI-certified in the shotcrete process with both vertical and overhead application, and have demonstrated experience and skill in the same type of work. Nozzlemen without underground experience will need to be specifically briefed and trained for the installation of shotcrete in reinforced shotcrete tunnel final linings. As noted above, shotcrete placement should be tested on a mock-up mimicking the project-specific reinforcement and anchor or lattice girder installation. Before the application in the tunnel, the nozzleman should be qualified for the project by shooting a mockup section with representative reinforcement. Proper shooting procedures and application sequence should be laid out in writing in the work plan and can often be tested and confirmed during the pre-construction mock-up construction.

RECOMMENDATIONS FOR THE OWNER

The owner should provide a design reflecting the specific challenges for a final lining using shotcrete, specifically focusing on reinforcing bar size, layout, splicing, and spacing. Minimum key criteria need to be specified like reinforcing bar rigidity and anchor spacing, reinforcement suspension or support, and the shotcrete material specification following the applicable ACI 506 documents [3, 4, 6]. Again, a key is properly executing pre-construction testing and the project-specific mock-ups, which should be mandatory and follow the ACI 506 guidelines [3, 4, 6].

The mock-up specimen should be saw cut or cored to clearly identify any delamination or defective shotcrete adjacent to reinforcement [7]. The owner should not allow the start of the tunnel shotcrete placement until the contractor has proven that their means, methods and procedures are capable of providing the required quality of shotcrete and proper encapsulation of reinforcement. Also, the owner should recognize that inspection of the proper installation of the reinforcement before the shotcrete installation and shotcrete placement may require the inspector to have more shotcrete specific knowledge than they may possess with conventional concrete construction. A qualified and experienced inspector is needed. Use of an ACI-Certified shotcrete inspector is preferred on these projects.

CONCLUSIONS

Installation of shotcrete tunnel final linings is a cost and time-efficient construction method, especially in areas where formwork is costly and labor-intensive. Nonetheless, the installation of shotcrete and proper encapsulation of reinforcement in underground applications is challenging. The owner and contractor should recognize the expected challenges before the start of construction. Experienced staff on either side is required for the successful execution of the project.

Acknowledgments

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References

1. American Concrete Institute: "ACI Concrete Terminology", ACI CT-18, 2018.

2. American Concrete Institute: "Building Code Requirements for Structural Concrete", ACI 318-19,2019.

3. American Concrete Institute: "Guide to Shotcrete", ACI 506R-16, 2016.

4. American Concrete Institute: "Specification for Shotcrete", ACI 506.2-13 (18), 2018.

5. American Concrete Institute: "Evaluation of Shotcrete", ACI 506.4R-19, 2019.

6. American Concrete Institute: "Guide for Specifying Underground Shotcrete", ACI 506.5R-09,2009.

7. American Concrete Institute: "Visual Shotcrete Core Quality Evaluation", ACI 506.6T-17, 2017.

8. American Shotcrete Association: "Position Paper - Spraying Shotcrete Overhead in Underground Applications", 2019.

9. American Shotcrete Association: "Spraying Shotcrete on Synthetic Sheet Waterproofing Membranes", 2019.

10. American Concrete Institute: "Shotcrete for the Craftsman" CCS-4 (20), 2020.

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Mechanical Application of Shotcrete in Underground Construction

INTRODUCTION

The manual hand application of shotcrete began over 100 years ago and continues today in a wide range of applications and projects. To provide a proper distance of the shotcrete nozzle tip to the underground surface wall, surface receiving shotcrete or 'substrate,' the hand application of shotcrete in larger diameter underground structures required the nozzlemen to operate from a man-lift or similar equipment. Working from elevated platforms and the close proximity of the nozzleman to the substrate added safety challenges to projects. Thus, as more underground projects started to use the wet-mix shotcrete process, spraying shotcrete with mechanical arms began to address these safety concerns.

Compared to manual shotcrete application, mechanized shotcreting equipment improves job safety and reduces nozzleman fatigue, especially when wet-mix shotcrete is used. Mechanized shotcrete applications allow more flexibility, increased reach, and more efficient mobility of the operation, which are important factors in planning and executing underground shotcrete projects. The self-contained mobile shotcrete application machines can also enhance safety in challenging areas. After the shotcrete operation is completed at one location, the self-contained equipment can be quickly redeployed to the next work area.

This position paper provides an overview of the basic design and operation of mechanical equipment for underground shotcrete applications, often referred to in the industry as a "mobile shotcrete sprayer," "shotcrete robot" or "shotcrete manipulator." This position paper uses the terms "mechanized shotcreting," "shotcrete nozzle manipulator," or "shotcrete boom manipulator" when describing the process and equipment. This is intended to distinguish this equipment from equipment used in manual shotcreting and to emphasize this equipment is controlled by operators and is not fully automated. It is important to recognize that the often used terms "robotic sprayer" or "robot" are inaccurate and can be misleading. Semi and fully automated mechanized systems have been under development for many years; however, it will likely take many more years before reliable fully automated systems become available and gain acceptance in the industry.[1]

COMPARISON OF MANUAL AND MECHANICAL SHOTCRETING

Dry-mix shotcrete (gunite) is commonly applied by manual spraying techniques. Because the shotcrete materials are delivered by pressured air, the weight of the shotcrete delivery line and nozzle is lighter compared to wet-mix shotcrete equivalents. In wet-mix shotcrete, the entire shotcrete delivery line is filled with wet concrete. This makes the portion of the line leading to the nozzle much heavier compared to the equipment used in dry-mix shotcrete application.

Therefore, mechanical spraying equipment is more commonly used in wet-mix shotcrete applications. This is particularly true if working near or under unsupported ground where thick shotcrete linings are needed or working in large tunnel cross-sections.

Manual application of shotcrete implies that the nozzleman is manually handling, operating, and moving the nozzle during shotcrete spraying. The manual application of dry-mix shotcrete is typically preferred in applications or projects:

1. with small daily or total shotcrete placement volumes,

2. requiring generally lower output rates compared to wet-mix shotcrete (e.g., concrete repair or rehabilitation projects),

Fig. 1: Shotcrete application by hand.

Fig. 2: Shotcrete application by mechanized equipment via radio remote.

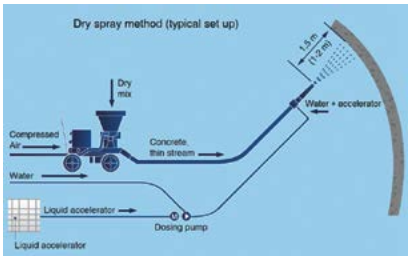

Fig. 3: Typical schematic diagram of dry-mix shotcrete equipment material flow.

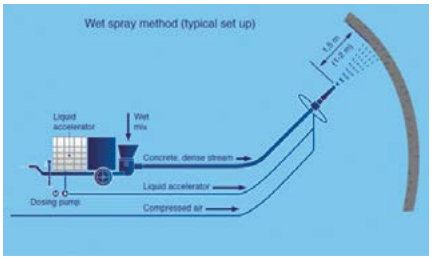

Fig. 4: Typical schematic diagram of wet-mix shotcrete equipment material flow.

Fig. 5: Typical tunnel electric-hydraulic sprayer.

3. where the smaller and lighter nozzle and hoses can be moved more easily by hand,
4. where the dry-mix shotcrete materials can be easily conveyed by compressed air from the shotcrete gun to the nozzle, and
5. where fast-reacting materials, that must remain dry until contact with water at the nozzle, are used.

To clearly distinguish it from manual application, mechanized shotcreting should be defined as "a shotcrete application using a hydraulic or electrically powered shotcrete boom manipulator." With wet-mix, the nozzle is typically rotated around the concrete flow centerline during the shotcrete application to enable proper distribution of the shotcrete and accelerator.

During the mechanical application of shotcrete, the nozzleman does not manually handle and move the nozzle for the shotcrete application. Instead, the operation of the boom manipulator is done by remote control (either wireless or cable). The mechanical application of wet-mix shotcrete is typically preferred in applications or projects:

1. where the required shotcrete placement volume is frequently large,
2. which require higher output rates (e.g., for ground support or tunnel linings),
3. where nozzle and hoses are larger and heavier and cannot be safely moved by hand, and
4. application reach would require scaffolding or a man-lift.

Mechanized shotcreting is the preferred method of applying wet-mix shotcrete in large underground projects. This is especially true when shooting overhead due to the exposure of the operator to rebound and 'fallouts' of fresh layers of hardening concrete that breaks off from the substrate.[2] For example, mechanized shotcreting is utilized in projects requiring higher output, such as initial and final support liners in new tunnels and underground cavern construction. Hose diameters are typically in the range of 2.0 to 2.5 in. (50 to 62 mm) inside diameter (ID) at the nozzle body. The delivery line weight of fresh wet-mix shotcrete being pumped through the line is several times heavier than the delivery line weight of pneumatically conveyed dry-mix shotcrete materials. Additionally, the wet-mix nozzle body is typically heavier compared to a dry-mix nozzle. Therefore, hand-application of wet-mix shotcrete can fatigue the nozzleman more quickly, leading to safety issues. The added weight can also cause operational challenges that may be detrimental to the quality of placed shotcrete.

Finally, it needs to be pointed out that dry-mix shotcrete application with shotcrete boom manipulator can be done but it is not common.

SAFETY

Elevated work locations can create a major risk in underground construction. Application of overhead shotcrete in larger diameter tunnels by hand is only possible from a man-carrying platform (man-lift) to provide optimum distance between the nozzle and substrate. However, the nozzleman's operation oftentimes is conducted at an elevation of 5 ft to 20 ft (1.5 to 6 m) above the 'invert' or tunnel ground level.

Typically, mechanized operation of the shotcreting nozzle allows the nozzleman to operate from the invert and does not require the nozzle operator to work from a man-lift. In most cases, mechanized equipment eliminates the potential hazards of elevated work for the nozzleman.

A major safety concern of underground applications is working under unsupported ground. Therefore, application

Fig. 6: Typical setup showing concrete hauler (left) feeding concrete pump of mechanized sprayer (right).

of shotcrete by hand is often not allowed due to potential fallout of substrate (rock, soil) or the hardening shotcrete. In such instances mechanized shotcrete booms are utilized, which allows, the nozzleman to operate from an area of supported ground and a safe distance from potential hazard.

Also, exposure to dust and rebound in the working area is a concern of manually applying shotcrete as the nozzleman operates directly behind the nozzle, near to the shotcrete being applied to the substrate. In mechanical spraying, the nozzleman can operate the system from an area farther away from the application site, where there is better air quality.

Mechanical shotcrete equipment is operated by hydraulic pressure, which is more powerful and potentially more dangerous, if not properly managed, than hand-applied pneumatic power. However, with remote control units the operator is farther away from the pressurized concrete and hydraulic hoses.

In summary, mechanical spraying shotcrete typically eliminates the hazards of elevated work, working near pressurized hoses, shotcrete rebound or fallout, and exposure to dust.

PRODUCTIVITY

The mechanized nozzle operation process, which utilizes a concrete pump with larger hose diameters, enhances the spraying performance of wet-mix shotcreting. This process typically allows 2 to 4 times more shotcrete placement than the dry-mix manual shotcreting process. The logistics of delivering wet-mix shotcrete to the heading can be simpler than those of a typical manual dry-mix process. And the remote controlled operation utilized for mechanized equipment is physically less demanding on the operator than nozzle operation by hand, thus, the performance of the operator is enhanced.

NOZZLE POSITIONING, COMPACTION, REBOUND AND VISIBILITY

The excavated substrate, for example in a drill-and-blast rock tunnel, can be a surface of varying angles, asperities, and fissures. Maintaining the proper distance and angle of the nozzle tip from the substrate allows the cement paste to fill these natural cracks and thus enhance the bond between the shotcrete and the substrate.

The remote-controlled operation of a mechanized boom allows for an easily manipulation of the nozzle. The optimum distance between the nozzle tip and the substrate surface of 4 to 5 ft (1.2 to 1.5 m) can be maintained as well as the optimum perpendicular angle to the substrate surface. Also, the continual rotation of the nozzle allows for a more uniform shotcrete thickness. Maintaining the proper distance and angle to substrate improves shotcrete compaction which increases shotcrete strength.

Dust and rebound in dry-mix shotcreting manual operation can impact the visibility of the nozzleman operating manually behind the nozzle. However, as previously mentioned, the visibility of the nozzleman operating during wet-mix mechanical shotcrete system is typically much better, as the nozzleman is not near the nozzle.

QUALITY CONTROL

Testing of mix-designs in pre-project trials, mockups, and certification of operators is typically a mandatory requirement and very important for the success of any underground shotcrete project. For mechanical shotcreting, all shotcrete placement should meet the recommendations of ACI 506[3].

Quality can be met by using shotcrete that is properly batched, pumped and applied by trained personnel. When using a rapid-set accelerator a proper calibration of the accelerator pump or dosing system in conjunction with early strength testing is essential to providing quality shotcrete placement.

MECHANIZED SHOTCRETE EQUIPMENT

1. SPRAYERS -

A typical underground mechanized shotcrete nozzle manipulator system has the following components:

- diesel or electric engine carrier (usually rubber-tired);
- electric power pack;

- concrete pump and line;
- accelerator pump (typically controlled by a computer-driven monitoring and control system synchronizing the concrete pump strokes with the accelerator pump dosage);
- shotcrete boom and nozzle manipulator;
- cable or radio remote control;
- on board air compressor; and
- shotcrete accelerator tank.

There are several manufacturers that specialize in developing and building mechanized shotcrete equipment, with different designs and sizes to match varying tunneling and mining excavation profiles and needs.

Some of these manufacturers offer compact diesel-hydraulic or electric-hydraulic powered, track-mounted and mechanical nozzle manipulators that can work with trailer mounted or skid mounted concrete pumps.

CARRIER & POWERPACK

Carriers, with the mechanical shotcrete equipment mounted on it, can be either rubber-tired or track-mounted units. They are typically powered by diesel engines. Battery-electric carriers are also available. The concrete pump, boom, and all other functions are typically operated with electric-hydraulic power packs in tunnels and by diesel-hydraulic power in mines.

ON-BOARD COMPRESSOR

In mine applications compressed air is generally available from the mine's main compressors; therefore, the sprayers used in these environments are often diesel-hydraulic where the operators hook the machine to the compressed air lines at each work site. The drawback of using a mine's compressed air is that there can be fluctuations in the air

volume or air pressure depending on other mining activities (such as drilling) taking place. Another potential issue is accumulated condensed water in the compressed air lines. Therefore, when there is no on-board air compressor, the operator needs to be aware of the potential fluctuations from mine air compressors during the shotcreting process.

Electric-hydraulic sprayers used in tunnel construction often have an electric on-board air compressor. These units are more independent and rely on the on-board produced compressed air with its more consistent airflow volume and pressure. Having a constant airflow makes the application easier to control and more uniform.

CONCRETE PUMP & LINES

Concrete pumps for mechanical sprayers are usually hydraulic piston pumps with swing tubes. They have a hopper, mixing paddles, grate, and grate vibrator. Electronic control systems allow smooth concrete pumping and interface with other systems on the machine such as the accelerator dosage system. The main function of the concrete pump and conveying system is to deliver the concrete to the nozzle at the end of the shotcrete boom conveyed through steel elbows, reducers, and rubber hoses. These delivery line components wear over time and require regular inspection and replacement to ensure safe and productive operation.

In some cases, the concrete pump is mounted on a separate carrier from the boom. In this case, the pump is either a stand-alone pump or may be mounted on the concrete truck delivering the concrete.

BOOM MANIPULATOR

Mechanical shotcrete booms have joints or knuckles that allow them to collapse into a small package to reduce the overall size during transportation and to avoid damage while allowing complete coverage of large tunnels and mine cross-sections when unfolded.

The shotcrete boom manipulator is operated by a qualified nozzleman with a remote control whose primary function is to maintain the boom at a proper distance and angle from the receiving substrate. The nozzleman controls the concrete pump output rate, compressor operation, and accelerator dosage rate. The nozzleman can also operate a high-pressure water nozzle or hydro-scaler (which is a specialty tool option) to ensure the substrate is free of any loose materials, diesel particulate matter and dust and is sufficiently wet before shotcreting. Optimal bond between the shotcrete and substrate is achieved when the substrate is clean and wetted to a saturated surface dry condition.

NOZZLE MANIPULATOR

At the end of the boom manipulator, the nozzle body allows a mixture of air and liquid accelerator to be introduced into the concrete flow and propel the mixed materials at high velocity out the nozzle. Then, the nozzle body and tip direct the shotcrete towards the substrate at speeds of up to 100 ft/s (30 m/s) ensuring good compaction and bond to the substrate. A certain amount of rebound (5 to 20% of the overall shotcrete volume in wet-mix shotcrete) is normal and to be expected when applying the initial layer of shotcrete onto the substrate as the cement coated aggregates bounce off the hard surface leaving cement paste on the substrate. Subsequent passes of shotcrete build layers of the full concrete mixture onto the substrate. Generally thicker single-pass layers can be applied by mechanical sprayers as compared to hand application. Rebound of hand application by dry-mix method can range from 15 to 35% of the shotcrete volume applied. To provide an even distribution of the shotcrete and accelerator, the nozzle is typically rotated with a continuous circular motion around the central axis of the nozzle.

ACCELERATOR SYSTEM

At the nozzle, the pumped concrete becomes sprayed concrete or shotcrete with addition of a mixture of compressed air and liquid accelerator. The accelerator dosage is typically computer monitored and controlled. A constant accelerator dosage based upon the concrete's mixture design cementitious content, is maintained by the accelerator pump rate and adjusted to the concrete pump rate.[4]

The chemical additive or accelerator pump is a very important and critical component of either manual or mechanized shotcrete spraying process. When working properly and in synchronization with the concrete pump output, it is a very effective means of applying thick layers of sprayed concrete on the walls and roof of tunnels, mine drifts and other underground openings. Also, close calibration and synchronization of accelerator and concrete pumps provides higher and more consistent shotcrete early strength values.

Two common types of accelerator pumps are: peristaltic (also known as hose pumps) and positive displacement (also known as rotor-stator or Moyno pumps). Rotor-stator pumps are more accurate than peristaltic pumps but both are widely used.

Tanks holding accelerator are typically mounted on the carrier. Larger shotcrete tunnel sprayers will have a plastic tote or IBC (intermediate bulk container) which will hold typically 275 or 330 gal (1040 or 1250 l). Smaller units typically have a metal tank. Accelerator tanks can be made of plastic, mild steel, or stainless steel. Mild steel tanks can be lined with plastic to protect the metal from corrosion. Accelerator tanks should be vented. Stainless steel tanks are recommended for alkali-free accelerators.

REMOTE CONTROL UNITS

The nozzleman operates the boom and all other functions of the shotcrete process utilizing a joystick box that is either connected to the sprayer via cable or, more commonly, linked by radio control. The remote-control unit offers the nozzleman complete freedom and flexibility of boom movement in all directions[1]. Also, radio control units provide no tripping hazard when compared with cable connected units.

The use of the remote control allows the nozzleman to operate the equipment from a safe distance that still provides good visibility of the operation and a safe working environment for the nozzleman.

SENSORS AND DATA GATHERING

Many component options are available for mechanized shotcrete sprayers such as the hydro-scaling nozzle.

As indicated in the Accelerator System section, sprayers can be equipped with smart systems that help synchronize the pumping of the concrete with the dosing of accelerator. This is done to reduce pulsation and to avoid overdosing of accelerator into shotcrete at the nozzle. Overdosing of accelerator greatly reduces the strength of the shotcrete.

Another productivity tool available for sprayers is a scanner unit which is mounted in the front of the machine. It can map the receiving substrate before and after shotcreting to provide immediate shotcrete thickness and applied volume information. It gives the operator a color-coded 3-D view of the tunnel distinctively showing where application thickness has been less than desirable so nozzleman can address the issue by applying a remedial layer without delay. Scans can also be uploaded and included in as-built drawings.

Also available are intelligent spraying systems that automate some of the functions the operator must perform such as standoff distance from the substrate and maintaining the angle of nozzle 90° to the substrate. Ultimately a truly mechanical applicator using artificial intelligence is envisioned for the future.[1]

2. CONCRETE HAULERS -

Shotcrete support equipment, which is also known as the "remix truck" or "underground concrete transport," is used to bring concrete to the shotcrete sprayer. It can be a standard ready-mix truck if the tunnel's cross section dimensions are sufficiently large. The remix truck might also be used to transfer accelerator and form oil to the sprayer. Form oil helps to keep the boom and other sprayer parts free of shotcrete overspray and rebound and reduce maintenance issues. Form oil is applied at the beginning of shift and removed by pressure washing at end of shift. It helps to keep equipment free of hardening concrete as soon as possible.

In special cases, the concrete pump is also mounted on the concrete hauler and is not installed on the boom carrier. Also, there are a couple of units available on the market where the shotcrete hauler and sprayer are combined into a single unit.

EQUIPMENT OPERATION CONSIDERATIONS

A clean substrate, free of loose material, dust, rebound, and diesel particulates is critical for proper bonding between shotcrete and the substrate and to minimize fall out.

Selection of a suitable concrete mixture for shotcrete placement is critically important for a successful outcome in either manual or mechanical shotcrete applications.

As previously mentioned, there are a few reputable sprayer manufacturers offering different equipment package options to choose from. The choice of equipment depends on the project shotcrete specifications, required boom reach, application rate, shotcrete thickness, power availability, size of underground openings, distance to batch plant, and many other factors.

Operators need to be trained in the proper use of the equipment before the project starts. Ideal training involves shooting mockups of simulated underground headings and panels on the surface. ACI Shotcrete Nozzlemen certification in the shotcrete process (wet-mix or dry-mix) and orientation (vertical and overhead) is recommended for operators or operator trainers. Nozzlemen need to have a minimum of 500 hours of nozzle experience (with at least 200 hours of the total with hand nozzling) before applying for ACI certification. Hand application experience helps nozzlemen to learn the fundamentals of shotcrete placement that can then be applied when using mechanized shotcrete sprayers. Large projects typically hire certified trainers to spend time with new nozzlemen for several shifts and up to a couple of weeks depending on the crew size and project needs.

RECOMMENDATIONS FOR THE CONTRACTOR

When considering hand versus mechanical application of shotcrete, contractors should consider operator fatigue, dust, visibility, equipment safety components, equipment maintenance requirements, and equipment quality of manufacturing among other factors.

Also, they should take into consideration that the cost of mechanized sprayers is much higher than that of hand spraying equipment. Thus, factors including output requirements, single or multiple headings, shotcrete liner thickness, and others project specific considerations must be evaluated prior to deciding on manual versus mechanized systems.

Finally, for the reasons previously discussed, nozzlemen training is one of the most important aspects of mechanized shotcrete spraying. Thus, it is recommended that nozzlemen have handheld experience prior to performing mechanized shotcrete spraying. The operator with hand-held experience will have a better appreciation and understanding of what is required to consistently achieve a high quality shotcrete installation.

RECOMMENDATIONS FOR THE OWNER

Designers and owners need to keep up with the state-of-the-art and latest developments of mechanized shotcreting. There are several recent developments, such as final tunnel lining with shotcrete or composite liners (for example, shotcrete-sprayed waterproofing-shotcrete), that can reduce overall cost and project timeline. Also, utilizing a scanner can ensure the proper thickness is applied and mapped while reducing over spraying and shotcrete material costs.

CONCLUSIONS

Increasingly, mechanized shotcreting in underground projects is replacing manual shotcrete application with leading reasons including higher safety and productivity coupled with a lower cost of in-place shotcrete. Technological advancements are continually improving mechanized spraying. The overall goal is automating the shotcrete process as much as possible and keeping the operator safe while producing a high-quality shotcrete placement. Until a fully autonomous automation system is developed, the well trained nozzleman remains a very important component of the shotcrete process.

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References

1. Lacerda, L. and Koivisto, M., "Towards Automated Concrete Spraying," Shotcrete Magazine, Fall 2018, 3 pp.

2. ASA Underground Committee, "Position Statement #1, Spraying Shotcrete Overhead in Underground Applications," American Shotcrete Association, Nashville, TN, 2019, 3 pp.

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

4. Zhang, L., "Accelerator Dosing Pump Calibration and Verification," Shotcrete Magazine, Summer 2012, pp 42-44 pp.

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The Value of VR Training for Today's Shotcrete Nozzlemen

By Matthew Wallace

Recruiting, training, and retaining skilled shotcrete nozzlemen is mission-critical for a company's success. Virtual, immersive training offers an effective, engaging mode of learning that supports the modern trainee. For beginning nozzlemen, virtual reality training gives them a safe, repeatable experience that can be completed in a classroom, free of job costs. Practice without cost or risk also helps improve job performance and satisfaction. These disruptive virtual reality (VR) technologies can provide safe, hands-on learning experiences without the field costs associated with hands-on training. Virtual learning is also valuable in today's socially distanced world with its shifting remote learning requirements. Interactive digital tools will deliver meaningful, adaptive training for skilled trades now and in the future. Though some level of hand nozzling experience is still needed the best nozzlemen will be trained, in part, using virtual reality.

Blending virtual reality with traditional learning is a great option because it combines the best of "tried and true" education methods with innovative and engaging training experiences. While cost-effective, textbooks and manuals fail to teach the nuance and awareness required for complex, hands-on skills. Replacing dull and unimaginative text with immersive learning creates high-retention experiences that engage the trainee both physically and mentally. Learning becomes practical, experiential, and immediate. Virtual training methods fuse the benefits of simulated hands-on, apprenticeship-style training with the traditional pedagogy available in printed training resources. This blended learning approach merges the best parts of traditional training methods with effective, experiential learning.

Virtual reality is a more engaging option because it uses technology to enhance training insights and functions in real-world contexts. Virtual and augmented reality (or mixed reality) provide experiences that make learning visual, interactive, and compelling. The technology enhances a training program's ability to expose trainees to practical challenges in a consequence-free environment. Virtual training is an accessible and practical alternative when working with real-life situations could be expensive, wasteful, or dangerous. Nozzlemen can practice on a virtual model of the next project without cost or consequence. Furthermore, trainers will be able to analyze trainee performance with objective data showing performance time and quality. The new data provides instructors insights for tracking student progress and points out specific skills deficiencies of the individual trainee. The instructor can then provide specific lessons and cues to remedy the trainee's performance.

Other industries have used virtual training for precision skills training. In manual arc-welding, Lincoln Electric's VRTEX® provides a virtual training experience for trainees with instant and aggressive feedback on their weld performance (Fig. 1). Trainees learn how to set up a welding machine, adjust gas flows, strike an arc, and construct and manipulate a weld puddle to create a quality weld. The virtual experiences develop a cognitive link between torch movement, body position, and correct machine settings. The student learns what to do and what it feels like fusing their practical knowledge with effective torch manipulation and body positioning. The trainee learns by doing, with virtual reality enhancing, every facet of a trainee's practice.

But, can virtual reality train a better welder? Research confirms that this fusion of practical and pedagogical knowledge works. A 2013 University of Iowa study[1] compared a blended training approach (50% virtual and 50% traditional) with traditional training methods. Each student completed weld projects, developed muscle memory, and learned how to create correct welds. As expected, in simulation-based activities, the blended training students consumed fewer raw materials. At the study's conclusion, all the students went into the weld booth and made test welds. These welds were then sent to certified welding inspectors for review. The certification rates for the VR students surpassed those of their traditionally trained counterparts by more than 40 percent, and they showed a greater proficiency with more difficult welds. The study also pointed out an unexpected side benefit of the VR approach. The students all showed an increased rate of collaborative learning and open communication. The VR trainees achieved a deeper understanding of the welding processes and a stronger ability to convey that understanding to their instructors.

Similar results can be found in painting and sandblasting. VRSim's SimSpray® is a virtual reality spray paint and blasting training system (Fig. 2). Through SimSpray, coatings professionals gain hands-on experience and develop transferable skills that prepare them for real-world projects. Custom lessons provide paint trainers and trainees with feedback and visual cues that aid students in learning how to paint walls or sandblast bridge components (Fig. 3). Students receive feedback including the depth of coverage or known defects caused by failures in their technique.

Fig 1 - VRTEX VR Welding Training

Would virtual training work for shotcrete? The techniques required for high-velocity spraying of concrete has characteristics in common with abrasive blasting and painting. Nozzlemen must know the basic formwork for the underlying shotcrete structure, how to manage their equipment and material mix, and the proper application techniques. Traditional training methods include basic theory and principles but rely on hands-on experiences to teach nozzlemen-in-training. Virtual training can help nozzlemen gain basic skills faster and better.

Virtual training could supplement current training with engaging and interactive experiential challenges. Nozzlemen can learn by doing in a safe virtual environment, reducing waste and gaining technique. Virtual systems will provide objective feedback. With a standardized rating system in place, trainers can set consistent benchmark standards for progression and differentiate the adequate from the exceptional. Using the virtual environment affords trainers the opportunity to augment training with cues to guide performance and provide analysis tools that assess a trainee's progress. Performance scores will assess everything from the trainee's speed, distance, and angle, to their time on the project and the amount of material used to complete it.

VR training tools would offer a safer learning experience and minimize the potential negative impact on job quality from on the job training. With such a high-velocity material application, poor application form and low equipment awareness can create dangerous worksite conditions. Teaching these principles in virtual environments mitigates the risk of teaching them on a live worksite, leading to improved on-site performance and less rework. These components combined will improve the skills of nozzlemen throughout the industry, improving quality and making worksites safer.

Fig. 2 - Sim Spray - Coating VR Training

VR training is more than a simulation; it's a training tool for trainees and trainers alike. Immersive, problem-based training methods create opportunities that leverage natural learning experiences and foster improved team communication skills. Projects set clear goals and challenge trainees with realistic work while the immersive and experiential nature of the tasks promotes sharing tips and discussing challenges. As trainees progress through projects, they work independently and collaboratively to overcome skill gaps. Trainees are given accessible and repeatable learning experiences for their core job skills and to improve the soft skills that create strong teams. Furthermore, training creates competition among students, reinforcing a trainee's competitive drive to excel. Performance scores mark individual progress while setting a bar for the next trainee to surpass. The same psychology that gets people to brag about their high scores can motivate trainees to practice. Guided repetition is the mother of skills expertise.

Trainers are empowered by the VR training tool's capacity to reduce their more tedious tasks and inform them with performance data. For trainers, the use of simulations with objective scoring creates more trainee engagement and tracks skills development. The trainers will diagnose student strengths and weaknesses and be able to supplement trainee curricula to strengthen the related skills. Realistic scoring systems grade project performance and allow graduated and adaptable learning progressions.

Training managers can make clearer decisions through objective performance data. The ability to evaluate trainee skills with measurable comparison data provides insight into the performance of an individual student and creates a quantifiable demonstration of the effectiveness of the enterprise's training efforts. This information affords the manager and organization the ability to make informed, data-driven decisions about teams and training programs.

Disruptive technologies may be easy to use, but they require programmatic implementations to realize their full potential. For them to be effective, the organization must commit to incorporating virtual training into its curriculum.

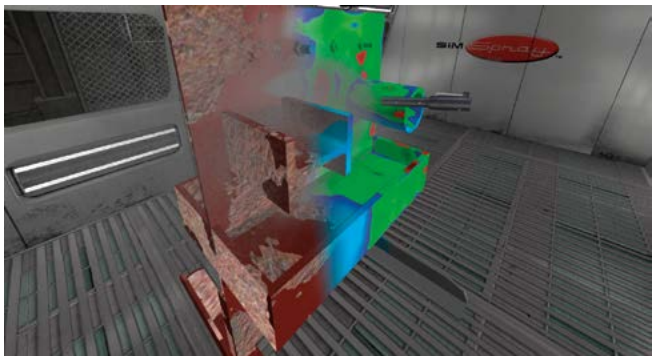

Fig. 3 - Visual feedback during VR training

Putting disruptive technologies like virtual training into practice requires consideration and planning. While cost is a consideration, the company must invest in systemic change, accepting the costs of adapting to a new way of thinking and a new way of training. Training the trainers is essential.

With a rapidly changing workforce, there is no more effective, or efficient way to train. The best shotcrete nozzlemen of tomorrow will have learned the basics of their job using virtual reality to supplement their classroom learning.

1. Stone, Richard T.; McLaurin, Elease; Zhong, Peihan; and Watts, Kristopher Patrick. (2013). Full Virtual Reality vs. Integrated Virtual Reality Training in Welding.

Matthew Wallace *is a recognized expert in the practical and cost-effective business applications of virtual reality. As CEO and President, Matthew leads and represents VRSim as it pioneers applications of cutting-edge technologies in skilled trades and education. Matthew joined VRSim in 2001 and has forged relationships with industry leaders like the Lincoln Electric Company, NTEA: The Association for the Work Truck Industry, product manufacturers, and fellow technology innovators.*

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Compliant Air Guns for Shotcrete

By Yann Curtis and Jordan Kozub

"Your blow pipe is not OSHA compliant and you must stop shotcrete work until it's replaced. You need a dead man trigger." - Job Site Safety Officer

Shotcrete operations with compliant air gun.

Our experience wasn't quite this abrupt, but it did prompt us to research and find safer air lances that are readily available on the market. And guess what? There are. We used what most consider "standard" equipment, a manually assembled air lance consisting of a ball valve for air volume control, threaded to an extension pipe, and crimped at the end for increased output pressure. (Fig. 1) With the exception of a few runaway air lances over the years, resulting in no injuries, they served us well. However, for this situation, ignorance is not bliss. It was our firm's responsibility to make things safer for our craftsmen and fellow trade partners.

Fig. 1: Non-compliant blow pipe variations.

SAFETY AIR GUN OPERATORS

It cannot be overstated just how impactful a skillful safety air gun operator can affect the quality of shotcrete placement. The removal of rebound (defined as loose aggregate not fully coated with paste) from behind reinforcing bars and against receiving surfaces drastically assists in the proper encapsulation of reinforcement and bonding of the concrete to the substrate. However, the importance of this crew member's work may often be overlooked next to the eye-catching nozzleman as concrete jettisons out the nozzle at 80 mi/hr (35 m/s). A nozzleman without a safety air gun operator working in tandem with him during shotcrete placement simply cannot be as effective.

Pistolas de aire compatibles para Shotcrete

Por Yann Curtis y Jordan Kozub

"Su tubo de soplado no es compatible con OSHA y debe detener el trabajo de shotcrete hasta que se reemplace. Necesitas un gatillo de hombre muerto."
- Oficial de Seguridad en el Sitio de Trabajo

Operaciones de concreto lanzado con lanza de aire compatible con las normas

Nuestra experiencia no fue tan abrupta, pero nos impulsó a investigar y encontrar lanzas de aire más seguras que están disponibles en el mercado. ¿Y adivina qué? Los hay. Utilizamos lo que la mayoría considera equipo "estándar", una lanza de aire montada manualmente que consiste en una válvula de bola para el control del volumen de aire, roscada a un tubo de extensión, y engarzada al final para aumentar la presión de salida. (Foto1) Con la excepción de algunas lanzas aéreas desbocarias a lo largo de los años, resultando en ninguna lesión, nos sirvieron bien. Sin embargo, para esta situación, la ignorancia no es dicha. Era responsabilidad de nuestra empresa hacer las cosas más seguras para nuestros artesanos y otros socios comerciales.

OPERADORES DE PISTOLAS DE AIRE DE SEGURIDAD

No se puede exagerar cuán impactante puede afectar a un hábil operador de pistola de aire de seguridad la calidad de la colocación del shotcrete. La eliminación del rebote (definido como agregado suelto no completamente recubierto con pasta) de detrás de las barras de refuerzo y contra las superficies receptoras ayuda drásticamente en la encapsulación adecuada de refuerzo y unión del hormigón al sustrato. Sin

Fig. 1: Diferentes lanzas de aire que no cumplen con las normas

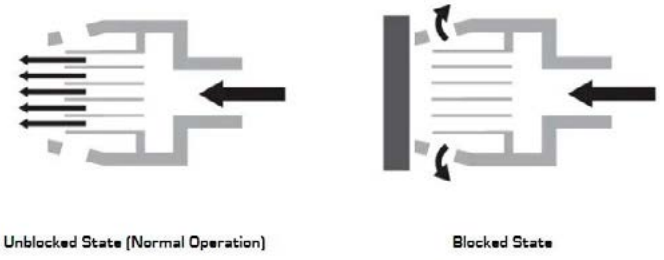


Fig. 2: Diagram of compliant blow pipes when dead ended at the nozzle.

Fig. 3: Dead-man trigger with ball valve installed for volume adjustment.

COMPRESSED AIR OSHA REGULATIONS

OSHA Standard 1910.242(b) states that "Compressed air shall not be used for cleaning purposes except were reduced to less than 30 lb/in² (0.2 Mpa) and then only with effective chip guarding and personal protective equipment (PPE)."

To further clarify the standard, the static air pressure at the nozzle shall not exceed 30 lb/in² if dead ended. An example of dead ending is when the gun tip is pressed against skin. (Fig. 2) In a properly designed safety air gun the output from the air compressor which feeds the air gun does not need the air compressor's output to be reduced below 30 lb/in².

The fees assessed by OSHA for infraction of the standard is up to $12,000 per homemade air gun in non-compliance. So it is important to become knowledgeable on the particulars as the OSHA standard can be misinterpreted by safety officers, and sometimes even OSHA inspectors. Terminology surrounding this piece of equipment, much like the term "shotcrete" for those not educated on the matter, is sometimes used incorrectly. Suppliers of compressed air tools report that "air lance" and "blow pipe" both generally indicate a non-compliant or homemade tool, while the term "safety air gun" signifies a compliant, manufactured tool. For any readers who are not under the jurisdiction of OSHA, the rationale of this ruling is still valid regardless of where the equipment is being used. Testing existing air guns for compliance with the 30 lb/in² limit is an option, although we found it more practical to simply purchase off-the-shelf, compliant products.

Finally, it should be reinforced that the standard specifically refers to the implementation of appropriate equipment safety during operation as a condition for compliance. Specifically, there are two features which address the safety considerations - the dead-man trigger and compliance with the maximum 30 lb/in² output pressure at nozzle end.

FEATURE: DEAD-MAN TRIGGER

There are several variations of a dead-man trigger on an air lance. All provide the same function. When the operator lets go of the trigger, air stops, similar to filling up your vehicle at a fuel station. This feature mitigates the chances of an unmanned loose air lance injury. A potentially restrictive issue we acknowledged immediately was the inability of a dead-man trigger to be throttled or volume-adjusted while working. Air lance operators are constantly adjusting the air volume during the job and an on/off handle wasn't going to provide that function. To implement a dead man trigger and provide the desired functionality, we installed an adjustable ball valve on the compressor-side of the trigger (Fig. 3). Doing so does not affect the safety function of the dead man trigger, nor does it make the device non-compliant.

Fig. 4: Venturi nozzle and noise reducing nozzle.

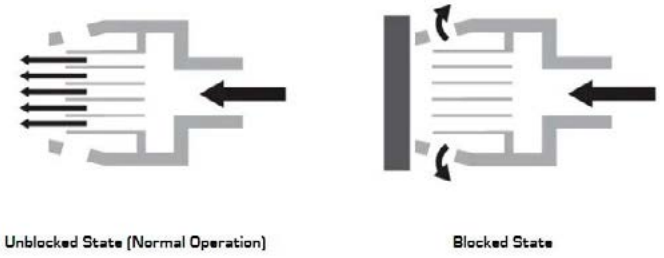


Fig. 2: Diagrama de lanza de aire aprobada cuando terminan sin salida en la boquilla

Fig. 3: Gatillo de hombre muerto con válvula de bola instalada para ajustar el volumen

embargo, la importancia del trabajo de este miembro de la tripulación a menudo puede pasarse por alto junto al llamativo boquilla, ya que el hormigón expulsa la boquilla a 80 mi/h (35 m/s). Un boquilla sin un operador de pistola de aire de seguridad que trabaja en conjunto con él durante la colocación de shotcrete simplemente no puede ser tan eficaz.

REGULACIONES OSHA DE AIRE COMPRIMIDO

La Norma 1910.242(b) de la OSHA establece que "el aire comprimido no se utilizará para fines de limpieza, excepto cuando se reduzca a menos de 30 lb/in² (0,2 Mpa) y luego solo con protección eficaz de virutas y equipo de protección personal (PPE)".

Para aclarar aún más la norma, la presión de aire estático en la boquilla no excederá de 30 lb/in² si se termina muerto. Un ejemplo de final muerto es cuando la punta del arma se presiona contra la piel. (Foto 2) En una pistola de aire de seguridad correctamente diseñada, la salida del compresor de aire que alimenta la pistola de aire no necesita que la salida del compresor de aire se reduzca por debajo de 30 lb/in².

Las tasas evaluadas por la OSHA para la infracción de la norma son de hasta $12,000 por arma de aire casera en incumplimiento. Por lo tanto, es importante conocer los detalles, ya que los oficiales de seguridad pueden malinterpretar el estándar OSHA, y a veces incluso los inspectores de la OSHA. La terminología que rodea esta pieza de equipo, al igual que el término "shotcrete" para aquellos que no están educados en la materia, a veces se utiliza incorrectamente. Los proveedores de herramientas de aire comprimido informan que la "lanza de aire" y la "tubería de soplado" generalmente indican una herramienta no conforme o casera, mientras que el término "arma de aire de seguridad" significa una herramienta fabricada y compatible. Para los lectores que no están bajo la jurisdicción de OSHA, la justificación de esta resolución sigue siendo válida independientemente de dónde se utilice el equipo. Probar las pistolas de aire existentes para cumplir con el límite de 30 lb/in² es una opción, aunque nos pareció más práctico simplemente comprar productos listos para usar y compatibles.

Por último, debe reforzarse que la norma se refiera específicamente a la implementación de la seguridad adecuada del equipo durante el funcionamiento como condición para el cumplimiento. Específicamente, hay dos características que abordan las consideraciones de seguridad: el disparador del hombre muerto y el cumplimiento de la presión de salida máxima de 30 lb/in² al final de la boquilla.

CARACTERÍSTICA: DEAD-MAN TRIGGER

Hay varias variaciones de un gatillo de hombre muerto en una lanza de aire. Todos proporcionan la misma función. Cuando el operador suelta el gatillo, el aire se detiene, similar al llenado de su vehículo en una estación de combustible. Esta característica mitiga las posibilidades de una lesión no tripulada de lanza de aire suelta. Un problema potencialmente restrictivo que reconocimos inmediatamente fue la incapacidad de un disparador de hombre muerto para ser limitado o ajustado por volumen mientras se trabaja. Los operadores de lanzas de aire están ajustando constantemente el volumen de aire durante el trabajo y un mango de encendido/apagado no iba a proporcionar esa función. Para implementar un gatillo de hombre muerto y proporcionar la funcionalidad deseada, instalamos una válvula de bola ajustable en el lado del compresor del gatillo (Foto 3). Si lo hace, no afecta a la función de seguridad del gatillo del muerto, ni hace que el dispositivo no sea conforme.

Fig. 4: Boquilla Venturi y boquilla reductora de ruido

FEATURE: 30 LB/IN² OUTPUT PRESSURE AT NOZZLE END

The use of a home-made, non-compliant air lance that does not feature a 30 lb/in² dead-end pressure release nozzle, or "venturi" nozzle, has been a common practice for years. The dangers of using home-made air lances can result in serious injury such as the exposure of open cuts to powerful compressed air, air embolisms to the skin and inner body, and in some extreme cases there have been recorded fatalities.

Utilizing an OSHA compliant nozzle that reduces the pressure to 30-lb/in² or less when pressed against the skin has two major benefits. The most important benefit is improved safety to avoid injuries. Another benefit is cost savings, as venturi nozzles are engineered to be more efficient. This is due to the orifices in the nozzle which take in outside air when being used, producing increased thrust for the air gun, and less air coming directly from the compressor, resulting in compressed air cost savings over time.

OTHER BENEFITS OF COMPLIANT SAFETY AIR GUNS

Using OSHA-compliant safety air guns on our shotcrete projects came with some additional, unforeseen benefits. Our crews are oftentimes using air guns for 6 to 8 hours per day, so favorable ergonomics, ease of use, and handling of equipment are paramount. Workers will face less strain, thus maintaining work efficiency throughout the day. The ergonomics of safety air guns are established through comfortable trigger assemblies, as well as suitable grips for workers to hold the tool as needed in various positions as the job warrants.

Another benefit is noise reduction when using complaint air guns. We exchanged venturi nozzles with noise-reducing nozzles that lower the sound level in use from 130dB to 101dB (Fig. 4). These noise-reducing nozzles consist of a circular array of 93 raised, miniature nozzles surrounded by a safety shroud. The geometry and spacing of these "nozzlettes" has been optimized to maximize air flow and reduce noise-inducing turbulence. The result is a column of high flow air that delivers superior thrust at greatly reduced noise levels. We found this as a noticeable and advantageous difference that not only improves safety measures (noise exposure), but also maintains team morale as communication and work can proceed more easily through the course of a workday.

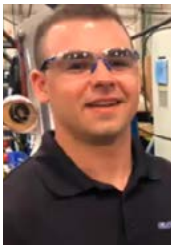
Manufactured air guns are more durable and last longer than homemade blow pipes. The trigger valves have not needed to be replaced or fixed due to leaking air. We expect these to last years without issues when properly maintained.

Finally, we found a noticeable improvement in the care and handling of the air gun compared to the non-compliant equipment. Manufactured air guns are more refined, both physically and visually. There's now a renewed respect for this important piece of equipment on the job site. Increased efforts are taken when handling the gun when in use as well as during regular maintenance.

SUMMARY

Habits are sometimes hard to break, but safety should always prevail. Our firm is pleased with these compliant, and yes, even improved safety air guns we've purchased for our crews (Fig. 4). Compliant air guns come at a higher cost compared to those that we as an industry have been accustomed to. However, they are a worthy investment, and one that not only has a significant impact on the quality of your work, but also on the safety of your employees and those around them. In summary, supply your crews with manufactured, guaranteed compliant safety air guns. Furthermore, educate your team about the dangers of homemade air guns or the manipulation of safety air guns, as part of your regular safety meetings.

Yann Curtis, *Vice President of CCP Shotcrete based in Austin, Texas, leads business development efforts and serves as Preconstruction Project Manager. Curtis frequently educates engineers, contractors, and project owners on shotcrete as a valuable alternative to cast concrete. Curtis is an ACI Certified wet mix nozzleman in the vertical and overhead positions who places a priority on being active in the field during technical projects. Curtis also serves as Vice President of SPA Skateparks, a design-build firm of poured in place skateparks for municipalities.*



Jordan Kozub, *Business Development Representative at Guardair Corporation based in Chicopee, MA, specializes in safety air gun OSHA compliance and has served as a safety consultant for companies across North America. Kozub has also created and implemented air gun safety procedures for corporate safety teams of numerous Fortune 500 Companies. Jordan spends most of his time in the field doing hands-on training and simulated OSHA audits, where he educates teams on safety and cost-saving alternatives.*

CARACTERÍSTICA: 30 LB/IN² PRESIÓN DE SALIDA AL FINAL DE LA BOQUILLA

El uso de una lanza de aire casera no conforme que no cuenta con una boquilla de liberación de presión de 30 lb/in², o boquilla "venturi", ha sido una práctica común durante años. Los peligros del uso de lanzas de aire caseras pueden resultar en lesiones graves como la exposición de cortes abiertos al aire comprimido potente, embolias de aire en la piel y el cuerpo interno, y en algunos casos extremos se han registrado muertes.

El uso de una boquilla compatible con OSHA que reduce la presión a 30 lb/in² o menos cuando se presiona contra la piel tiene dos beneficios principales. El beneficio más importante es la mejora de la seguridad para evitar lesiones. Otro beneficio es el ahorro de costos, ya que las boquillas venturi están diseñadas para ser más eficientes. Esto se debe a los orificios de la boquilla que toman aire exterior cuando se utilizan, produciendo un mayor empuje para la pistola de aire, y menos aire proveniente directamente del compresor, lo que resulta en ahorros de costos de aire comprimido con el tiempo.

OTROS BENEFICIOS DE LAS PISTOLAS DE AIRE DE SEGURIDAD CONFORMES

El uso de pistolas de aire de seguridad compatibles con OSHA en nuestros proyectos de shotcretes vino con algunos beneficios adicionales e imprevistos. Nuestras tripulaciones a menudo utilizan pistolas de aire durante 6 a 8 horas al día, por lo que la ergonomía favorable, la facilidad de uso y el manejo del equipo son primordiales. Los trabajadores se enfrentarán a menos tensión, manteniendo así la eficiencia del trabajo durante todo el día. La ergonomía de los cañones de aire de seguridad se establece a través de cómodos conjuntos de gatillo, así como agarres adecuados para que los trabajadores mantengan la herramienta según sea necesario en varios puestos como lo garantiza el trabajo.

Otro beneficio es la reducción de ruido cuando se utilizan pistolas de aire de queja. Intercambiamos boquillas venturi con boquillas reductoras de ruido que reducen el nivel de sonido en uso de 130dB a 101dB (Foto 4). Estas boquillas reductoras de ruido consisten en una matriz circular de 93 boquillas en miniatura elevadas rodeadas por una cubierta de seguridad. La geometría y el espaciado de estas "boquillas" se han optimizado para maximizar el flujo de aire y reducir la turbulencia que induce ruido. El resultado es una columna de aire de alto flujo que ofrece un empuje superior a niveles de ruido muy reducidos. Encontramos esto como una diferencia notable y ventajosa que no sólo mejora las medidas de seguridad (exposición al ruido), sino que también mantiene la moral del equipo, ya que la comunicación y el trabajo pueden proceder más fácilmente a lo largo de una jornada laboral.

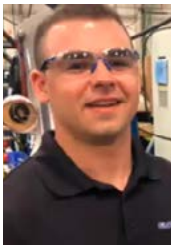
Las pistolas de aire fabricadas son más duraderas y duran más que las tuberías de soplado caseras. Las válvulas de disparo no han necesitado ser reemplazadas o fijadas debido a fugas de aire. Esperamos que estos duren años sin problemas cuando se mantengan adecuadamente.

Por último, encontramos una mejora notable en el cuidado y manejo de la pistola de aire en comparación con el equipo no conforme. Las pistolas de aire fabricadas son más refinadas, tanto física como visualmente. Ahora hay un renovado respeto por este importante equipo en el sitio de trabajo. Se realizan mayores esfuerzos al manipular el cañón cuando se utiliza, así como durante el mantenimiento regular.

RESUMEN

Los hábitos a veces son difíciles de romper, pero la seguridad siempre debe prevalecer. Nuestra firma está satisfecha con estas normas, y sí, incluso con pistolas de aire de seguridad mejoradas que hemos comprado para nuestras tripulaciones. Las pistolas de aire compatibles tienen un costo más alto en comparación con las que nosotros como industria estamos acostumbrados. Sin embargo, son una inversión digna, y una que no sólo tiene un impacto significativo en la calidad de su trabajo, sino también en la seguridad de sus empleados y los que los rodean. En resumen, suministre a sus tripulaciones pistolas de aire de seguridad fabricadas y garantizadas. Además, educa a tu equipo sobre los peligros de las pistolas de aire caseras o la manipulación de pistolas de aire de seguridad, como parte de tus reuniones de seguridad regulares.

Yann Curtis, *Vicepresidente de CCP Shotcrete con sede en Austin, Texas, dirige los esfuerzos de desarrollo de negocios y sirve como Gerente de proyecto de Preconstrucción. Curtis educa frecuentemente a ingenieros, contratistas y dueños de proyectos en el concreto lanzado como una alternativa valiosa al concreto convencional. Curtis es un nozzleman de mezcla húmeda certificado por ACI en las posiciones vertical ysobrecabeza que da prioridad a ser activo en el campo durante los proyectos técnicos. Curtis también se desempeña como Vicepresidente de SPA Skateparks, una firma de diseño-construcción de skateparks para los municipios.*



Jordan Kozub, *Representante de Desarrollo de Negocios en Guardair Corporation con sede en Chicopee, MA, se especializa en el cumplimiento de la OSHA de las armas de aire de seguridad y ha servido como consultor de seguridad para empresas en toda América del Norte. Kozub también ha creado e implementado procedimientos de seguridad de lanzas de aire para equipos de seguridad corporativos de numerosas compañías Fortune 500. Jordan pasa la mayor parte de su tiempo en el campo haciendo entrenamiento práctico y simulando auditorías de OSHA, donde educa a los equipos en seguridad y alternativas que ahorran costos.*

Dry-mix Shotcrete Equipment Safety

By Mason Guarino

Construction safety is something that is talked about a lot, however it is not always followed in day-to-day work as it should be. I recently had the opportunity to work with a Civil contractor that not only talks the talk and walks the walk, but most importantly, sticks to it. Currently on this project, everyone is required to wear hard hats, ANSI 2 vests, pants, safety toe boots, safety glasses, gloves, and masks 100% of the time when on site. Everyone on site participates in this safety plan and reminds each other if they are missing something. It is a culture of safety that is enjoyable to be around because everyone is on the same page with no exceptions. Unfortunately, you can still see current YouTube videos and other social media posts with shotcrete crews, even nozzlemen, not wearing safety glasses. If you look at videos from some other parts of the world you may even see crews wearing short shorts, even the nozzlemen. Other than that, they do seem to be working safely, but I will never understand shorts while shooting. When you look back a few decades it was not uncommon for a residential dry-mix shotcrete crew to have a cooler full of beer on their truck. Luckily, things have changed, and most crews have at least a basic safety program and most follow it.

Fig. 1: Gunite gun opened

Dry-mix shotcrete equipment is quite different when compared to wet-mix shotcrete equipment. Wet-mix shotcrete equipment is essentially concrete pumping with smaller line pumps and thus is in much wider use than dry-mix shotcrete. No other trade or industry uses a dry-mix shotcrete gun. Though the dry-mix gun is smaller than a wet-mix pump it should not be taken for granted, especially when it can take off a finger and shoot it across the site if the crew member working on it is not careful. And yes, unfortunately this has happened.

Dry-mix shotcrete materials can be delivered with a volumetric truck, ready-mix truck or in prepackaged bags on a flatbed truck or trailer. The flatbed typically is not a danger to the crew since usually they are not on site when the materials are delivered. Ready-mix trucks are straight forward and some operators like to swing their chutes around. With a dry-mix material delivery the discharge chute is typically as short as possible and doesn't need to move much. Volumetric trucks probably pose the most danger to the shotcrete crew as it is not uncommon for a safety guard to be left uncovered after a quick repair in the field. Experienced crews have extra gears and chains along with other miscellaneous items in the back of a crew truck to keep the equipment running throughout the day. The easiest and most positive step to ensure the volumetric trucks are safe, is to not operate them with the guards removed. Always reinstall them before starting production so that nothing, like clothing or hands, gets caught in the exposed machinery. Augers, belts, and chains all pose "caught inside" hazards. It is important to make sure that new drivers or operators are aware of the dangers inherent in the truck machinery before they are asked to operate the volumetric truck. Keep it simple, keep it safe - always keep guards and covers installed during production.

Operating dry-mix shotcrete guns can be hazardous to the gunman in a couple of ways - during maintenance of a gun and when the gun is not running properly. When material isn't flowing

smoothly through the hopper the gunman may be tempted to remove the grate on top of the gun. It is never a good idea to remove or disable a safety feature. It is there for your safety!

Overly wet or overly dry material can increase the danger of a dry-mix gun operation. When the sand is too wet it will build up in the hopper and sometimes create a void between the shotcrete material in the hopper and the bowl. This may tempt the operator to stick things down in the gun to get shotcrete material moving. However, this type of problem will just keep occurring, negatively affecting production as well as material quality. The best solution is to resolve the wet sand issue before trying to shoot.

When sand is too dry it can make the dry-mix gun a dusty mess creating an inhalation hazard. Too dry material can also allow a build-up of static charge through the delivery hose that may temporarily affect the nozzleman's ability to hold onto the hose. Having been on the receiving end of a shock from dry material I can admit it is scary. When it first starts, it is confusing as your hands just feel tense and strange then it builds fast and continues and it can even be difficult at times to signal to shut the gun down while your hands and legs are getting electrical shocks. Keeping the sand at the proper moisture content or having static control hoses and dust mitigation systems when using dry sand or prebagged materials can prevent these safety issues.

A pre-dampener can be used to help slightly moisten prepackaged materials to control dust and static build-up. However, be careful because some prebagged materials include rapid-set accelerators and the pre-dampening can cause different issues. Hoses with grounding wires can be connected to the gun where it is grounded. There are also dry-mix hoses available that dissipate static charges so the nozzlemen doesn't feel them. Both methods to control static build-up work well.

When maintaining a dry-mix gun it is good practice to disable the drive mechanism to the gun whether it be air or hydraulic driven. There is typically at least a secondary valve that can be shut, or during more extensive gun maintenance, just disconnect the power supply from the gun.

Delivery line plugs are scary with wet-mix and dry-mix shotcrete. The plugs are different on both and with lots of experience on the nozzle of both wet-mix and dry-mix I find dry-mix plugs to be more frightening. Wet-mix plugs are quick and explosive but then the event is over. Dry-mix plugs allow air pressure to build quickly behind them reaching the pressure the air compressor is rated for. Since air compresses when the plug releases, it pops, and then you feel the air flow and pressure building at the nozzle. This can cause the nozzleman to lose control of the nozzle. It can knock a 250 lb (113 kg) nozzlemen over easily. As the nozzlemen, gun operator, or crew member if you see the material flow from the nozzle stop when it is not anticipated, the gun needs to be shut down immediately. Most of the time the plug will develop at the goose neck area of the gun from buildup of material around the surface but sometimes it can be in the delivery line. Once air flow and pressure to the nozzle is cut off, you should walk the delivery line from the nozzle end back toward the gun. Typically, you can find a hard part in the hose and in many cases, it is near a coupling. Once the location of the plug is identified it can be broken up with a hammer. I prefer to use a framing hammer instead of a sledgehammer because you can lightly tap to break up the plug as opposed to a sledgehammer which has a much higher chance of damaging the hose. Once the plug is located and broken up, disconnect the closest coupling and shake what you can out of the hose. Then run air through the hose slowly at first to confirm the plug is freed. Once it is cleared the air can be ramped up to continue to clear the line. If the plug persists, repeat the plug identification steps. If the plug is from a hose that was left unclean and has hard half-moons of hardened concrete in it, it can be more difficult to clear. Rolling the hose around and hitting it with a hammer while shaking out the ends can help but it may not get the last few blockages out. I have worked closely with the gun operator while running a slow amount of air through the line and hitting the hose at the same time. This should dislodge any hard pieces and allow them to slowly move down the hose. If the hose stops allowing a small amount of air through, shut the gun down immediately to eliminate the potential to buildup pressure in the line and move forward shaking and hitting the hose clean. If wet sand is used, it is good to end every day by leaving the air running and hammering the hose starting at the nozzle and working your way back to dislodge anything that has built up in the hose. This is more common when using smaller hoses, but it benefits larger hoses as well.

My last safety tip goes to the new laborers removing rebound. When shoveling out of a pool or over a wall, always keep your back to the wall that you are shoveling up or over, this position works your back muscles in a safer and more natural manner than if you are facing the wall.

Shotcrete safety should be taken seriously by the whole crew, from the new laborers shoveling up rebound to the experienced shotcrete crew members. When necessary, wear safety glasses and respirators and look out for those around you. It is easy for someone to forget their safety glasses and hard hat after lunch or after a break. Help them remember that they forgot their safety gear.

Mason Guarino *started in the pool industry when he was 14, learning how to install reinforcing bars. Since then, he has worked on all phases of swimming pool construction. Guarino has been with South Shore Gunite Pools & Spas, Inc., full-time since graduating from the Wentworth Institute of Technology with his BS in construction management in 2009. Guarino currently serves as Treasurer on ASA's Executive Committee, Chair of the ASA Pool & Recreational Shotcrete Committee, and is an ACI Certified Nozzleman.*

Technological Developments in Shotcrete Spraying

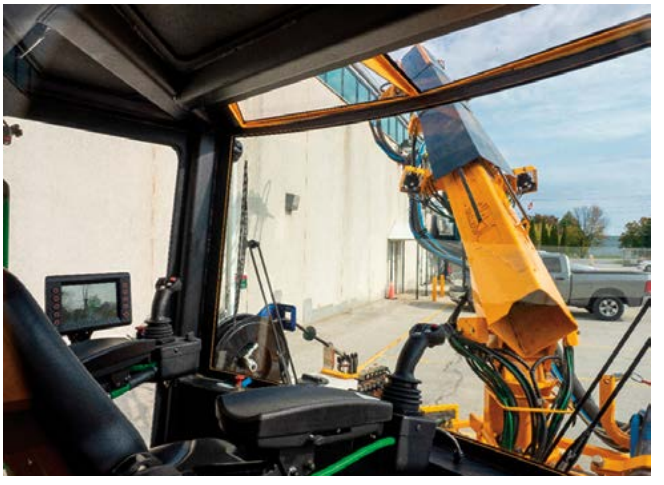
By Dan Millette and Jonathan Lavallee

Shotcrete spraying machines have evolved rather slowly over the years with major improvements being in the concrete pumps, water scalers on the booms and remote-control systems. However, over the last few years, there have been some major advances in helping operators do a better and safer job. One of these developments is thickness monitoring systems. Normet and Jaycon have different systems that they have been using for a few years now with some success. This is becoming a requested option on many machine orders, and rightfully so, as it allows the operator to apply enough concrete to offer adequate strength while not over-applying and wasting concrete. It also eliminates the need to apply manual/mechanical thickness monitoring devices or trying to measure the thickness of freshly placed concrete, which both constitute a safety hazard due to the potential to be under unsupported and lose ground.

MacLean Engineering has been manufacturing shotcrete sprayers and mixers for the mining and tunneling industries for several years and have just finished building and testing a new prototype sprayer with advanced safety features. We have been developing a real-time 3D thickness monitoring system so that the operator does not need to spray, scan, and wait for results before going back over the missed or deficient areas. There have also been requests from several companies for a machine that does not require the operator to leave the ROPS/FOPS cab to spray, thus supporting the No-Boots-on-the-Ground initiative within the industry.

The biggest challenge with spraying from the cab is for the operator to physically see what is being sprayed. This new machine moves the cab forward for increased visibility of the tunnel section. Other enhancements to visibility include an operator's seat that can move horizontally from one side of the cab to the other, with the control joysticks built onto the seat, and the thickness monitor in view of the operator at all times. An overhead window also helps the operator see above when working overhead. Curved windows add strength and significantly reduce noise levels in the cab. Attention was given to minimizing items placed in the operator's line of spraying vision. In some cases, it may also be necessary to spray from outside of the cab and to accommodate that request, a wireless remote control is available.

SS5 Prototype Shotcrete Sprayer Leaving Plant



View of spray boom through windshield from inside of cab

Along with being quieter, this cab also offers small features that enhance comfort and cleanliness such as boot washers on the entry steps. The boom is a diamond shape to keep concrete overspray and rebound from sticking to flat surfaces and entering the rollers and guides. The guides on the boom can be replaced without disassembling the boom to cut maintenance costs and time, effectively allowing mechanics to perform maintenance within the headings if required. A parallel lancing boom is also available for the tunneling industry and specific mining applications. The new concrete pump has a capacity of 30 yd^3/hr per hour (23 m^3/hr) and lowers to

Battery-powered 8 cu. yd. transmixer truck

Operator at controls inside of cab

the ground on a hydraulic frame to eliminate the need to climb onto the machine to clean the hopper or pump, and to make it easier to discharge into from any transmixer.

Improvements were also made to the entire accelerator dosing system to reduce the amount of accelerator required. Temperature sensors for the concrete, accelerator, and ambient air conditions, as well as an input for slump all help to provide the right dosage of accelerator for conditions. The auto-dosing system is also set up to receive information via Bluetooth from a properly equipped transmixer truck so that the sprayer knows what the slump, concrete temperature, and water content of the mix are before the load is discharged into its hopper. Potentially providing significant Quality Control aspects, this transmixer technology is currently in development.

Another major innovation with all mining equipment has been in the electrification of equipment to eliminate diesel particulates, noise, and heat underground. This new sprayer can be ordered as either a diesel or EV unit – the first prototype was an EV. Either way, an AC powerpack is included so that the spraying can be done on AC power, utilizing a jumbo plug or installed services to either save the batteries or to enable shutting down the diesel engine during spraying operations. The battery concept was originally designed to simply get the sprayer to the spraying location where it could be plugged into AC power. But during the underground testing phase in our test mine, we decided to see how long we could spray on battery power only and we found that the battery will last for approximately 15 yd^3 (11 m^3) of concrete application before requiring a recharge, with enough power left over to tram to a location for full recharge. A full recharge can be done in approximately 40 minutes with the on-board charger. However, the battery will not run an on-board air compressor while shooting if so equipped, as it requires too much power. Additionally, an 8 yd^3 (6 m^3) transmixer that runs on battery is available.

Being able to monitor the thickness of the application in real-time allows a shotcreting operation to optimize their use of concrete for an opening. And this ability is only one step away from completely autonomous spraying, further enhancing safety, which is currently under development.

Dan Millette *is the manager of US Operations for MacLean Equipment USA, Inc., a manufacturer of mining equipment. An architect and a mining engineer, he has over 40 years of experience in the shotcrete industry.*

Millette has worked in the industry in various capacities, beginning as a nozzleman and later in R&D, then in testing and product development of shotcrete materials including chemical admixtures and specialty products. He is currently managing the start-up of a new branch in Elko, NV and expanding the US operations West of the Mississippi river to include both the mining and tunneling industries.

Jonathan Lavallee *is the Global Product Manager of the Shotcrete Line of Equipment for MacLean Engineering. He is a civil engineer with nearly 20 years of extensive experience in the shotcrete, ready-mix concrete, and mining industries.*

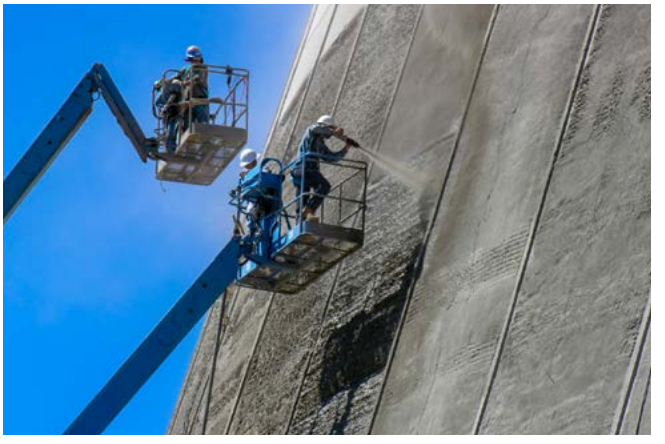
Lavallee started his career as a quality control technician for the ready-mix industry in Sudbury, Ontario. This then led to shotcrete-specific projects for underground mining regionally, and working on various high-profile mining projects overseas. His expertise presented him with opportunities to manage the shotcrete and concrete production, application, and training at such projects as the Oyu Tolgoi Project, Grasberg Mine, Tenke Fungurume Mine as an employee and as a consultant. Lavallee also has experience as a global technical services expert for shotcrete in the chemical admixture product industry. He is currently managing the shotcrete product line for MacLean's global operations overseeing an expansion of products and technologies for the mining and tunneling business.

Coastal Gunite Construction Company

Old Mill Creek Sewer rehabilitation, St. Louis, MO

Coastal Gunite Construction Company has provided structural shotcrete services in the commercial, industrial, energy, and public markets for over 35 years. Since 1983, Coastal Gunite Construction Company has held an unwavering commitment to providing owners and engineers with technically capable and competent commercial shotcrete construction services.

By specializing in shotcrete construction services, Coastal Gunite has developed a team of well-trained, highly experienced tradesmen. Coastal Gunite has more than 125 years of shotcrete experience among their site superintendents and employs trained and certified shotcrete nozzlemen. Recently, Coastal Gunite became the first ASA Qualified Shotcrete Contractor in Advanced Dry-Mix. In addition, Coastal Gunite is experienced in the application



Jacksonville Electric Authority Cooling Tower rehabilitation

of wet-mix shotcrete and can refine the process as needed to improve integrity, compressive strength and to prevent migration of corrosive agents.

Coastal Gunite Construction Company performs structural shotcrete construction services for projects of all sizes and duration. Depending on the project, Coastal Gunite Construction Company can dispatch single or multiple mobile crews to complete any project cost-effectively and ahead of schedule. Whether it is a small culvert or a tower stretching to the sky, Coastal Gunite has the capability to efficiently and effectively get the job done.

Coastal Gunite has developed a proven track record in both quality and safety. As a result, Coastal Gunite is pre-qualified for work with Departments of Transportation in over 20 states and has vast experience internationally as well as with Federal, State, and Local agencies, including various airport authorities, power utilities, and the US Army Corps of Engineers. All Coastal Gunite work is licensed, bonded, and insured.

Coastal Gunite is also the recipient of several awards and accolades. In recent years, Coastal Gunite has been recognized for outstanding achievement by the American Shotcrete Association and the International Concrete Repair Institute.

Curt White, founder and owner, has built the company from the ground up and his hands-on involvement in the industry (he is one of the Charter members of ASA) has contributed towards his successful operation spanning over the past 3 decades. At the beginning of 2020, Curt passed the leadership torch to his team, as he continues to guide and consult with them on a regular basis.

Today, Coastal Gunite provides services from offices located in Maryland, North Carolina, Tennessee, and Florida. For additional information please visit our website www.coastalgunite.com.

PennDOT Liberty Tunnel wall rehabilitation, Pittsburgh, PA

DC Water Adit construction, Washington, DC

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

NCDOT Herbert C. Bonner Bridge sub_superstructure rehabilitation, Nags Head, NC

GCU
GULF COAST UNDERGROUND

DESIGN. BUILD. DELIVER.
INFRASTRUCTURE REHABILITATION SOLUTIONS

Save Time. Save Money. Develop Relationships.

Gulf Coast Underground (GCU), LLC, is a full service general construction and engineering firm. One major component of our business is to investigate and evaluate the condition of municipal and industrial infrastructure, while another is to provide the latest technologies available to rehabilitate or replace the system. Our in house Design-Build capabilities truly set us apart from our competition. Since 2003, GCU has provided honest and dependable, long-term solutions across the Southeastern United States. From the outset, GCU was built upon relationships and our top priorities have been and will continue to be to serve our clients with professionalism, provide them with cost and time saving solutions, and prove ourselves to be a trusted technical resource.

MISSION

Our intent is for GCU, to be recognized as the premier sewer infrastructure inspection and rehabilitation contractor in the Southeast. We aim to provide quality trenchless sewer rehabilitation using our innovative methods and performance driven teams to deliver upgraded infrastructure that our clients can trust.

VISION

GCU is not “just” a construction company. We are a dedicated team of individuals all working towards common goals, while understanding that the combined efforts of us all are greater than the sum of our individual efforts. Through honest business practices, continued education, and a commitment to providing our employees with all of the necessary tools to become masters of their craft; we will create a positive culture while making GCU an excellent place to build a career.

AREAS OF OPERATION

Alabama, Mississippi, Georgia, Florida, Tennessee, Virginia, Louisiana, Arkansas North Carolina, South Carolina, Kentucky, and Texas

ENGINEERING EVALUATION SERVICES

Reports & Rehabilitation recommendations are available from a Professional Engineer.

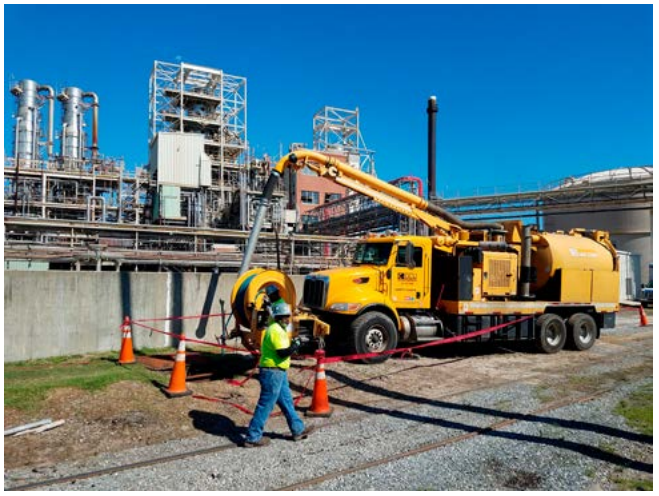
- CCTV and Cleaning of Storm and Sanitary Sewers
- Structural Concrete Inspections
- Pipeline Inspection
- GIS and Mapping Solutions

STRUCTURE LININGS/ REHABILITATION

- Shotcrete Rehabilitation
- Chemical Grouting
- Spray Applied Liner
- Systems Hydroblasting

TRENCHLESS PIPELINE REHABILITATION

- Main Line Cured in Place Pipe (CIPP) 6” to 96”
- Pipe Bursting
- Main Line/Lateral Line
- Grouting Cured in Place for Pressure Pipe



GULF COAST UNDERGROUND (GCU), LLC

Spencer Tuell, PE, President
5655 Middle Road
Theodore, AL 36582
Email: stuell@gulfcoastunderground.com
Cell: (251) 472-6684
Fax: (866) 720-9834
Website: www.gulfcoastunderground.com

Aarcomm Systems Inc.

PRIMARY CONTACT: Doug Graham
PHONE: (805)980-1000
EMAIL: doug@aarcomm.com
WEBSITE: https://www.aarcomm.com/
COUNTRY: Canada

LOCATION:
18 Fawcett Road, Coquitlam, British Columbia V3K 6X9

Blastcrete Equipment, LLC

PRIMARY CONTACT: Tripp Farrell
PHONE: (256) 235-2700
EMAIL: TRIPP@BLASTCRETE.COM
WEBSITE: www.blastcrete.com
COUNTRY: USA

Blastcrete Equipment, LLC is a shotcrete equipment manufacutrer specializin in shotcrete pumps, mixer/pump combinations, mixers, dry process gunning machines, and predampeners. We offer customized solutions coupled with the best customers service in the industry. Please visit us at www.Blastcrete.com

LOCATION:
Blastcrete Equipment, LLC, 2000 COBB AVE., ANNISTON, AL 36201

CanCrete Equipment Ltd.

PRIMARY CONTACT: Marcia Duiker
PHONE: (416) 749-2843
EMAIL: sales@cancrete.ca
WEBSITE: www.cancrete.ca
COUNTRY: CAN

Whether you shoot dry mix gunite or wet mix concrete, **CanCrete** carries the shotcrete equipment that you'll need to get the job done. Experienced in many applications, from structural shotcrete, shoring, pools, restoration, to refractory and more – we understand your business needs, stocking the equipment, parts & accessories that you need.

LOCATIONS:

Toronto
1810 Meyerside Drive, Mississauga, ON, L5T 1B4
(416) 749 2843

Orangeville
10 Coles Cres., Mono, ON, L9W 272
(519) 942 8844

Montreal
1855 Rue Cunard, Laval, QC, H7S 2C7
(514) 884 0076

Cemen Tech Inc

PRIMARY CONTACT: Mark Rinehart
PHONE: (800) 247-2464
EMAIL: mriinehart@cementech.com
WEBSITE: www.cementech.com
COUNTRY: USA

LOCATION:
1700 N 14th Street, Indianola, IA 50125

Gary Carlson Equipment Co

PRIMARY CONTACT: Gary R Carlson
PHONE: (763) 792-9123
EMAIL:
garycarlson@garycarlsonequip.com
WEBSITE: www.garycarlsonequip.com
COUNTRY: USA

Gary Carlson Equipment stocks for rental and sales a very large fleet of new and like new shotcrete guns, pumps and grouting equipment for customers across North America. We also offer crew training.

LOCATION:
1380 County Road C West, Roseville, MN 55113

Gunite Supply & Equipment

PRIMARY CONTACT: Tom Norman
PHONE: 888-321-5526
EMAIL: info@gunitesupply.com
WEBSITE: www.airplaco.com
COUNTRY: USA

The Gunite Supply & Equipment Company began business in 1947 and has been the premier OEM of dry process shotcrete (gunite) equipment in the construction industry since the early beginnings of the Gunite process. Gunite Supply specializes in the design and manufacturing of the C-10SL /C-10HHD Rotary Bowl Gunite Machines, shotcrete parts, tools and accessories.

LOCATION:
4141 Airport Road, Cincinnati, OH 45226

Minova

PRIMARY CONTACT: Carl Baur
PHONE: (502) 542-4973
EMAIL: carl.baur@minovaglobal.com
WEBSITE: www.minovaglobal.com
COUNTRY: USA

LOCATION:
1400 B and H Industrial Ct, Millstadt, IL 62260

Normet Americas, Inc.

PRIMARY CONTACT: Lauro Lacerda
PHONE: (801) 596-4700
EMAIL: lauro.lacerda@normet.com
WEBSITE: www.normet.com
COUNTRY: USA

At **Normet** we design, manufacture and sell standard or custom shotcrete-blasting-logistics equipment, construction chemicals and rock reinforcement to many projects worldwide. We provide state-of-the-art solutions to underground mining, tunneling and heavy civil construction. With our innovative technology and passion for our industry we offer continuous improvement to your processes for safety, productivity and profitability.

LOCATION:
Normet Americas, Inc., 1414 S Gladiola St, Salt Lake City, UT 84104

Olin Engineering Inc

PRIMARY CONTACT: David O Swain
PHONE: (714) 897-1230
EMAIL: dave@olinpump.com
WEBSITE: www.olinpump.com
COUNTRY: USA

LOCATION:
15622 Computer Lane, Huntington Beach, CA 92649

Putzmeister

PRIMARY CONTACT: Robert J Harmon
PHONE: (610) 909-9519
EMAIL: harmonb@putzam.com
WEBSITE: Putzmeister.com
COUNTRY: USA

LOCATION:
1733 90th Street, Sturtevant, WI 53177

Quikspray, Inc.

PRIMARY CONTACT: Leah Barker
PHONE: (419) 732-2611
EMAIL: leah@quikspray.com
WEBSITE: www.quikspray.com
COUNTRY: USA

Quikspray®, Inc., is a manufacturer of material handling peristaltic pumps and mixers for the shotcrete industry. Quikspray® products are available in different sizes, capacities and power configurations to meet a variety of industry needs.

LOCATION:
PO Box 327, Port Clinton, OH 43452

REED Shotcrete Equipment

PRIMARY CONTACT: Mike Newcomb
PHONE: (909) 287-2100
EMAIL: mike.newcomb@reedmfg.com
WEBSITE: www.reedpumps.com
COUNTRY: USA

LOCATION:
13822 Oaks Ave, Chino, CA 91710

Schwing America, Inc.

PRIMARY CONTACT: Jason Zignego
PHONE: (651) 429-0999
EMAIL: jzignego@schwing.com
WEBSITE: www.schwing.com
COUNTRY: USA

LOCATION:
5900 Centerville Road, Saint Paul, MN 55127

Shotcrete Helmet

PRIMARY CONTACT: Dominic Quail
PHONE: (519) 442-2046
EMAIL: info@shotcretehelmet.com
WEBSITE: www.shotcretehelmet.com
COUNTRY: CAN

Shotcrete Helmet, the Nozzlemens choice for respiratory, head and vision protection while working with shotcrete. Shotcrete Helmet is comfortable and easy to wear and use.

LOCATION:
PO Box 430 Stn Main, Paris, ON N3L 3T5 Canada

Sika STM

PRIMARY CONTACT: Patrick Bridger
PHONE: (610) 443-1800
EMAIL: bridger.patrick@us.sika.com
COUNTRY: USA

SIKA Shotcrete Tunneling and Mining include pre-packaged shotcrete material, as well as mixing and placement equipment, intended for mining, tunneling, refractory, concrete construction and concrete rehabilitation projects. Sika STM supports your complete shotcrete operation. For more information, visit usa.sika.com

LOCATION:
201 Polito Avenue, Lyndhurst, NJ 07071

Thiessen Team USA Inc

PRIMARY CONTACT: James Schumacher
PHONE: (775) 777-1205
EMAIL: jschumacher@thiessenteam.com
WEBSITE: www.thiessenteam.com
COUNTRY: USA

LOCATION:
PO Box 40, Elko, NV 89803

Top Shot Concrete Inc

PRIMARY CONTACT: Andrew Donovan
PHONE: (306) 242-4155
EMAIL: info@topshotconcrete.com
WEBSITE: www.topshotconcrete.com
COUNTRY: CAN

LOCATION:
3807 Arthur Rose Avenue, Saskatoon, SK S7P 0C7 Canada

Western Shotcrete Equipment

PRIMARY CONTACT: Jill Harpole
PHONE: (385) 389-2630
EMAIL: jillharpole@wseshotcrete.com
WEBSITE: www.wseshotcrete.com
COUNTRY: USA

LOCATION:
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ASA'S OUTSTANDING PROJECT AWARDS CELEBRATION

ASA held its 16th Annual Outstanding Project Awards celebration on Wednesday, March 24, 2021. Industry leaders and members of ASA joined the celebration virtually to witness the 2020 project winners, Carl Akeley Award winners, graduate scholarship award winner, plus hear from the incoming and out-going president and participate in giveaways. This capstone event can be viewed online at *www.shotcrete.org/awards-celebration*. A full list of our sponsors and project profiles are available for you to review. Projects will be featured in the Winter issue of Shotcrete magazine.

THE 2021 MEDIA KIT IS AVAILABLE!

We invite you to grow your business by investing your marketing dollars though advertising in ASA's *Shotcrete* magazine. *Shotcrete* magazine is the only international magazine focused exclusively on the growing 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. *Shotcrete* offers a unique opportunity to reach the international shotcrete industry with your resources. Questions and insertion orders can be sent directly to Tosha Holden at *Tosha.Holden@shotcrete.org.*

NEW - ASA'S MONTHLY, VIRTUAL TOWN HALL MEETINGS

Join us every month for ASA's Virtual Town Hall Meetings. Virtual town hall meetings will focus on industry and association updates, plus allow you the opportunity to connect and network with the leaders of ASA. Registration is free, but required to receive meeting link. Upcoming topics are:

- May 21, 2021 – Shotcrete Certification – tips for a smooth session
- June 25, 2021 – What I wish someone told me about nozzling 10 years ago!

Specific details to follow soon! Check out ASA's *calendar* view upcoming meetings (Shotcrete.org/Calendar).

ASA AT WORLD OF CONCRETE 2021

World of Concrete (WOC) 2021 will be held June 7 - 10, 2021, at the Las Vegas Convention Center, Las Vegas, NV. As a longtime co-sponsor of this industry event, ASA will be exhibiting and hosting several events and seminars. Register now using **ASA's Source Code: A17** at *www.worldofconcrete.com/en/register.html.* See our full line-up of ASA @ WOC activities here: *www.shotcrete.org/WOC*

ASA Shotcrete Nozzlemen Education Class

WOC Registration code: ASATU

The ASA Shotcrete Nozzlemen Education Class is a requirement for all nozzlemen wishing to pursue certification as an ACI Shotcrete Nozzleman through ASA. This 7-hour program provides a great overview of the shotcrete process for owners, contractors, and project managers. This registration includes the required CP60 workbook (available in English or Spanish) and a complimentary 1-year ASA Nozzleman membership. Registering for this class also requires registration for a WOC Exhibit-Only Pass, available for $25 using ASA's source code: A17. Please note this class alone will not result in certification.

Recognizing Quality Shotcrete – NEW for WOC 2021!

WOC Registration code: ASAWE (course only);
WOC Registration code: ASAWEX (course and exam)

With the strong growth of shotcrete construction, the concrete construction industry needs on-site inspectors who are knowledgeable about producing high-quality and durable shotcrete. This one-day session from ASA provides guidance on over 40 critical elements of shotcrete applications to properly evaluate the overall quality of shotcrete – valuable information for onsite inspectors, general contractors, shotcrete contractors and others who may use shotcrete sub-contractors. Topics covered include material selections, equipment, placement techniques, finishing, curing, protection, testing and safety as it relates to the shotcrete process.

An optional ACI Shotcrete Inspector certification exam will be available at the end of the seminar.

ASA Shotcrete Contractor Education

WOC Registration code: ASATH (course only with reference material);
WOC Registration code: ASATHX (course, reference material, and exam)

With the strong growth of shotcrete construction, the concrete construction industry needs shotcrete contractors who are knowledgeable about the shotcrete business. This seminar is intended for the existing shotcrete

contractor pursuing ASA Shotcrete Contractor Qualification. However, this seminar will be beneficial to all concrete contractors interested in learning more about quality shotcrete placement of structural concrete regardless of interest to pursue certification. Although a concrete contractor may be experienced in form-and-pour concrete construction, shotcrete has fundamentally different equipment, material selection, crew responsibilities, application techniques, testing, curing, and protection that needs 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 shotcrete applications.

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

Those qualifying individuals pursuing ASA Shotcrete 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. For more information, visit *www.shotcrete.org/education-certification/.*

THE ART OF SHOTCRETE
BECOME "INSTAGRAM FAMOUS"

ASA launches a new photo competition! Showcase the Art of Shotcrete by tagging ASA in your Instagram photos. Photos should highlight techniques and designs that show the creativity, functionality, and beauty of shotcrete. Photos will be judged quarterly by ASA's Marketing Committee and winning photos will be featured in Shotcrete magazine and ASA's social media platforms.

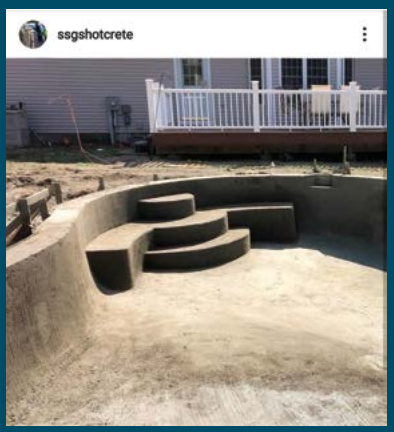
There's no limit to the number of images you can submit, so take photos often and submit often. This is an easy way show off your work to the shotcrete community… and be famous!

Submission is easy, add @ArtofShotcrete to your next Instagram post to submit your photo. Submissions close at the end of each quarter. Future deadline dates: June 30, 2021; September 30, 2021; and December 31, 2021.

The Art of Shotcrete WINNERS

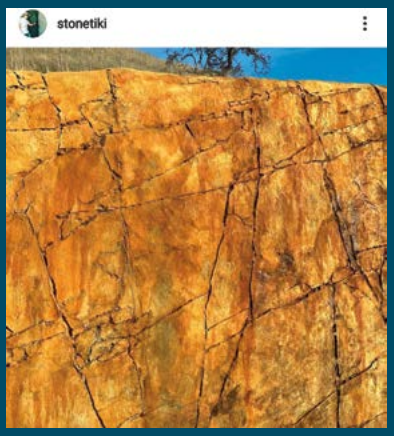
Congratulations to our first group of **Art of Shotcrete** winners! Thank you all for submitting photos in the 3rd Quarter judging of the Art of Shotcrete.

Project: Backyard Pool Steps & Benches
South Shore Gunite Pools & Spas Inc.
12 Esquire Road, North Billerica, MA 01862
Contact Person: Mason Guarino
Email: rguarino@southshoregunite-pools.com
Phone Number: (800) 649-8080
IG: @SSGpools



Project: Burnside Skatepark
McDowell Concrete, LLC
PO Box 42032, Portland, OR 97242
Contact Person: Jesse McDowell
Email: mcdowellconcretellc@gmail.com
Phone Number: (541) 373-1205
IG: @OregonShotcrete

Project: Malibu Canyon, Calabasas, CA
Stonetiki
Contact Person: Chris Felts
Email: stonetiki@gmail.com
Phone Number: (619) 888-2838
IG: @Stonetiki



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CORPORATE MEMBERS

Pinnacle Design Build
Cumming, GA
Primary Contact: Joshua Hall
jhall@pdbgi.com

CanMine Contracting LP
Burnaby, BC, Canada
Primary Contact: Andrea Suter
andrea.suter@canmine.ca

Torrent Shotcrete Structures Ltd.
Coquitlam, BC, Canada
Primary Contact: Carl King
carlk@torrentshotcrete.com

Keller - North America
Little Elm, TX
Primary Contact: Rachel Walker
rwalker@keller-na.com

Western Grater Contracting LTD
Victoria, BC, Canada
Primary Contact: Peter Piovesan
peter.piovesan@norlandlimited.com

Aarcomm Systems Inc.
Coquitlam, BC, Canada
Primary Contact: Doug Graham
doug@aarcomm.com

Blue Pacific Shotcrete
Mission Viejo, CA
Primary Contact: Jeff Solt
jeff@bluepacificshotcrete.com

TCC Materials
Mendota Heights, MN
Primary Contact: John Pederson
jpederson@tccmaterials.com

BCC Ohio Inc
New London, OH
Primary Contact: William Given
pmolnar@bccohioinc.com

Marathon Underground Constructors Corporation
Greely, Ontario, Canada
Primary Contact: Chris Duval
cduval@marathonunderground.com

Amelie Construction & Supply, LLC
Spring Church, PA
Primary Contact: Scott Stonecheck, P.E.
sstonecheck@amelieconstruction.com

Anderson Poolworks
Wilsonville, OR
Primary Contact: Craig Nicholson
craig@andersonpoolworks.com

Jones Excavating
West Jordan, UT
Primary Contact: Marcus Howells
marcush@jonesexcavating.com

INDIVIDUALS

Tom Bowles
Pool Crafters, LLC

Frank Townsend
Patriot Shotcrete

STUDENTS

Tyler Kleinsasser
South Dakota School of Mines and Technology

Neiv Jaising
Mukesh Patel School of Technology
Management & Engineering

INTERESTED IN BECOMING A MEMBER OF ASA?

Read about the benefits of being a member of ASA and find a Membership Application under the ASA Membership tab of www.shotcrete.org.

Leading professionals choose shotcrete over cast-in-place concrete because of its many benefits:

- **Savings** in labor, material handling and time
- **Versatility**, little or no forming allows you to create complex shapes
- **Sustainability** so you can feel even better about your choice

Before you pour, learn more at www.shotcrete.org

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info@shotcrete.org

(248) 963-0210

HARD-CEM-ENHANCED SHOTCRETE

Kryton's Hard-Cem® admixture can bring new levels of performance and value to your most demanding projects. Shotcrete is used in some of the most challenging environments subject to harsh abrasive and erosive wear. Although shotcrete is strong and durable, its cement paste binder remains the weakest link in service against physical deterioration. Hard-Cem is a powdered additive designed specifically to improve the cement paste and protect the shotcrete from abrasive and erosive damage. Hard-Cem is easy to use and highly versatile, and can be used anywhere that physical deterioration threatens the durability and serviceability of a structure. The use of Hard-Cem in shotcrete was vetted through a specific test program using wet-mix shotcrete, with all test panels shot by an independent ACI-certified shotcrete crew. They found that shotcrete containing Hard-Cem had normal pumping, shooting, and finishing properties, with no increase in rebound, good compatibility with air entrainment, and normal strength development. When test panels were tested for abrasion resistance following *ASTM C627* using a specially modified Robinson floor tester with an 800-pound load, the Hard-Cem-treated panel withstood 2.5 times more abrasion. With this ability, Hard-Cem-enhanced shotcrete has been used to construct durable spillways, make repairs to wastewater treatment facilities, and add longevity to skate parks and other structures. You can learn more about Hard-Cem by visiting www.kryton.com/products/hard-cem/ or by calling 1-800-267-8280.

TAKE CONTROL OF YOUR GUNITE PROJECTS

Are you looking for a higher quality mixture without sand and cement inconsistencies? Do you need the ability to produce dry-mix shotcrete (gunite) or wet-mix shotcrete depending on the job? Have you ever wanted to know how much of each material went into the mixture after a pour?

As the demand for pools have increased to historic levels, contractors need to complete high-quality work in a timely manner. Their ability to stay on schedule by quickly moving from project to project is vital. Conventional mixers used in shotcrete applications utilize primitive mechanics that limit your ability to adjust speed and output of materials, and you'd be amazed if you realized just how much free cement is given away with each pour.

Cemen Tech, the world's largest volumetric concrete mixer manufacturer, has recently introduced the M30X. It has an onboard carrying capacity of 12 yd³ (9 m³) and a production rate of up to 30 yd³/hr (27 m³/hr). The unit is built to meet increasing contractor demands by giving operators full control over the consistency and quality of their concrete. As jobsite conditions change, such as the weather, so does your mixture. The M30X is designed with an adjustable gate system to account for on the job changes. An auxiliary hydraulic circuit can be added to power dry-mix guns as well. Optional water and admix systems with flow meters allow operators to increase or decrease the slump when mixing wet shotcrete. A single unit is capable of pouring standard concrete, dry gunite, wet shotcrete and a variety of other mixes. Traditional pool contractors can easily integrate concrete pool decks, pathways, patios or other standard concrete applications into their business. Instead of waiting on Ready Mix or other sub-contractors, take control of the entire operation with a single mixer.

Not only is the M30X flexible with what it can pour, it is also extremely accurate compared to current methods. The mixer uses a proven dual-auger metering system to proportion cement with precise consistency at +/-1%. A 24 in. wide conveyor belt with molded vanner edges combined with heavy hitter vibrators brings a consistent and reliable flow of materials. A printed ticket after the pour displays exactly what went into the mixture. The proven accuracy and performance of the M30X is demonstrated through the Volumetric Mixer Manufacturer Bureau (VMMB) plate. This plate can be found on the unit next to the serial number plate. It certifies the mixer is in accordance with standards outlined by the Bureau and ASTM C685.

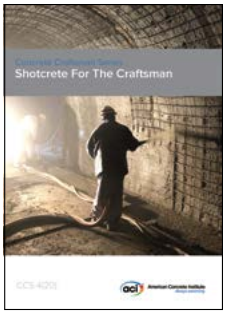
Although market demands for contractors are continually changing, Cemen Tech quality and performance has not. The company has a rich 50-year history producing award

winning equipment. The M30X is no exception. It has mixed and dispensed concrete everywhere you live, work, or play. Cemen Tech mixers are backed by a Performance Guarantee, 24 hr parts and a superior support team unmatched in the industry. For more information on the M30X or related mixers, visit www.cementech.com.

WESTERN SHOTCRETE EQUIPMENT EXPANDS WARRIOR SHOTCRETE PUMP OFFERINGS

Western Shotcrete Equipment, a leader in shotcrete pumping technology, has introduced its newest offering in the Warrior shotcrete pump lineup. The all-new 400 model has been designed to deliver best-in-class performance in a compact and efficient package. It utilizes a 74 horsepower Cummins Tier 4 Final engine, which features near-zero emissions and requires no regeneration or complex sensors. Even with this smaller package, the 400 is capable of pumping high-pressure concrete at 43 yd^3/hr (33 m^3/hr). The 400 is an ideal shotcrete pump for smaller projects such as swimming pools and line pumping, or other jobs that benefit from increased mobility. Available mid-2021.

ACI Publishes Updated Shotcrete for the Craftsman



The American Concrete Institute recently released an updated version of its popular "Shotcrete for the Craftsman" publication, one of the five titles available in the ACI Concrete Craftsman series. ACI's "Shotcrete for the Craftsman" provides shotcrete nozzlemen with an understanding of basic concrete technology and describes and illustrates how to properly place quality shotcrete.

This updated version of "Shotcrete for the Craftsman" features updated photographs, full-color figures, and a rearranged structure of the content highlighting the similarities and differences between concrete and shotcrete. ACI's Shotcrete for the Craftsman serves as the source content for the ACI Shotcrete Nozzleman and Nozzleman-in-Training certification programs.

"ACI's Shotcrete Nozzleman Certification Committee (C660) felt that an updated workbook was necessary to meet the current standards," stated Randle Emmrich, Chair, ACI Committee C660. "We also organized the publication in a way that would be easier to read with updated figures."

The information found in this publication combined with ACI 506.2, "Specification for Shotcrete," and ACI 506R, "Guide to Shotcrete," provides shotcrete professionals with a comprehensive set of resources.

Additional titles in the ACI Concrete Craftsman series include:

- Concrete Fundamentals (English and Spanish)
- Slabs on Ground
- Supported Beans and Slabs
- Placing and Finishing Decorative Concrete

Visit concrete.org for additional information or to purchase the "Shotcrete for the Craftsman" publication in print or digital formats.

Patriot Shotcrete announces their new President, Frank Townsend

Frank Townsend is now the Owner/ President of Patriot Shotcrete. Previously Frank was the Vice President of Superior Gunite. Patriot Shotcrete is DBE as a Service Disabled Veteran Owned Small Business that serves as a specialty concrete contractor located in New Jersey servicing the East Coast. Patriot builds, maintains, and rehabilitates bridges, piers, culverts, aqueducts, basement walls, pools, and support of excavation applications using either the wet or dry process shotcrete. Frank served in the Army for eight and a half years and has been actively involved in the shotcrete industry nationwide for the past nine years. www.patriotshotcrete.com.

American Concrete Pumping Association (ACPA) Announces 2020 Scholarship Recipients

The American Concrete Pumping Association (ACPA) announces Jesse Odom and Lauren Bone as co-recipients of the association's first annual Bob Weatherton Scholarship. Odom is a sophomore at Lamar University in Beaumont, Texas, studying construction management. Bone is a freshman at the University of Colorado Boulder studying civil engineering.

The scholarship is named in honor of the late "Big Bob" Weatherton of The Concrete Pump Store in California. Weatherton served on the ACPA Board of Directors for more than 40 years and is remembered as one of the industry's most avid champions.

Open to eligible members and their families, as well as to members' employees and their families, the Bob Weatherton scholarship recognizes the potential for leadership and industry advancement that Weatherton exemplified throughout his career. Scholarships are for undergraduate, graduate and vocational students in fields related to concrete, concrete pumping, construction and engineering, construction management and administration, and vocational studies related to concrete pumps and trucks.

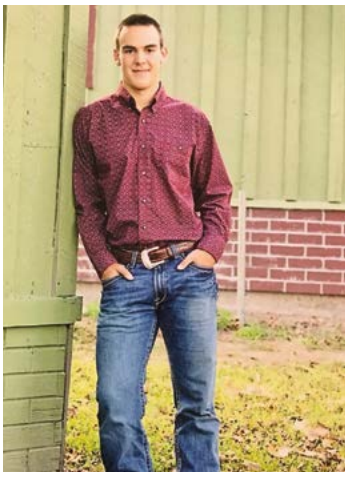
"We are proud to carry on Bob Weatherton's legacy in the concrete pumping industry through a scholarship in his memory," says Christi Collins, ACPA Executive Director. "Bob was a devoted member of the association and faithful advocate of concrete pumping. It is our privilege to honor two highly exceptional students among the many qualified and diverse candidates."

Evaluations were completed separately by a panel of judges, who are members of the ACPA Scholarship Committee. Judges submitted their scores individually to an independent accounting firm to tabulate the results. The two individuals who were awarded the greatest number of points were announced as the winners.

At Lamar University, Odom is an active member of the Construction Management Student Association, which provides volunteer assistance to local businesses and the people of southeast Texas. His volunteer experience also includes the high-stress atmosphere of serving his local volunteer fire department.

During college, Odom's internship with Bo-Mac Contractors in Beaumont, Texas, helped him realize he enjoys the

preconstruction phase of projects. As such, Odom's long-term plans are to become a scheduler/planner for a civil contractor in the industrial sector.



"I am very thankful for the American Concrete Pumping Association offering the Bob Weatherton Scholarship," says Odom. "This scholarship will allow me to focus on my academic career even more now."

Having grown up in the concrete pumping industry, Bone has had a love of construction machinery and the tasks it accomplishes from an early age. This, along with a proficiency in math and science, led Lauren to the University of Colorado Boulder, where she enrolled in the fall of 2020 to pursue a civil engineering degree.

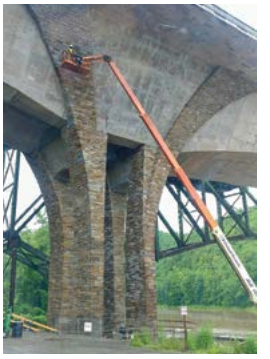
"It is a privilege and honor to be selected for this award," says Lauren. "I am truly thankful for the ACPA for recognizing and rewarding my hard work over the years. This makes me feel proud of all the work I have put in and confident in what I will achieve in the future."

For more information about Bob Weatherton Scholarship, contact the ACPA National Office at 614-431-5618 or email acpa@concretepumpers.com. For more information about the ACPA, visit www.concretepumpers.com.

Connect with ACPA on its social media channels:

- Like ACPA on Facebook: facebook.com/ACPAPumpers
- Watch ACPA videos on YouTube: youtube.com/user/acpaconcrete
- Follow ACPA on Instagram: instagram.com/acpa_concretepumpers
- Connect with ACPA on LinkedIn: https://www.linkedin.com/company/american-concrete-pumping-association

Decorative Concrete 2020 Awards Winners



The Decorative Concrete Council (DCC), a specialty council of the American Society of Concrete Contractors (ASCC), St. Louis, Mo., has announced the winners of its 12th annual Decorative Concrete Awards competition. The winners were recognized at a virtual ceremony as part of ASCC's Annual Conference, September 24, 2020

Superior Gunite, Lake View Terrace, CA won the WOW! Award, best overall project, for Brattleboro Bridge in Vermont. "The challenge was not only to place concrete on the fins, but to seamlessly match the sculpted rock forms," said Frank Townsend, Superior Gunite. The use of shotcrete allowed access for placement as well as the ability to carve the wet concrete to match the look of the previous precast panels. Each fin is approximately 28 ft (8.5 m) in height and expanded in width from 8 to 24 ft to (2.4 to 7.3 m) at the top, for a total of 390 ft² (36 m²).

Other winners can be viewed online at *https://ascconline.org/Portals/0/2020-dcc-awards.pdf.*

SHOTCRETE CALENDAR

Please check with the meeting provider as some meetings may be postponed or cancelled after publication of this issue of Shotcrete.

MAY 3 – 5, 2021	**Deep Foundations Institute – Shotcrete Short Course** Table Mountain Inn & Edgar Mine | Golden, CO **www.dfi.org**
MAY 21, 2021	**ASA Town Hall** Shotcrete Certification - tips for a smooth session **www.shotcrete.org/calendar**
JUNE 7 – 10, 2021	**World of Concrete 2021** Las Vegas Convention Center | Las Vegas, NV Registration now open! For $25 Exhibit Only passes, use Source Code: **A17** **www.worldofconcrete.com**
JUNE 8, 2021	**ASA Shotcrete Nozzleman Education @ WOC 2021** Las Vegas Convention Center | Las Vegas, NV Course Code: **ASATU** Required for New & Nozzlemen-in-Training pursuing ACI Certification **www.shotcrete.org/WOC**
JUNE 9, 2021	**Recognizing Quality Shotcrete @ WOC 2021** Las Vegas Convention Center | Las Vegas, NV Course Code: **ASAWE** – course only; **ASAWEX** – course with exam **www.shotcrete.org/WOC**
JUNE 10, 2021	**Shotcrete Contractor Education @ WOC 2021** Las Vegas Convention Center | Las Vegas, NV Course Code: **ASATH** – course only; **ASATHX** – course with exam **www.shotcrete.org/WOC**
JUNE 13 – 16, 2021	**2021 SME Rapid Excavation & Tunneling Conference (RETC 2021)** Las Vegas, NV **www.retc.org**
JUNE 25, 2021	**ASA Town Hall** What I wish someone told me about nozzling 10 years ago **www.shotcrete.org/calendar**
JULY 23, 2021	**ASA Town Hall** What makes it Outstanding? Tips for submitting an Outstanding Shotcrete Project entry. **www.shotcrete.org/calendar**
AUGUST 24 – 26, 2021	**SDC Technology Forum 50** Virtual Conference **www.acifoundation.org**
SEPTEMBER 13 – 15, 2021	**MINExpo INTERNATIONAL® 2021** Las Vegas Convention Center | Las Vegas, NV **www.minexpo.com**
OCTOBER 2021 DATES TBD	**ASA's Fall Committee Meetings** **www.shotcrete.org/News/Calendar**
OCTOBER 17 – 21, 2021	**ACI Concrete Convention – Fall 2021** Hilton Atlanta Downtown **www.concrete.org**

NOVEMBER 16 – 18, 2021	**International Pool | Spa |Patio Expo** Kay Bailey Hutchison Convention Center | Dallas, TX **www.poolspapatio.com**
NOVEMBER 16, 2021	**ASA Shotcrete Nozzleman Education @ PSP 2021** Kay Bailey Hutchison Convention Center | Dallas, TX Required for New & Nozzlemen-in-Training pursuing ACI Certification **www.shotcrete.org/Events**
NOVEMBER 17, 2021	**Recognizing Quality Shotcrete @ PSP 2021** Kay Bailey Hutchison Convention Center | Dallas, TX **www.shotcrete.org/Events**
DECEMBER 5 – 8, 2021	**ASTM International Committee C09, Concrete and Concrete Aggregates** Atlanta Marriott Marquis | Atlanta, GA **www.astm.org**
JANUARY 18 – 20, 2022	**World of Concrete 2022** Las Vegas Convention Center | Las Vegas, NV **www.worldofconcrete.com**
JANUARY 19 – 22, 2022	**Southwest Pool & Spa Show 2022** Henry B. Gonzalez Convention Center | San Antonio, TX **www.swpsshow.com**
JANUARY 25 – 27, 2022	**2022 Pool & Spa Show in Atlantic City** Atlantic City Convention Center | Atlantic City, NJ **Thepoolspashow.com**
FEBRUARY 27 – MARCH 1, 2022	**2022 ASA Shotcrete Convention & Technology Conference** Sonesta Resort | Hilton Head, SC **www.shotcrete.org**
JUNE 17 - 24, 2022	**North American Tunneling Conference (NAT) 2022** Philadelphia, PA **www.natconference.com**
MORE INFORMATION	To see a full list, current updates, and active links to each event, visit www.shotcrete.org/calendar.

AVAILABLE ASA SESSIONS:

ASA Shotcrete Nozzleman Education @ WOC
Course Code: ASATU

Recognizing Quality Shotcrete @ WOC
Course Code: ASAWE & ASAWEX

Shotcrete Contractor Education @ WOC
Course Code: ASATH & ASATHX

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). Questions can be submitted to info@shotcrete.org. Selected FAQs can also be found on the ASA website at www.shotcrete.org/FAQs.

Question: *Can a gunite bridge surface be painted? And if so, what preparation/materials are recommended.*

Answer: Yes, shotcrete is a placement method for concrete, so any coating appropriate for concrete would be applicable to dry-mix shotcrete (Gunite). Many coating manufacturer's specify new concrete should be a certain age before applying their coating. Generally, the concrete surface should be clean and dry before coating.

The surface texture provided on the shotcrete can affect the coating application. A hard, smooth steel trowel finish will tend to be quite slick, and the coating may not bond as well as a floated or sponge finish. A light abrasive blast may be considered to roughen the surface and give more bond. If using a gun or rodded finish for the shotcrete, the coating will generally require quite a bit more material to be able to fill the depressions in the surface.

Question: *Can carbon nanotubes be used in shotcrete?*

Answer: Shotcrete is a placement method for concrete so most admixture or supplemental cementitious materials that can be used in cast concrete will work with shotcrete placement. In fact, shotcrete contractors have been some of the most innovative adopters of new concrete technologies. Silica fume (microsilica) is a ultrafine particle 100 times smaller than cement that enjoys early and wide use in shotcrete due to its ability to make concrete stickier and more cohesive. This facilitates overhead placements and can provide thicker layers. Shotcrete has also used other ultrafine and nanoparticles, like colloidal silica, clay-based particles and the carbon nanotubes you mentioned.

The ultrafine and nanoparticles can provide many benefits to fresh concrete, as well as hardened properties. This may include:

- Improve the pumpability of wet-mix concrete;
- Reduce rebound and dust due to increased "stickiness";
- Ease the finishing process;
- Reduced permeability by filling pores between cement in the paste;
- Enhanced corrosion resistance for embedded reinforcement;
- Enhanced resistance to chemical attack.

Question: *We have a cast-in-place wall with extensive rock pockets and voids from inadequate vibration during casting. One option is to tear down the wall and replace, however we are wondering if shotcrete can be used to repair the deficiencies. If so, what are the recommended procedures to prepare and shotcrete the repairs?*

Answer: Shotcrete is a great solution to your wall casting issue. In all shotcrete repair to get the best bond you need to:

1. Chip back to sound substrate – all the rock pockets and voids should be chipped out (or you can use hydrodemolition) to sound concrete.
2. If the chipped-out area is deep into the wall, make sure to have the opening at about a 45° angle from the back of the chipped out area to the surface so that the air flow providing shotcrete's high velocity can escape and not be trapped.
3. Do not feather edge the perimeter of the repaired opening. Provide a ¾ to 1 in. (19 to 25 mm) roughly square shoulder at the perimeter edge. If this is sawcut make sure the sawed surface is roughened before shotcreting.
4. Thoroughly clean the chipped-out area to remove all dust.
5. Bring the entire chipped out area to a saturated surface dry condition.
6. Do NOT use a bonding agent. It will detract from the inherent excellent bond of shotcrete.
7. Use an experienced shotcrete nozzleman (ACI-certified in the vertical orientation for the process being used) with a quality concrete mixture, and proper shotcrete equipment.
8. Make sure the shotcrete finishers are experienced and do not tear or delaminate the shot sections.
9. Protect the freshly shot and finished sections from freezing or extremely hot weather.
10. Cure the shot sections for a minimum of 7 days. A water cure is preferred to a curing membrane.

Either wet-mix or dry-mix would be suitable for your project. The shotcrete contractor you select for the project should recommend the process they are best suited for based on their crew experience and equipment. Appropriate testing for this type of repair may include compression testing of the materials from shotcreted panels (ASTM C1140 *Standard Practice for Preparing and Testing Specimens from Shotcrete Test Panels*, ASTM C1604 *Standard Test Method for Obtaining and Testing Drilled Cores of Shotcrete*, and ACI 506.2 *Specification for Shotcrete*), and bond pull-off tests to verify the bond of the shotcreted material to the original substrate.

For more guidance on shotcrete and its use in concrete repairs, you may want to review ACI 506R-16 *Guide to Shotcrete,* as it can give you more detailed information about shotcrete materials, surface preparation, shotcrete crews and placement, testing, protection and curing.

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