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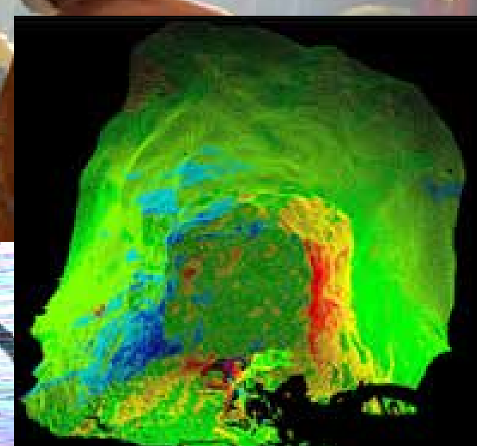
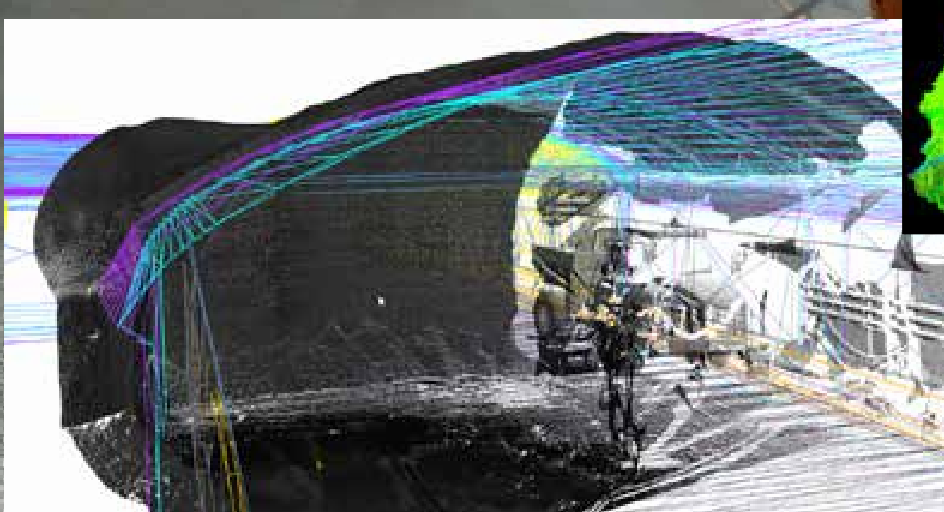
Innovations In Shotcrete





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FEATURES

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

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

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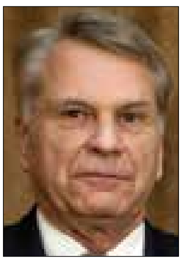
On the cover: Main photo, Shotcrete demo with an Aliva 520 Electric Sprayer. Photo courtesy of Sika.

Overlay images - Laser scans of shotcreted tunnel section.

New Beginnings

By Ryan Poole



As incoming president of ASA, I would like to take this opportunity to thank all the members of the association for the chance to serve in this capacity. I am looking forward to the coming year with all it holds and hope to be able to help advance the mission of ASA especially in these uncertain times.

Over the years, as ASA has grown, we have faced many opportunities and challenges all of which have been met and overcome in one way or another. As we started this year, I witnessed the organization embrace a significant opportunity and challenge in the changing of our association management company. Change is not easy, especially with having over 20 years in one firm. We are grateful for the things we've learned along the way and excited to see ASA continue to grow and broaden its contributions to the shotcrete industry as we rally the resources and services of our new association management firm, Virtual Inc. As things have unfolded, this change in management companies has come at a most fortuitous time since staff had already made the decision to begin working remotely with the transition which took effect March 1st. This allowed ASA to have all of the necessary systems in place and operational before offices were closed and "stay at home" orders became mandatory across the country thus saving valuable time and effort, in addition to keeping the association operating seamlessly or nearly so.

Due to the timing and release of this issue of our magazine, I must assume that many things with regards to COVID-19 will have changed and will continue to change going forward at least in the near term. One of the more serious concerns at this time is what will be necessary and required to perform Shotcrete Nozzlemen Certification sessions in light of "social distancing" and the limitations on the numbers of people who may occupy a given space. The need for Shotcrete Nozzleman Certification continues to grow especially in light of its recent inclusion in the ACI 318 code. As restrictions are lifting in various areas around North America, companies are taking the necessary precautions and protocols to provide a safe environment to conduct certification sessions. Other programs, such as the ACI Inspector Certification and the ASA Contractor Qualification program, both include an educational component which is also subject to face-to-face meeting constraints. While some remote seminars are possible, these full-day seminars benefit most from opportunities to interact and discuss participant experiences. The varying local requirements and local philosophes around the country and indeed world, presents a great challenge as ASA respects all local mandates in our scheduling and assignment of examiners and speakers for these programs

I would like to thank all the committee chairs and members of those committees for your ongoing efforts and support. In spite of being unable to hold our spring meetings face to face, it has become incumbent on all of us to focus on continuing to achieve our committee goals and objectives through online meetings, email and any other means that may be beneficial for continuing the advancement ASA. Indeed, moving all our Spring Committee meetings to virtual meetings this year proved to be a very productive and efficient use of our members' time and sparked a desire to meet more frequently in these virtual settings to continue the important work of the association.

At this time especially, all input and assistance from the membership of ASA is extremely important. We encourage you to reach out with any ideas, suggestions or concerns that you believe are of value at this time.

Membership Committee

By Jason Myers

Membership has its Privileges! A famous slogan, back in the nineties, of American Express was "Membership has its privileges." This is a lesson that was true back then and still applies today. The American Shotcrete Association (ASA) has had a long history of promoting, defining, and improving the shotcrete industry and the power of the organization is in its members. But just as the slogan goes, the only way to fully enjoy the benefits of ASA is by being an active member. All of us can look at our bank statements and see the different clubs and memberships that we belong to but hardly ever use or do not use to its full benefit. ASA is like one of those that if you can give a little of your time and effort the rewards can far outweigh the cost.

In the time I have been an active member I have enjoyed hearing veteran members reminisce over the various discussions and arguments that have occurred over the years and the lessons that they have learned and the positive effects that they have had in the shotcrete industry. The members of ASA were some of the most prominent figures in the development of the ACI Nozzleman Certification program and continue to aid in the writing of the ACI 506 shotcrete documents that we use today. It is great to listen and observe veteran members work towards a common professional goal, allowing others to enjoy the fruits of their labor.

ASA is presently working on numerous areas of the shotcrete industry which we believe will make the industry better. From working through the OSHA Silica regulations, Contractor Qualification program for shotcrete contractors, a Safety program, and the first comprehensive guidelines for shotcreting a structurally reliable pool, to name a few, are some of the areas that the different ASA committees are actively engaged in. By relying on the experiences and knowledge we each possess, we wrestle issues and find ways to solve these issues thus striving to raise the quality bar for the entire industry. It is one thing to read and try to understand the articles and position papers that guide the industry by yourself, but it's so much more effective to work as a team by listening to the discussions during the development of these items allowing you the opportunity to have influence over the items as well. You'll experience the breadth of the discussions that have gone in to producing an approved a document and hearing how others deal with similar circumstances. I have had many meals, and an even greater number of drinks, with other ASA members where we have each shared information on how we go about our business and solved problems we are currently facing or could face in the near future.

Just as members from the past have influenced the shotcrete industry, it is up to the present and future members to shape how shotcrete continues to evolve and change. There is only one way to be influential in the near future and that is to be an active member. As in many tasks, a single set of hands makes for an impossible task, but with many hands anything is possible. ASA committees are always looking for new active members. It is by the various discussions and interactions of these committees, that we are able to determine where to strengthen our industry and where the hot buttons of the future lie. The world is getting increasingly more complex and global with the competitive edges getting harder and harder. You can face these challenges by yourself or by being an active ASA member, working together as a united front to solve the problems of the future and define the competitive advantages of shotcrete in the industry rather than being defined by it.

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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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Changes – Moving in So Many Different Ways

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

WE HAVE MOVED OUT - Please note that the mailing address for all our customer service correspondence is no longer in Farmington Hills. Both Alice McComas (our Assistant Director) and I are still in Michigan and fully embracing the "Work from Home" office trend. The postal forwarding service has been very hit or miss (mostly miss), so checks and other correspondence have been delayed, returned, or somehow swallowed by a black hole somewhere outside Detroit. Please update our address in your company contact records. The new address for our business correspondence is:

> American Shotcrete Association
> 25 Century Blvd, Suite #505
> Nashville, TN 37214

MOVIN' IN - On April 6, we welcomed Tosha Holden on board as our Marketing and Editorial Manager. Tosha has a great can-do attitude, a wide variety of association experience, a strong work ethic…and is a superlative baker. Tosha is filling the role that Lacey Stachel had with us over the last two years, plus adds time for more marketing focus, and assistance with Alice in our awards and other programs. She is joining Alice and me here in the Southeastern Michigan area. This keeps the key staff, so important to our core business, together in one area where we can meet when needed face-to-face. Especially challenging was bringing Tosha on board with the "Stay Home – Stay Safe" order but we've made great progress. Tosha has proven to be a fast learner, discovering the ins and outs of quarterly magazine production, our ASA programs and about shotcrete and our industry. You will find a lot more background on Tosha in our Association News section.

MOVIN' UP - We welcome on board our new ASA President, Ryan Poole. Ryan has moved up through the officer ranks and long committee service to ASA. We look forward to his leadership through what has already proven to be quite a challenging year. I want to thank Cathy Burkert (who has moved up to that esteemed position of Past President) for her close attention, and dedicated service to ASA as last year's president. Cathy really took her role to heart and kept a close eye on what was happening in ASA throughout her term. It was certainly a pleasure working with her and seeing her demonstrated commitment to advancing ASA and the industry. Lars Balck has moved up to Vice President, Axel Nitschke has moved up to Secretary and Mason Guarino has moved up from his Board position into the Treasurer role. We look forward to working with all the officers on the Executive Committee this year.

MOVIN' BACK HOME – The COVID-19 pandemic hit Michigan hard. Especially our area in the Southeastern section of the state. On March 23, the

Michigan governor ordered all non-essential workers to “Stay Home – Stay Safe”. Fortunately, both Alice and I were already setup at home as we started with the new association management firm, Virtual Inc., on March 1. Thus, we were able to keep on rolling with full effectiveness despite the challenges of the pandemic. Tosha joined us a month later. We keep in constant contact with Teams chat, phone and video calls (as long as the internet keeps working) and though maybe not as interactive as working together in an office environment, we have maintained our efficiency and effectiveness.

MOVIN’ FORWARD – As I mentioned in the Winter issue, we moved to a new association management association effective March 1. Their management model is quite different from our old firm. We see more flexibility in selecting services, and a true desire to provide us the customer service we need.

However, this is a big change. A totally new website, new committee pages, new bookstore, new association management system, new accounting software. Also ramping up new Virtual support staff in accounting, magazine production, event services, customer service and shipping on our programs and processes.

As many of you who are contractors or subcontractors find on your projects when you roll up to the job for the first time, the owner, GC or engineer’s concept of “everything is ready to go” maybe isn’t exactly accurate. We can feel that pain. We are making great progress in getting all aspects of our business up to speed. It is taking longer than we hoped but with the complexity of our Association business it was not entirely unexpected. We appreciate your patience as we work to get everything in place and smooth out some of the bumps along the way.

Finally, the impact of the COVID-19 closing of most states in the US and provinces in Canada has slowed our nozzleman certification sessions. However, we had strong session activity before the shutdowns started in March and the backlog of demand is now increasing our sessions in May and June. Though slowed a bit we are financially strong and hoping to make up for lost ground through the rest of 2020.

These are challenging times. Not just for our members here in North America but for our members around the world. Our workplaces may look different as we implement new precautions but our ability to adapt and get work done exemplifies our strength and resilience. I hope you, your families and co-workers are staying safe and healthy.

Developing Dust Reduced and Low Cracking Potential - Dry-Mix Shotcrete Mixes

By William Clements and Cody Fournier

Although dry-mix shotcrete has been used extensively in both mining, tunneling and concrete repair projects, it suffers from the reputation that it will produce more dust than other repair methods or even wet-mix shotcrete. Due to the fact that dry-mix shotcrete is most often applied using pre-packaged bagged material, the act of emptying the shotcrete itself into the shotcrete spraying equipment inherently generates dust. In contrast, the vast majority of wet-mix shotcrete is sprayed using shotcrete supplied via ready-mix trucks which introduces little to no dust generation at the jobsite itself. Dust is generated at the ready-mix plant during batching and controlled by the ready-mix shotcrete supplier via engineering controls such as dust collection. By the time the contractor receives the material it is fully mixed and does not emit any dust on-site. There are options available to reduce the amount of dust generated while spraying dry-mix shotcrete but using dust-reducing additives to the pre-packaged dry-mix shotcrete is still an area of interest for development. This article explores the results of testing several dust-reducing additives, how dust generation can be evaluated, and how the inclusion of these additives can affect the mechanical properties of dry-mix shotcrete

Previous work has shown that by modifying the mixture design of conventional dry-mix shotcrete, the cracking resistance can be greatly increased in laboratory conditions (Clements & Robertson, 2019). Although it was found that removing silica fume from the formulation greatly increased the cracking resistance, it also drastically increases the rebound observed during shotcrete placement. As a result, King - A Sika Company (KING) developed a testing program to evaluate four prototype mixture designs to select the mixture with the lowest cracking potential for further development. The selected candidate mixture was sprayed following an intensive testing protocol to characterize the desired mechanical and durability properties of the mixture. The initial results of the testing program and the preliminary results of the full characterization testing program are contained in this article.

Dry-Mix Shotcrete Dust Generation

Workplace dust is an unavoidable risk in many construction-related occupations and especially true for dry-mix shotcrete. Prolonged exposure of workers to elevated concentrations of silica dust can lead to irreversible physical damage such as silicosis. Currently, the only reliable, proactive defense is the use of proper engineering controls such as suitable ventilation, appropriate dust respirators and appropriate PPE. However, the best form of risk management is to eliminate or reduce the potential of the risk itself.

When observing dry-mix shotcrete placement, it is first important to identify the regions where dust can potentially be generated. Dust is generated at high concentrations in two specific regions: at the discharge from the nozzle; and feeding material into the dry-mix shotcrete machine (Figure 1 and 2).

Fig.1: Case 1-High concentration of dust emitted from the nozzle.

Fig. 2: Case 2: High concentration of dust emitted when pre-packaged dry-mix is emptied into the material hopper of a dry-mix shotcrete machine.

QUANTIFYING DUST

When it comes to quantifying dust levels at the hopper for dry-mix shotcrete, two methodologies can be proposed. These methodologies shall be referred to as the "static" and "dynamic" method of testing.

A static dust emission test involves measuring the dust levels with the DustView II from Palas based on the standard CIPAC MT 171. (CIPAC, 2015). This device functions by dropping a powder sample of 0.035 ounces (30g) down a cylindrical tube. As the powder descends, dust particles are measured through extinction measurement with a laser beam. The results are then summarized with an optical dust value, referred to as the "Dust Number". The Dust Number can be calculated using the software offered by the device and serves as a manner to interpret dust emission activity.

Dust Number = Maximum Dust Value + Dust Value 30-seconds after the Maximum Dust Value. (Palas, n.d)

As per CIPAC MT 171, and as seen in Figure 3, in the event where the Dust Number is lower than 25, it shall be considered as being "essential non dusty". An "essential non dusty" material is one where dust levels are lowered but can still be seen by the naked eye.

Figure 4 is an example of how DustView II records

Category	Range of results		Interpretation
	gravimetric "collected dust" [mg]	optical dust value	
1	0 - 12	0 - 10	nearly dust-free
2	> 12 - 30	> 10 - 25	essential non dusty
3	> 30	> 25	dusty

Fig. 3: CIPAC MT 171 table for evaluating the level of optical dust emissions for DustView II (CIPAC, 2015).

the activity of dust particles during static testing. The graph showcases how the dust activity peaks in the initial moments and then decreases gradually as the dust settles. The Dust Number for this particular test was 18.63 which would mean that the product falls in second category from Figure 3.

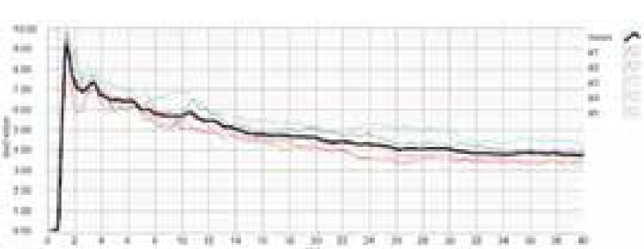

Fig. 4: An example of the results which can be obtained from the DustView II.

The dynamic method takes measurements during a live test with real equipment and external activities. During a real dry-mix shotcrete test, there are many variables which can generate additional dust: compressed air, ambient wind pressures and currents, movement from equipment and personnel, entrapped-air, etc. This manner of testing uses the DustTrak II Aerosol Monitor 8530 by TSI. The DustTrak II performs readings with gravimetric sampling. It is capable of measuring aerosol concentrations ranging from 0.001 to 400 mg/m^3. (TSI, n.d).

In KING's shotcrete laboratory, a series of tests were conducted to see where the dust should be measured. Three locations for the monitors were established for the testing (Figure 5):

- Location A – situated 1 ft (0.3 m) from the hopper of the dry-mix shotcrete machine;
- Location B – set 10 ft (3 m) from Location A and;
- Location C – located in the shotcrete shooting chamber.

The chamber was rectangular in shape and the entrance was sealed with rubber lathes to contain dust from the nozzle. Through trial and error, it was deemed too turbulent to take accurate readings when the DustTrak II was placed in the shooting chamber at Location C. For Location B the aerosol recordings did not depict any significant differences between shooting and not shooting. It was only at Location A when the monitor was placed 1 ft (0.3 m) from the dry-mix shotcrete machine , that significant fluctuations were recorded, and corresponded with the shotcreting activities.

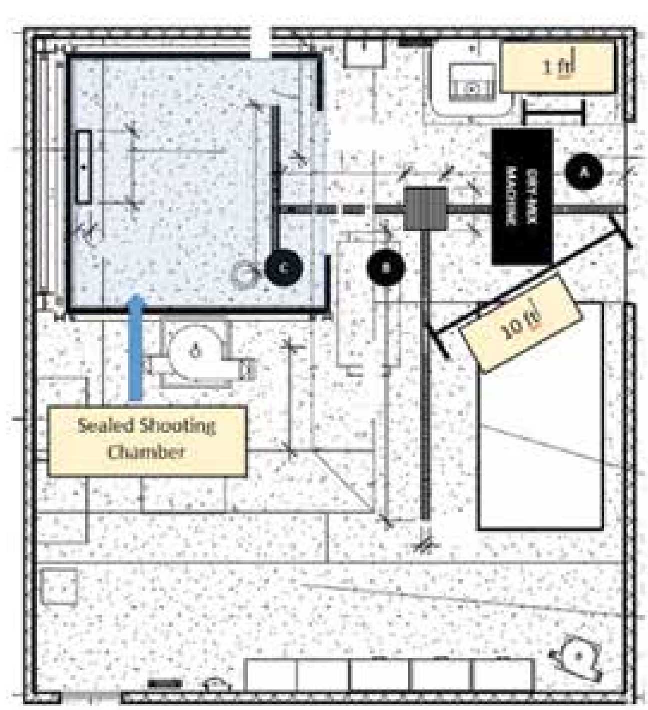

Fig. 5: Locations A, B & C for DustTrak II Aerosol Monitor 8530 dust level monitoring.

DEVELOPMENT OF A DUST REDUCED SHOTCRETE

Trials to date for reducing the amount of dust generated during dry-mix shotcreting for Case 2 are still in the preliminary stages. General findings have been positive for reducing emissions. However, dust reducing additives used thus far were shown to influence two major components of dry-mix shotcreting: 1) The amount of water required at the nozzle to properly hydrate the mix; and 2) A reduction in early and later-age strength gain.

In Figure 6, there is an example of how DustTrak II records the activity of dust particles during dynamic testing. The orange curve is the control mixture and the green and yellow are with two different types of dust reducing admixtures. Everything in gray represents dust generated by other equipment.

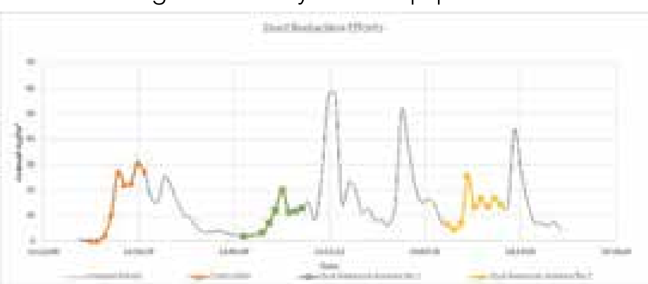

Fig. 6: Dynamic test results for dry-mix shotcretes with and without dust reducing additives.

Dust reducing additives have been effective at lowering dust emissions by up to 43% in dry-mix shotcrete mixes when using the dynamic method. When comparing the compressive strengths for the different formulations as seen in Figure 7, the strength development is slower. However, the differences in strength can be associated with the fact that more water was required at the nozzle to produce a cohesive spray. When observing results from the Rapid Chloride Ion Penetration (RCP) ASTM C 1202, the relationship between additional water can be seen. Referring to Table 1, the early RCP values are elevated for one of the dust additives but at 28 days all formulations reach relatively low coulomb ratings. Figures 8, 9 and 10 show the visible reduction of dust at the hopper when using the dust reduction additives.

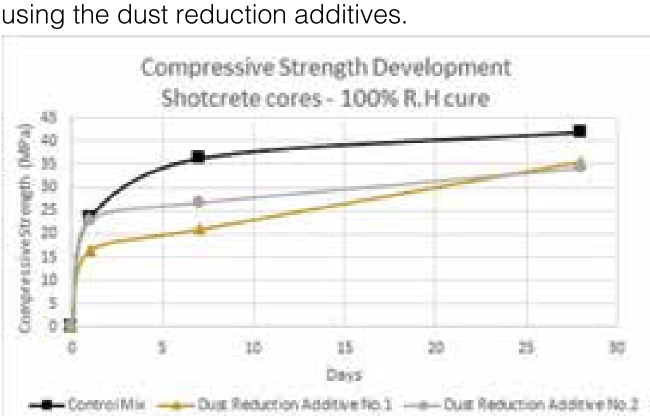

Fig. 7: Compressive Strength development for dry-mix shotcretes with and without dust reducing additives.

Mix Design	Chloride Ion Penetration (7 Days)s	Chloride Ion Penetration (28 Days)
Control	1500 coulombs	650 coulombs
Dust Reduction Additive No. 1	3600 coulombs	750 coulombs
Dust Reduction Additive No. 1	1400 coulombs	500 coulombs

Table 1: Chloride Ion Penetration results for dry-mix shotcretes with and without dust reducing additives.

Fig. 8: Dry-mix shotcrete without any additives.

Fig. 9: Dust Reduction Additive No.1.

Fig. 10: Dust Reduction Additive No.2.

LOW CRACKING POTENTIAL DRY-MIX SHOTCRETE

When repairing concrete structures, best practice is replacing any deteriorated concrete, with a material that closely matches the mechanical properties of the substrate when possible. Even though shotcrete can be very similar to cast-in-place concrete when shot, the shotcrete process and mixture design can invariably lead to increased shrinkage and volume change. This volume change becomes very important for a shotcreted concrete repair, as the substrate restrains the shotcrete from shrinking after placement. If the tensile stress developed in the patch or resurfaced area exceeds the tensile strength of the shotcrete it will lead to cracking or de-bonding.

To characterize the volume change of shotcrete AASHTO T 344 standard test method (ring test) was adapted to the shotcrete process at Laval University (Girard, Jolin, Bissonnette & Lemay, 2017). Using this method, KING was able to screen several prototype mixture designs for a low cracking potential dry-mix shotcrete. During this testing program the ring specimens (Figure 11) were wet cured for a period of 3 days, followed by being placed in a controlled environment at 50% (±5%) relative humidity and a temperature of 70 ± 2°F (21 ± 1°C). The results of this testing program are presented in Table 2.

Mix No.	Compressive Strength ASTM C 1604 (7 Days)	Compressive Strength ASTM C 1604 (28 Days)	Age of Cracking AASHTO T 344 (Days)
1	5800 psi (40 MPa)	7100 psi (49 MPa)	15
2	6235 psi (43 MPa)	6815 psi (47 MPa)	25
3	6380 psi (44 MPa)	6525 psi (45 MPa)	45
4	4640 psi (32 MPa)	5510 psi (38 MPa)	38

Table 2: Age of cracking for different prototype dry-mix shotcrete formulas.

Based on the results of the initial screening tests Mix No. 3 was selected for the next phase, which included a testing program to assess many mechanical and durability properties. This testing program also included the spraying of AASHTO T 344 rings which were then cured using three different curing regimes. The three curing regimes included exposure to 50% (±5%) relative humidity for the entire age of the specimen (Dry), three days of wet curing followed by exposure to 50% (±5%) relative humidity (Wet) and curing compound being applied to the exposed surfaces of the ring after spraying and demoulding then exposure to 50% (±5%) relative humidity for the entire age of the specimen (Curing Compound). All the ring specimens in each curing regime were maintained at a temperature of 70 ± 2°F (21 ± 1°C). The preliminary results of the ring tests performed in the second phase of the testing program for the candidate low cracking potential dry-mix shotcrete are presented in Table 3.

Curing Regime for Rings	Age of Cracking AASHTO T 344 (Days)
Dry (50% RH)	20
Wet (3 Days Wet, 50% RH)	42+*
Curing Compound (50% RH)	42+*
4640 psi (32 MPa)	5510 psi (38 MPa)

*Table 3: Age of cracking for low cracking potential dry-mix shotcrete using different curing methods. *Rings had not cracked at the time of publishing this article.*

It can be seen that exposing the rings of this candidate mixture to 50% (±5%) relative humidity without any curing, can still perform better than typical silica fume enhanced dry-mix shotcrete with three days of wet curing which would normally crack near six to seven days (Menu, Pépin Beaudet, Jolin, Bissonnette & Molez, 2018). However, in comparison to exposing the rings to either three days of wet curing or using curing compound has extended the age of cracking, to such an extent that the rings had not cracked prior to the publication this article and continue to be monitored.

Conclusions

Dust reduction technology for shotcrete is an area that needs further research. Improving the health and safety of the workers who are exposed to dust daily will benefit these individuals and the entire shotcrete industry. Dry-mix shotcrete with reduced dust emissions are currently achievable, but the effect of the additives on the physical properties and durability of shotcrete must be explored further.

It has been shown that by modifying the mixture design of dry-mix shotcrete, the cracking potential can be greatly reduced. Upon selecting the best performing mix design, it can also be seen that using no curing with the low cracking potential dry-mix shotcrete is better than current dry-mix shotcrete technology with three days of wet curing. In a laboratory environment it was observed that the use of three days of wet curing or the use of curing compound with this new technology can drastically reduce the potential for cracking. Low cracking potential dry-mix shotcrete continues to be evaluated to assess the appropriate durability parameters.

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The Influence of the Nozzle Tip on Shotcrete Spray Performance

By Pierre Siccardi, Achraf Laradh, Simon Bérubé, and Marc Jolin

Shotcrete placement is by definition driven by the particles' high velocities. The kinetic energy provided by the velocity is how we obtain the desired consolidation of the in-place material upon impact to achieve good performances. Thus, it is important to look at the velocities found in the shotcrete spray using a rigorous approach to compare different nozzles.

WHAT WE KNOW

In the past, some researchers have tried to explore the rebound phase of shotcrete placement. The most advanced work, made by Armelin (1997), led to a model of a single particle impact on an elasto-plastic substrate. His work especially outlines the importance of the velocity on the particle impact energy, and more widely, on overall rebound.

To have a better understanding of what is going on during the spraying, the placement and rebound phases, this theory had to be extended from a single particle to the entire spray stream. Past research at the Université Laval Shotcrete Laboratory discovered specific patterns in the shotcrete spray for each process and equipment employed. Nicolas Ginouse was the first to develop a method to properly measure particle velocities from the nozzle tip to the receiving surface. By filming the spray with a high-speed camera and tracking the particles frame by frame, he was able to evaluate the particles' velocities in the entire spray stream. Noteworthy, he found that particles kept accelerating after exiting the nozzle as the maximal velocities measured are greater at 1.0 m (3.2 ft) than at 0.5 m (1.6 ft) from the nozzle tip (Fig. 1).

Also, velocities are not uniformly distributed around the central axis of the spray stream. The wet-mix process produces more uniform velocities than the dry-mix process. This means that a higher proportion of particles are travelling at a faster speed in wet-mix (Ginouse & Jolin, 2014).

Finally, one can observe that in dry-mix the exact velocity pattern changes with the type of nozzle tip. The speed reduction at the edges is more important with the double-bubble nozzle-type (in green) than the spirolet nozzle (in red).

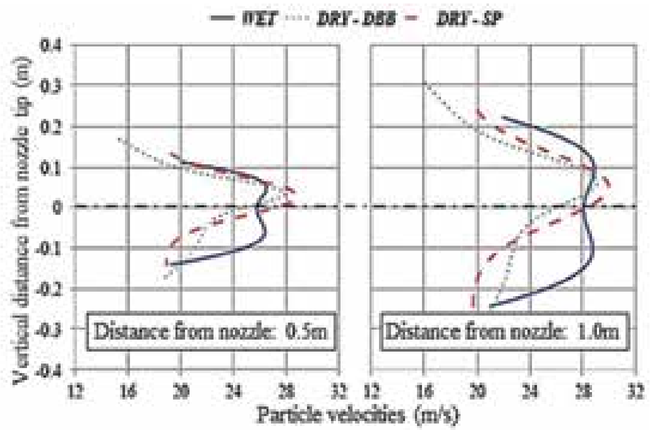

Fig. 1: Fitted velocity profiles at 0.5m and 1.0 m for the wet-mix (in blue) and dry-mix (in green and red)

These discoveries have provided a major step forward in our understanding of the shotcrete placement process. According to Armelin (1997), rebound is linked with the ratio between the kinetic energy of a particle and the debonding energy. Given that kinetic energy depends on the square of the speed, it is logical to believe that velocity spray patterns play a key role in rebound. Thus, the hypothesis that the lower value of rebound produced with wet-mix compared to dry-mix is partly due to their very different velocity profile within the spray stream. Thus, efficiency of the nozzle can be evaluated through analysis of the velocity patterns.

One key observation of Ginouse's study is that a shotcrete spray can be simply characterized by two parameters: the maximum velocity and the spray opening angle.

RESEARCH DYNAMIC

The results of Ginouse's research have opened many R&D topics. Thus, a series of projects have emerged to extend the research effort on the study of the shotcrete spray. One of these research topics was about the influence of the equipment (nozzle) on the performance, especially concerning rebound, in each process.

Simon Bérubé has been a part of this momentum established at Université Laval Shotcrete Laboratory. His research (Bérubé, 2017) has focused on the influence of the nozzle on the particle velocities in wet-mix shotcrete, and on the mass distribution in the dry-mix spray stream of concrete.

This article develops one specific aspect of Bérubé's project. By using the same setup as Ginouse, this research evaluated the influence of the nozzle body and the nozzle tip shape on the spray pattern in wet-mix shotcrete.

METHODOLOGY

This study took place in a controlled laboratory environment with conventional industrial shotcrete equipment. A shotcrete hydraulic cylinder pump, an Allentown Powercreter 10, was used to pump a modern shotcrete mixture designed for wet-mix placement. To lubricate the 50 mm (2 in.) 20 m (65 ft) long delivery hose, a cement grout with the same water/binder ratio as the concrete, was pumped before the spraying.

Fig. 2 shows the experimental set-up for the imaging device used in our facility. The 1250 frames per second capacity camera is positioned perpendicular to the screen and the shotcrete spray. The white screen helps to ensure a adequate contrast to discern particles in the spray when the processing on captured images is done. When shotcreting, the nozzle is held in a static support and kept motionless to avoid the effects due to movement of the nozzle and the material stream.

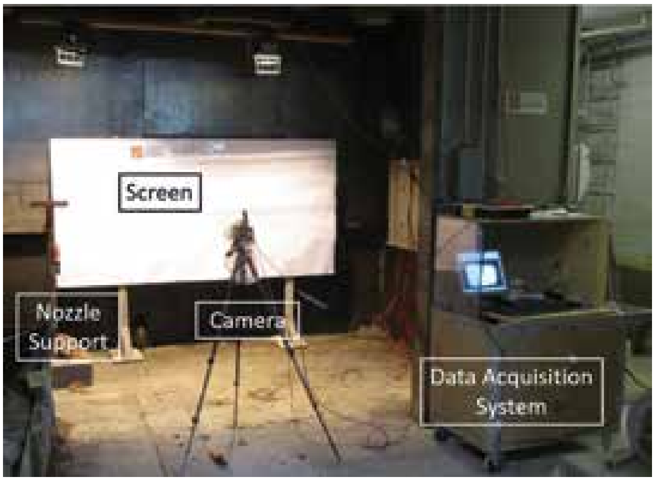

Fig. 2: Experimental imaging device (Bérubé, 2017)

Images are then post-processed with specialized software to track the particles image by image. With the data acquired, particle velocity profile and spray limits can be defined.

Two conventional nozzles, the so-called ACME Nozzle and the 1978 Nozzle (Fig. 3), were put to the test. Those nozzles present some interesting differences: while both air rings are similar (8 holes), the air plenum of the 1978 Nozzle is clearly thinner and narrower than the one found on the ACME Nozzle, and the ACME Nozzle has a 19.1 mm (0.75 in.) air inlet whereas the 1978 Nozzle has a 12.7 mm (0.5 in.).

Fig. 3: Tested nozzles during experiments - ACME (top) and 1978 (bottom) (Bérubé, 2017)

Moreover, the nozzle tips have noticeable differences (Fig. 4). The ACME Nozzle tip (referred to as long nozzle tip) is 193 mm (7.6 in.) long and has a 31 mm (1.2 in.) diameter outlet, whereas the 1978 Nozzle tip (referred to as short nozzle tip) is 130 mm (5.1 in.) long and has a 36 mm (1.4 in.) diameter outlet. The ACME Nozzle tip is therefore longer and more tapered than the 1978 Nozzle tip. Furthermore, these two nozzle tips have different rigidity due to their thicknesses and the rubber used. The long nozzle tip is stiffer.

Fig. 4: Close-up of the nozzle tips

PHASE 1

The first trials of the project brought to light interesting differences in the concrete spray produced by the two nozzles presented before.

Table 1 presents the spray characteristics at 1.0 m from the nozzle outlet for the two nozzles and for two different airflows.

Characteristics	ACME		1978	
Airflow (ft^3/min)	150	200	150	200
Vmax (m/s)	24.0	23.5	16.0	16.9
Angle (°)	28.2	27.2	49.6	52.0

Table 1: Spray Characteristics for the two nozzles

As shown in Table 1, particles in the spray produced by the ACME Nozzle travels around 50% faster than the one in the 1978 spray for both airflows. Moreover, the ACME spray is half narrower than the 1978 spray.

The first interesting observation is the nozzle (body and nozzle tip) has a noticeable effect on the particle velocities and spray limits. To investigate the origin of those differences, the second step of this project was to focus more on this piece of equipment.

PHASE 2

To explore further, the nozzle tips were switched. This way, the long nozzle tip was put on the 1978 Nozzle body, and the short nozzle tip likewise switched to the ACME Nozzle body. Table 2 presents the experimental program and the results obtained with each configuration.

Body	Tip	Vmax (m/s)	
		150 ft^3/min	200 ft^3/min
ACME	Long	24.0	23.5
	Short	18.5	23.0
1978	Long	19.5	22.4
	Short	16.0	16.9

Table 2: Maximum velocity for each nozzle configuration

DISCUSSION

From a theoretical rebound point of view, the ACME Nozzle body combined with the long nozzle tip proved to be the best configuration achievable, considering the particles velocities. For both 150 and 200 ft^3/min air flow, particles traveled around 24 m/s (79 ft/s). The worst configuration would be the 1978 Nozzle body combined with the short nozzle tip. Particles travel around 16 to 17 m/s (52 to 56 ft/s) regardless of the airflow.

INFLUENCE OF THE NOZZLE BODY

To evaluate the nozzle tip efficiency in future research, velocities will be compared using the 150 ft^3/min air flow since that is the more critical case for spray velocities. Using the same nozzle body, the short nozzle tip always produced lower particle velocities compared to the long nozzle tip.

It is interesting to mention that, at 200 ft^3/min, a good nozzle body (ACME) combined with the extra airflow helped to reduce the "bad" effect of the short nozzle tip.

CONCLUSION

This brief study showed the importance of choosing both the right nozzle body and the right nozzle tip to ensure optimal placement conditions. Moreover, it seems that increasing the airflow will not always increase particle velocities. Cutting the end of the nozzle tip reduces back thrust and may facilitate nozzle movement for the nozzleman and is sometimes seen on construction sites. However, this practice will lead to a reduction in the shotcrete spray velocity and in turn reduce the shotcrete placement quality and overall performance.

The authors would like to acknowledge Andy Kultgen with ConForms for his help and suggestions in this project, as well as supplying the different nozzles used in this study.

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Following a bachelor's degree in mechanical engineering from the Arts et Métiers in France, ***Pierre Siccardi*** *pursued his studies at Université Laval, Québec, Canada where he obtained his master's degree. His research project on shotcrete nozzles led to the filing of a patent. He is currently pursuing his PhD under the supervision of Prof. Marc Jolin. His project now focuses on the homogeneity and the adjustment of concrete mixes in a mixer truck using an on-board system.*

Simon Bérubé *earned his civil engineering bachelor's degree from Université Laval in 2014. Following that, he completed his master's degree in the same field in 2018 under Dr. Marc Jolin, during which he undertook a research project on shotcrete equipment modelization. Simon Bérubé now works for CIMA+ since 2016, a private engineering firm located in Quebec City.*

Achraf Laradh *is a master's student in the Department of Civil and Water Engineering at Université Laval, Québec City, QC, Canada. The focus of his graduate research project is to model the spray of concrete to evaluate the placement quality considering the rebound of the shotcrete. He received his engineering degree at Arts et Métiers Paristech, France.*

Marc Jolin, FACI*, is a Full Professor in the Department of Civil and Water Engineering at Université Laval. He received his PhD from the University of British Columbia, Vancouver, BC, Canada, in 1999. An active member of Centre de Recherche sur les Infrastructures en Béton (CRIB), he is involved in projects on service life, reinforcement encasement quality, fibers, admixtures and rheology of shotcrete. He is Past Chair of the ACI Comittee 506 Shotcreting, and secretary of ACI Subcommitee C601-I, Shotcrete Inspector, Shotcrete Inspector, and is a member and Past Chair of ACI committee C660, Shotcrete Nozzleman Certification.*

Shotcrete Systems

By Brian Lywandowsky

My name is Brian Lywandowsky and I work for a large concrete construction company in the San Francisco Bay Area. I've worked in the concrete pumping business since I was sixteen. Since then, I have owned a small pumping business with my father and in 2007, I moved onto the company where I work today. I currently manage the Concrete Pumping and Lightweight Cellular Concrete divisions.

In my years as an owner-operator of boom and line pumps, I had some experience with shotcrete, with the majority of it being in the pool industry. Most of the shotcrete work I witness now is commercial work in the Bay Area and Northern California that consists of perimeter walls in subterranean parking garages, large shear walls, columns, retaining walls, sculpted walls, and repairs on bridges, just to name a few.

After spending time with the shotcrete crews in the field, I was able to learn more about the industry from a different point of view than just the pumping side of the business. I was very impressed with how well the shotcrete crews would perform their jobs on a day-to-day basis. The crews would often arrive on a job that was not set up or properly prepared. Many times, they needed to set up the delivery line comprised of steel pipe and rubber hose using unique techniques and with a limited amount of time. Once the job was set up and they could begin shooting, the crew would face less than ideal conditions, such as improper tied reinforcing bars, inadequately supported forms, and other obstacles. This made it tough to shoot properly, not to mention having to remove rebound from the work area to a designated disposal location. However, the crews would just put their heads down and go to work, producing a fantastic end product.

The shotcrete crews have also done a great job understanding what it takes to get the most out of the pumping equipment. They've figured out that using steel pipe on any pour that required more than 100 ft (30 m) of delivery line would keep pumping pressures to a minimum, create less breakdowns of the equipment, and help get more volume of concrete placed per hour. Using steel pipe from the back of the pump and limiting the rubber hose is a huge help to the overall daily production. It also helps eliminate premature wear of the outside of the rubber hoses caused by the sliding or sawing action produced by long runs and high line pressure in a rubber-only delivery system.

Using the concepts I learned while owning and operating concrete boom pumps, my experience could help crews optimize the set up and cleanup of the pumping system portions of the job. When starting a new project with difficult conditions, we now show up with a truck either a day or two before the job begins with all the necessary pumping components. We'll go ahead and install the delivery system so we are ready to shotcrete on shoot day. We designed specialized mobile parts that clamp to solider beams, standpipe 90-degree elbows, and brackets that can be bolted or welded to the existing buildings or structures.

Fig. 1: Long vertical run of shotcrete line, "a shotcrete standpipe"

COMPRESSED AIR METHOD

When on the job, I've seen many crews cleaning both rubber and steel delivery systems with compressed air. I believe this is the norm in the industry. The blowout process crews used had likely evolved over time after many near misses and hose whippings. Crews would start by using air with no type of dart or plug to force the concrete out of the system. This would serve to limit, but not prevent, the amount of hose whippings at the end of

Fig. 2: Steel delivery line exiting pump

the line caused by the compressed air moving through the line. The pump operator would unhook the system from the pump and then use a blowout cap to push air through the system, starting at the pump and blowing the concrete out the end of the hose. Typically, the largest guy on the crew would try to control the hose end as the air was being applied to the delivery line being cleaned out. He would hold the hose for dear life and get a series of small but somewhat controlled explosions of concrete at the end of the rubber hose. This went on until more air than concrete was being expelled from the end hose indicating the majority of the concrete was cleared out of the system.

In the next step, the pump operator removed the blowout cap and placed a small sponge in the line and reattached the blowout cap to the pump end of the hose. Once again, the man on the discharge end would kneel on the ground with the hose running between his legs or alternately trying to tie down the hose in some way. He would then signal the operator to start the air flow and hold on with a grip that was second to none. By leaving a minimal amount of the concrete in the system, it becomes much more difficult to be able to judge where the sponge is within the system and how fast it is traveling. As it travels closer to the end hose, it can create hose whipping.

The use of compressed air to clear concrete from the system is extremely dangerous. However, with the proper training and correct parts, this process can be safe, fast, and clean. The American Concrete Pumping Association (ACPA) has created rules for cleaning pipes with compressed air, that I believe need to be implemented into the American Shotcrete Association (ASA) safety guidelines. The shotcrete system is different from placing boom type work when it comes to using diverter valves and designated pumping stations. While shotcrete locations typically change from day to day and are not typically using a diverter valve, the rest of the ACPA rules still apply.

Be extremely careful when using compressed air to clean out the placing line.

1. Cleaning with air requires two trained people.
2. No person is allowed to be near the discharge end of delivery line.
3. A dart catcher must be used and the outlet must be controlled.
4. A proper blowout cap must be used.
5. The discharge end of the delivery line should be in a position to permit easy discharge of concrete.
6. The dart or plug used must not be able to let compressed air pass by and into the concrete.
7. No rubber hose can be cleaned with air unless using an attachment specifically used for clean-out into a designated box or mixer truck.
8. Work on the delivery line is allowed only after line has been relieved of compressed air.
9. A good, reliable method of communication between the operator and crew at the end of the delivery line is needed.
10. All PPE must be worn when cleaning out the delivery line, including gloves, safety goggles, ear plugs, respirator, long sleeve shirt, work boots, and vest.

Fig. 3: Shotcrete standpipe clamp and support

Compressed air can only be used to clean out a steel delivery line. It must never be used on rubber hose as the hose whipping effect at the discharge end can be extremely dangerous. When using compressed air, one must be able to control and catch the object that is used to clear the line. It is also very important to only have trained people doing the cleanout. A blowout cap must have the proper distance between the air inlet and dump valve. The catcher must be properly sized to not allow the dart to escape but allow the exiting concrete to easily flow through it. A proper plug or dart must be used to push concrete and it must not let air bypass directly into the concrete. Allowing air to bypass can create a blockage by separating the concrete.

When the shotcrete placement is finished, the trained crew members will remove the rubber hose and connect a dart catcher to the end of the steel line. Once this is done, the operator will breach the line at the pump and insert a rubber dart on the pump end of the line. The operator and designated crew member must be able to communicate, generally by radio. The pump operator will begin to insert air into the delivery line and once concrete begins to move, he will begin to control the amount of air being added to the system. As the concrete begins to move and clear the line, it will take less pressure to move the concrete. The existing air in the system will begin to decompress, accelerating the plug or dart. It is important to feather the air into the system and open the dump valve at the blowout cap to relieve air and keep a slow and steady flow through the delivery line. It is important to have a trained crew member communicate with the operator when the dart is speeding up, and how close the dart is from exiting the system to keep a controlled blowout.

Cleaning the rubber hose can be done very easily by using a garden hose with 50 psi of water pressure. Once the rubber hose has been disconnected from the steel delivery line, a clump of wet paper is forced into the hose. A water cap is clamped onto the hose and a standard water hose is hooked up and used to clear the concrete from the hose. The hose is cleared when the paper exits the other end of the hose.

WATER WASHOUT

The water washout is by far the safest and most practical means to clean both the steel and rubber delivery lines. By using water, one has a material that doesn't compress and have the potential for an explosive discharge that has unfortunately become the norm in the shotcrete industry.

Water cleanout only works when one has access to a good water supply from a high flow water source such as a fire hydrant, water buffalo, or water truck. At the end of the shooting, the operator cleans the hopper and valve by doing a quick washout of the pump and inserts a plug or dart into the delivery line at the back of the pump. They should then fill the hopper and, once full, begin to pump water through the system until the plug or dart is pumped out of the end of the system. The water method is far safer than using compressed air because it eliminates the potential for violent hose whippings. Concrete pumps are capable of producing

Fig. 4: Blowout cap

Fig. 5: Dart catcher

Fig. 6: Steel line transitioning into rubber hose for final discharge

Fig. 7: Shotcrete standpipe

much greater line pressure than even high-pressure air compressors. However, the challenges are often the availability of water and a place to put the water once the system has been cleared.

SUMMARY

Either one of these cleanout processes when properly executed will decrease cleanup time, create a cleaner steel and rubber system, and make priming the system for the next day's shooting much more successful. The safety aspect is the most important consideration for using proper techniques in the cleaning of the delivery line. Using trained crew members and proven techniques will keep everybody safe and give them the best possible process so they can safely and efficiently place shotcrete each and every day they go to work.

Brian Lywandowsky *has been in the concrete pumping business for 31 years. He started out as a partner at Eagle Concrete Pumping with his parents. The business was small and started out with two ball valve pea gravel pumps then steadily grew the company into a fleet of five boom pumps and four-line pumps. In 2007, Lywandowsky sold Eagle Concrete Pumping to The Conco Companies and went to work for Conco as an Area Manager in Redding, CA. After seven years with Conco in Redding, Lywandowsky made the move to the Bay Area and has worked his way to now managing the Northern California pumping operation. In addition to concrete pumping, Lywandowsky provides support and leadership in the development and production of a new Lightweight Cellular Concrete operation known as Con-Foam along with his work in Conco's shotcrete business.*

Real-time In-Situ Technology for Shotcrete Construction

By Benny Chen, Christian Reich, Peter Ayres, and Nicholas Carter

Construction of sprayed concrete lining (SCL) ground support across the world utilizes the construct, verify and rework cycle. This methodology typically requires survey verification of the as-built result against design for each stage of the ground support installation. However, processing and analyzing the measurement data is a time consuming and often intensive manual process. Often once the survey information is available the construction crew will have already left, this will require rework on the next cycle.

Leveraging the latest in high-density LiDAR and high-speed computing technologies, provides the ability for construction crews to receive near real-time feedback of their SCL construction against design. This potentially can significantly improve the efficiency and quality of SCL reinforcement, while reducing waste in construction.

CONSTRUCTION CHALLENGES

In a typical shotcrete application stage, the thickness of shotcrete applied is highly dependent on the skill and experience of the nozzlemen. Upon completion of the shotcrete placement the compliance of the sprayed concrete thickness with the design requirements is not known until after a survey is completed. The survey results highlight areas of over spray (excessive thickness) or under spray (deficient thickness), resulting in shotcrete wastage or costly rework.

For example, during application of shotcrete nozzlemen often use bolt tips as guidance to allow them to gauge the approximate depth of their placement. The nozzleman's experience plays a large role in ensuring that the correct thickness is achieved. However, to reduce the amount of under spray sections and prevent rework the nozzleman may choose to place more shotcrete than required.

In many tunnel and cavern projects, the design profile of the tunnel or cavern is critical and requires strict thickness tolerances during SCL construction to ensure the as-built sections fall within the design profile specifications. In these types of construction, both under spray and over spray could result in non-compliance which then requires very costly and time-consuming rework. Often depth pins and string lines are installed in the area to provide guidance to the nozzlemen, allowing them to visually gauge when they have achieved profile. The process of installing depth pins and string lines are time consuming and labor intensive. This significantly increases the time and cost of construction. Once installed, the nozzlemen will have to estimate the placement thickness between the string lines, which once again is heavily dependent on the skill and experience of the nozzlemen.

STATE OF THE ART CONSTRUCTION TECHNOLOGY

Since the introduction of the Building Information Modeling (BIM) standards, governments around the world are rapidly adapting BIM for their construction projects. This is evident in countries including Hong Kong, Singapore, Norway and Sweden. Figure 1 show the core BIM construction workflow where design and authoring of the architectural and tunnel designs are done in 3D CAD software, such as Revit and Civil3D, where a full 3D model of the completed section is created. This is followed by the Virtual Design and Construction (VDC) process where a complete construction simulation is run using the CAD models. This helps validate the both the construction process and the schedule. Clash detection is also accomplished with the design model to detect any potential design conflicts before the construction plan is approved.

Fig. 1: BIM Construction Workflow

BIM construction is one of the key reasons for the use of laser scanner technology. 3D Laser scanners are used to scan as-built construction elements. Scanning is typically carried out by a survey team where the laser scanner is deployed in the excavation heading to collect the as-built scan data. This scan data is then brought up to the project office, where a powerful desktop computer analyses the data in a georeferenced coordinate system. This point cloud data set often requires some manual processing to correct for measurement errors and to correlate with the design data. The entire process is required before producing a report that can be used for analysis and then feedback to the construction crew. This process typically takes between 2 to 4 hours per station. Hence, the use of such technology in civil constructions are limited.

Since 2016 the rapid adoption of high-speed embedded computing platforms, like Field-Programmable Gate Array (FPGA) and Graphics Processing Unit (GPU) processor cores for embedded systems, advanced data processing has become prevalent. These technologies allow battery-powered devices to achieve computing performance of one trillion floating-point operations per second (1teraFLOPS). Part of this rapid adoption is due to the global development of algorithms and processor cores for machine learning platforms and real-time autonomous vehicle projects.

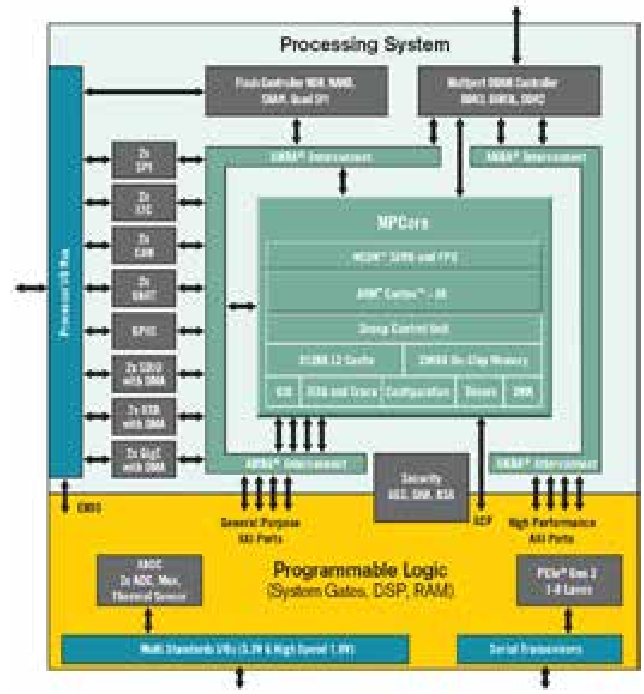

Fig. 2: Xilinx FPGA Architecture

By using FPGA based System-on-Chip (SoC) technology, similar to the Zynq-mp processor core technology that can deliver teraflops of computing performance, computationally intensive signal processing algorithms can be implemented in the hardware using the Programmable Logic portion of the system (see Figure 2). The Programmable Logic area, in yellow, allows the computer designer to create custom digital signal processing cores, like GPUs, and execute them in parallel, allowing high speed processing of large datasets. The Programmable Logic area also has the benefit of having dedicated memory banks that support concurrent access, unlike conventional computer memory access, via a common bus architecture. The architecture above makes it possible to process high-density data, like the 3D point cloud data produced by laser scanners in real-time.

REAL-TIME IN-SITU MEASUREMENT TECHNOLOGY

Real-time in-situ measurement technology refers to a portable measurement device equipped with onboard high-speed computing capabilities to deliver live or near real-time high-resolution information. One example is the production of information such as deformation or shotcrete thickness results in 3D. Figure 3 shows the comparison between using a conventional LiDAR against an in-situ LiDAR technology, in this case the Geotechnical Monitoring LiDAR (GML).

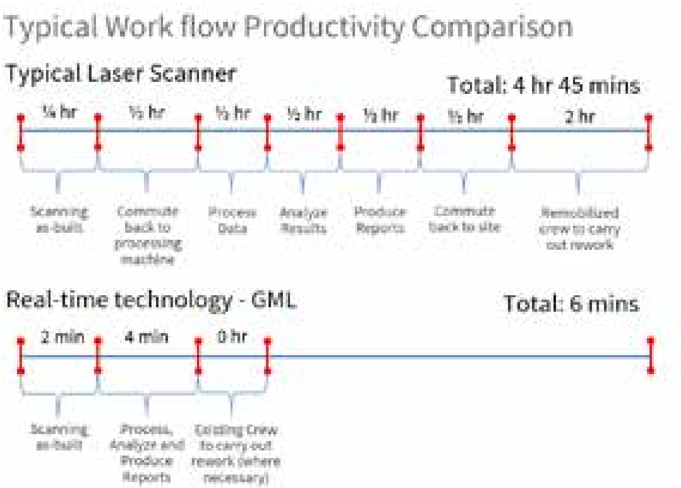

Fig. 3: LiDAR vs In-situ LiDAR Workflow Comparison

In the above comparison, the ability to analyze and report the desired construction results automatically and in minutes has the potential to significantly change SCL construction processes.

GEOTECHNICAL MONITORING LIDAR (GML) TECHNOLOGY

The GML technology was designed and developed by GroundProbe, a mining technology company that supplies slope stability monitoring radar systems such as the SSR-XT for the mining industry. Figure 4 shows the GML system as a complete standalone battery-operated LiDAR solution, that was designed to be a one person operation. This technology is equipped with an onboard high-speed computing device and signal processing software, that can produce high density point cloud information in real-time.

MEASUREMENT ACCURACY

The first proof of suitability for the new technology was to verify the measurement accuracy for shotcrete thickness measurements, against the existing total station pick up by survey control.

The GML was deployed in various control environments in a tunnel project to verify the thickness measurements. The first method was to compare the results of existing shotcrete thickness reports produced by the survey pick-ups against the thickness reported by the GML scanner. In this process, the GML was setup next to the total station during conventional pickup to scan the excavated sections before any shotcrete was installed. Upon installation of the bolts and shotcrete, both the GML and the total station were redeployed to complete the final as-placed scan. These results were tabulated in typical profile section views as per Figure 5.

Fig. 4: Geotechnical Monitoring LiDAR (GML)

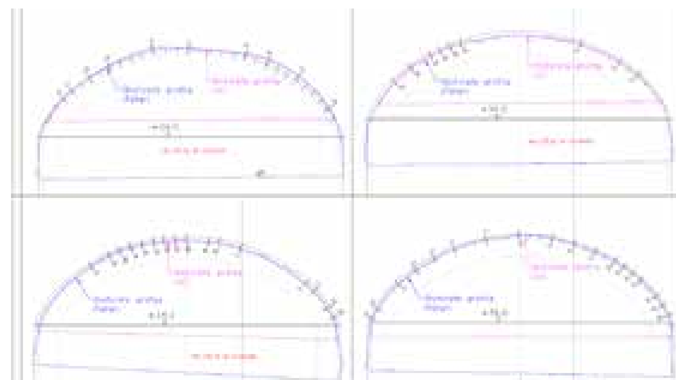

Fig. 5: GML & Total Station Comparison Results

In Figure 5, the GML results are in blue and the results of the total station survey are in pink. Results can be seen in all four scans, the GML results were almost identical to the total station measurements.

In another verification test, core samples were drilled to check the thickness against the GML measurements. In this test, the GML was deployed to scan the section before any shotcrete was installed. Once the shotcrete had been placed and cured the drill rig was deployed to drill four test holes, where the depth of the cores were measured. These four holes were marked on the tunnel surface to allow the user to locate the holes in the GML data.

Figure 6 shows the drill results in the GML SSR-Viewer software. The image was produced by the GML data and clearly shows the marked holes. For each marked hole a group of points were selected, creating the annotated figures shown in the figure. An average thickness measurement was computed for each of the annotated group of points and displayed in the charts.

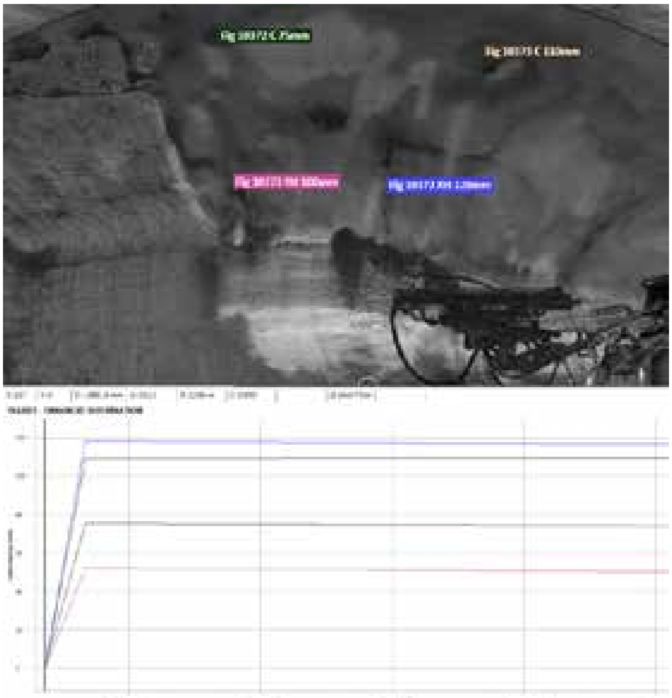

Fig. 6: GML & Drill Test Comparison Results

Table 1 shows the core sample measurements, against the GML measured results, for the placed shotcrete thickness. The GML thickness measurements were accurate to within 1-2 mm (0.04 to 0.08 in.). However, there was a large discrepancy with the results for Fig 10373RH, as notated in the table below. This was subsequently investigated, and it was found the core samples had not been measured correctly.

Figure Name	Drilled Results	GML Results
Fig 10373 C	110mm	109.3mm
Fig 10372	75mm	75.4mm
Fig 10372 RH	120mm	118.2mm
Fig 10373 RH	100mm	52mm

Table 1: GML & Drill Test Comparison Results Table

CHECK AGAINST DESIGN PROFILE

When operating in Profile Mode, the GML can import BIM CAD models into the device and automatically calculate the deviations against the design model. This allowed the construction crew to have real-time feedback of their work while in the tunnel. Figure 7 shows an example of the software operating in Construction Guidance Mode in a tunnel excavation operation.

In Figure 7, the grey point cloud is the scan data and it overlays the different design profile data, shown in purple and blue. The software automatically calculates the distance (in millimeters) to and from the selected profile lines, to produce the deviations in a hot-cold heat map.

Fig. 7: GML Profile Mode

LIVE SHOTCRETE SPRAY GUIDANCE

The following case study was based on data from an Australian tunneling project in 2018. The project used GML for managing the shotcrete thickness for the primary lining ground support in a road header cut tunnel.

The typical construction issue faced in this project was the amount of shotcrete being ordered for each cut. Quantities were based on a calculated estimation, often with large amounts of excess material being ordered to accommodate rebound and the spraying skill of the nozzlemen. During the spraying stage, the nozzlemen have depth pins to gauge the spray thickness, hence the final sprayed thickness varies widely depending on the skill of the nozzleman.

In this project, the GML was used to provide in-situ feedback to the nozzlemen to guide them to spray to the required design thickness. Since the GML was introduced in a later stage of the project it was challenging to change the operating procedure. This required significant planning to be able to train and guide the nozzlemen to spray to the correct thickness. Using the GML system helped to reduce the overall shotcrete usage for the project.

In the early stages of implementation, the GML was used to characterize the quality of shotcrete application by the different nozzlemen. Figure 8 shows the typical spray quality before use of the GML to guide the nozzlemen. The shotcrete thickness in the images were represented with red for areas under design thickness, purple for areas over design thickness and green for areas with the desired design thickness. As illustrated in in Figure 8a, the sprayer was able to cover the bolts correctly but left large areas under sprayed between the bolts. Figure 8b, shows the opposite. Often the nozzlemen would overspray the entire area just to ensure there were no under spray areas resulting in using significantly more shotcrete than necessary.

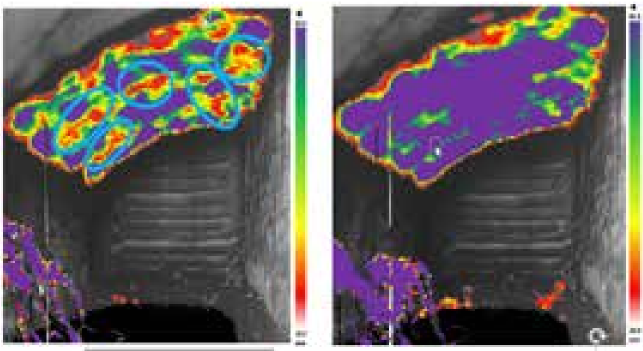

Fig. 8: Detection of overspray and under spray of shotcrete

During the first four weeks of the project, after buy-in from the site engineers, foremen and nozzlemen, the project started seeing improvement in the spray quality. The sprayer was able to use the GML guidance to cover up the thin spots as seen in Figure 8b. However, there were still some amount of overspray. Figure 9 shows an example where the nozzlemen was able to detect thin areas and rectify them immediately using the GML.

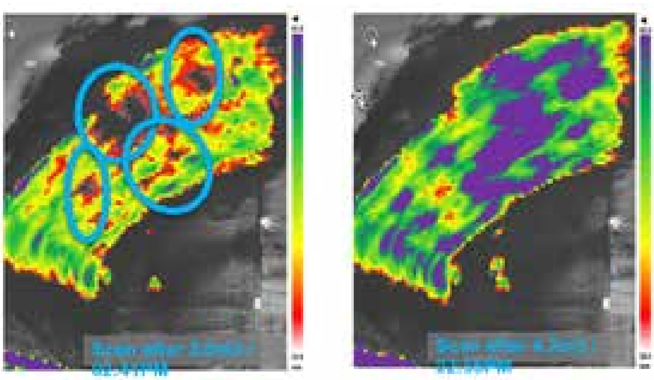

Fig. 9: Nozzlemen guided to fix up thin spots in shotcrete application

Shortly after the first month, the majority of the nozzlemen were able to use the GML to guide their shotcrete placement to reduce the amount of over spray. Figure 10 shows the reduction of overspray areas. In this example, the nozzlemen were able to reduce 33% of shotcrete usage by using the GML. More importantly, this was achieved within two weeks.

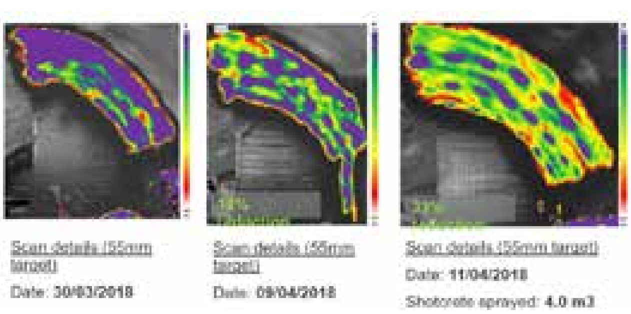

Fig. 10: Reduction of shotcrete usage

The GML was used in the project for a total of eight months and after the first month using the GML the project was able to reduce the shotcrete material orders by 30% for the remaining seven months of operation.

Shotcrete Final Lining Construction

The following case study was based on data from another Australian tunneling project between March and May of 2019. The project utilized GML for controlling the shotcrete spraying process for the tunnel-wide, final lining, to reduce or eliminate rework due to shotcrete not meeting the required minimum thickness.

In this final lining shotcrete application, shotcrete was sprayed continuously between cross passage (CP) to cross passage, completing a 390 ft (120 m) section at a time. This required the shotcrete rig and crew to move 13 to 20 ft (4 to 6 m) each time, to complete shotcreting the entire section. Given the design requirements for thickness and the tunnel design profile, depth pins and string lines were installed as guides prior to the spraying of the final shotcrete lining. The string lines were installed by a crew of two operators, one surveyor and the use of Mobile Elevated Work Platform (MEWP). The installation took the crews approximately two shifts to complete each section. Figure 11 shows a tunnel section that has the depth-pins and string-lines installed.

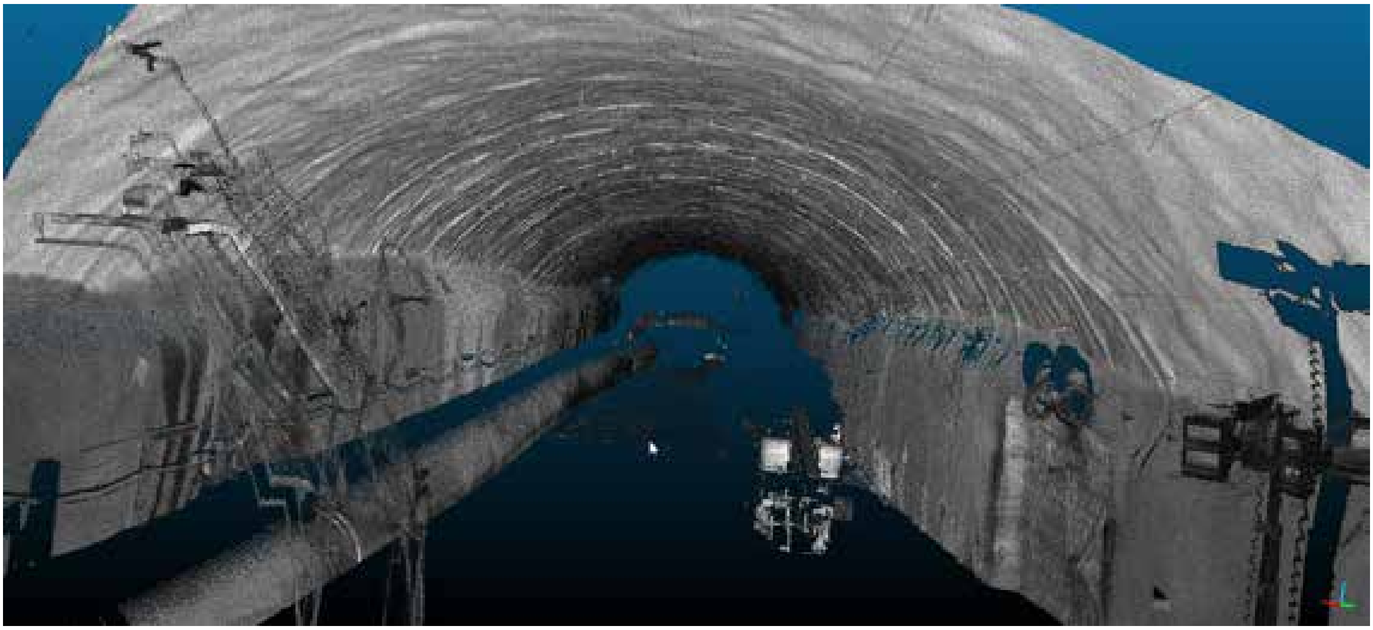

Fig. 11: Depth-pin and string line installation in tunnel section

Prior to the use of GML, the nozzlemen were using the string lines as a guide to spray the desired thickness and profile. Once the spray was completed, the section was surveyed to verify the shotcrete placement against the design profile and required thickness. The project ran for months and found there were too many thin spots that required rework, despite the installation of depth pins and string lines. The GML was then deployed simply as a verification tool to capture the construction baseline. Figure 12 shows a typical rework issue on the project.

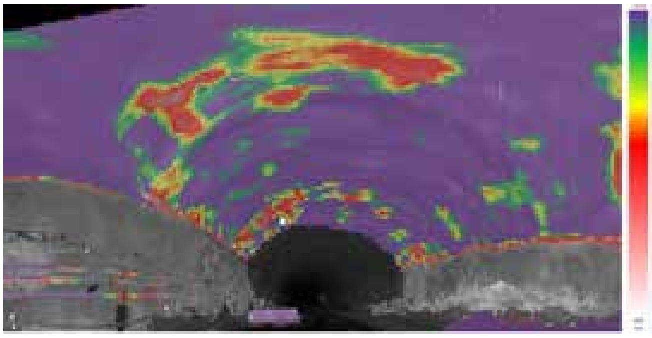

Fig. 12: GML scan showing under spray sections in Red

Figure 12 shows thin spots represented in the hot color palette (red) and over sprayed sections in the cold color palette (purple). The thin spots were spread across the entire sections requiring significant amounts of rework and verification by dedicated rework crews.

GML DEPLOYMENT CHALLENGES

The first key question regarding deployment of the technology was whether it can operate in cycle, particularly during the SCL stage of the tunnel construction process, to monitor spray conformance.

During spray conformance monitoring, the GML is typically deployed next to the front stabilization jack of the shotcrete rig and remains in place during the entire spray sequence. This position allows a wide scan area to be captured with minimal obstruction from the shotcrete rig. The GML completes a baseline scan under two minutes before the shotcrete operator starts to spray. Once the shotcrete operator is satisfied with the first pass, the boom is lowered, and a second scan is captured. As shown in Figure 13, the results are then presented to the shotcrete operator on a tablet to indicate any areas that have not reached the required thickness. The scanner operator then uses a laser pointer or cap lamp to guide the shotcrete operator to respray the thin areas. Once both operators are satisfied, a final scan is taken to confirm the results.

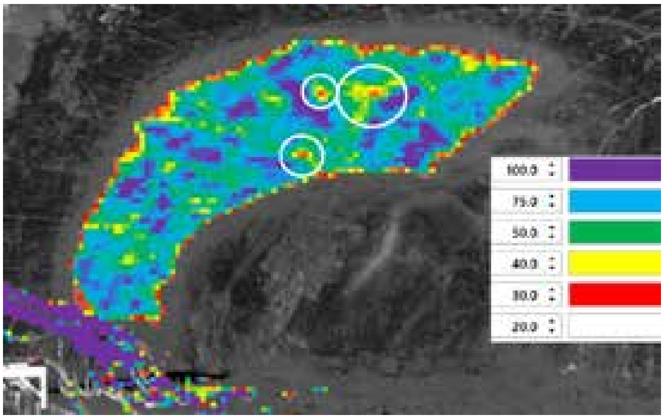

Fig. 13: GML Scan Color threshold for spray thickness

The other key issue was the nature of the final lining spraying process, were the shotcrete rig and crew needed to advance at every 13 to 20 ft section. This required the GML to be relocated with the rig to operate in cycle. The GroundProbe team worked closely with the shotcrete crew along with engineers to develop a shotcreting sequence that allows the GML to operate in cycle. Leveraging the rapid processing capabilities of the GML, the system was able to operate without delay for the majority of the construction.

Given the support of the engineering and final lining team, and lots of teamwork, the project was able to begin to achieve the desired results within the second week of deployment. Figure 14 shows the desired spray result. In Figure 14, it can clearly be seen that there were no thin spots and the reduction of over sprayed sections was significant.

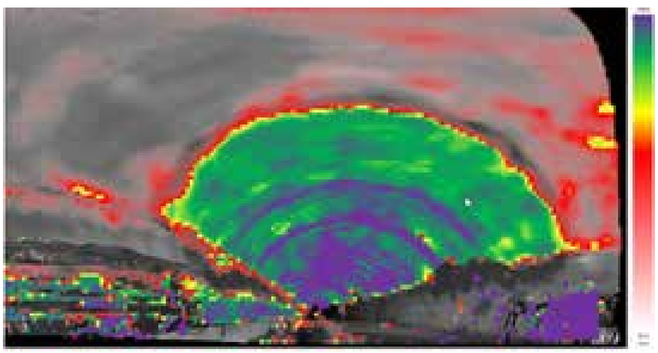

Fig. 14: GML guided spray with zero non-compliant thin spots

This was a considerable improvement on the project and the technology was introduced to cover more areas of final lining construction within the project. Inside the initial two months of deployment, the final lining teams were able to complete 2.6 miles (4.2km) of final lining construction without rework, significantly reducing the amount of shotcrete material used for the project.

Conclusion

The rapid progression of powerful embedded computing and LiDAR technology enables the development of near real-time in-situ scanning solutions. These advances allowed application of the new technology into SCL construction operations and enabled modifying current practices to achieve improved safety, quality and cost savings.

The rapid advancements in computing technology is certainly a key enabler, allowing technology designers to develop tools that could significantly evolve the mining and construction industry. However, the success of such technology relies heavily on the people operating in the industry. Our experience shows that the success of the case studies referenced in this paper, depended heavily on the engagement of the engineering and construction crews, especially the nozzlemen. One of the biggest challenges faced was the management of change in the construction processes. Effective communication and a collaborative approach, to reach a desired solution, was critical to the success of introducing the changes. Leveraging the experience of the foreman and nozzlemen also was a key element in the development of the technology and the construction process.

Finally, project management teams also play an important role in fostering the development of innovative technologies by adopting them at an early stage of a project. This is critical for any emerging technology to achieve the desired potential, and to incrementally change the current state of the art.

Acknowledgement

We would like to thank the excavation and final lining teams mentioned in this article, especially the nozzlemen and site engineers for their contribution to the technology. We would also like to thank the monitoring team from 21MT, led by Christian Reich, for their highly skilled operators that helped to train and integrate the GML technologies into the construction projects.

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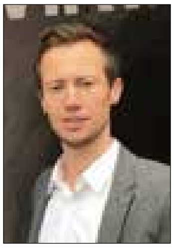
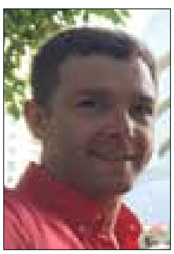
*For the last 11 years, **Ben Chen** has played a lead technical and commercial role in delivering the technology roadmap and his team was able to deliver an array of technologies to significantly diversify and grow the company's brand, market share and revenue. More recently, his team has delivered the Geotechnical Monitoring Lidar (GML) technology that won the Financial Review 2018 Most Innovative Products and Most Innovative Company awards. In the same year they also delivered the Geotechical Monitoring Station (GMS) technology that won the 2018 Good Product Design Awards.*



***Christian Reich** is the Founder and Managing Director of 21MT, an Australian company committed to implementing innovative technologies and solutions in the mining and tunneling industries. Since 2018, Christian has led 21MT in developing extensive experience using Groundprobe's real-time GML scan technology in Australian tunneling projects and has established a proven track record of efficiency improvements by integrating real-time scanning into the excavation cycle. Previously Christian worked at Atlas Copco in Germany as the Product Manager for underground rock excavation equipment. He graduated from Technische Universität Clausthal in mining engineering and business studies.*



***Peter Ayres** is the Lead – Tunnelling Solutions for GroundProbe and a former Technical Services Manager for Orica. Currently he is working with the GroundProbe's Product Development team in the development and implementation of the GML system globally to both Mining and Civil industry. Over the past 12 years, he has worked as a Tunnel Designer with Arup in New York, USA, followed by 6 years with Leighton Contractors (Asia) Ltd. in Hong Kong as a Tunnelling Engineer and Blasting Engineer. Projects have included the 7 Line Extension, NY; West Kowloon Terminus & XRL822, HK; Harbour Area Treatment Scheme, HK; and the Tseung Kwan O – Lam Tin Tunnel, HK. Peter has an M.Eng. in Mining Engineer from Camborne School of Mines - University of Exeter and is currently studying for an LLM in Construction Law and Arbitration at Robert Gordon University.*

***Nick Carter** is the Lead – Technical Solutions at GroundProbe and has been involved in the innovation and development of GroundProbe's emerging technologies since 2011. He has travelled to the farthest and deepest expanses of the earth to provide mining and civil markets with these technologies and globalized understanding of the application requirements. He currently works on the Geotechnical Monitoring Lidar (GML) technology with a small, core team of talented people who regularly solve challenging problems with creative solutions. The GML has received innovation awards from the Australian Financial Review and most recently won the Technology Transfer Award at the 2019 Institution of Engineering Technology (IET) Innovation Awards in London.*

New Application Method of Sprayed UHPFRC

By Satoru Kobayashi

The decline in the number of workers in the construction industry is a severe problem in Japan. Formwork is indispensable for concrete structures, but due to the shortage of carpenters, formwork assembly tends to be slow and can cause project delays. To deal with this problem, new workers are being hired and formwork carpenters are being trained, but the payoff is not immediate because the acquisition of the required skills takes several years of education and experience. The "formless construction method" that eschews formwork, might be a possible solution (Fig. 1), substituting an outer shell formed with sprayed mortar. The reinforced concrete structure is then created by placing reinforcing bar and casting self-compacting concrete (SCC) inside the outer shell.

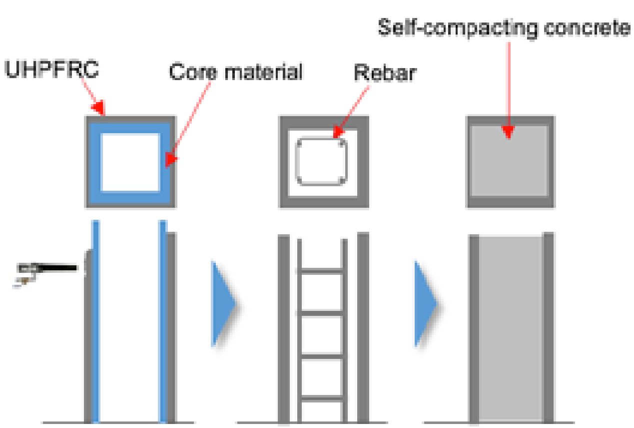


Fig. 1: Concept of formless construction method

In this approach, the lateral pressure of the fresh concrete stresses the outer shell during concrete casting, so the shell must have high tensile strength. Since Japan is an earthquake-prone country, structures are required to have strong deformation performance and must resist the large bending and compressive stresses generated during earthquakes. Furthermore, to reduce the life cycle cost of the structure and increase its sustainability, both high durability and maintenance-free design of the structure are required. Thus, the outer shell must have a high resistance to chloride ion penetration and other aggressive exposures.

To satisfy the performance requirements, we decided to use Ultra High Strength Fiber Reinforced Concrete (UHPFRC) as the sprayed material. UHPFRC is a high-strength and high-ductility material with compressive strength of 22,000 to 36,000 lb/in^2 (150 to 250 MPa) and tensile strength not lower than 1200 lb/in^2 (8 MPa). It is also characterized by a highly dense concrete matrix with very low water and air permeability and thus high chloride resistance. In Japan, UHPFRC has been used mainly for factory produced precast products. Recently, with the advent of mass manufacturing of precast members with large sections, the application of UHPFRC to civil engineering structures has been increasing. The largest such project to date is the application of UHPFRC for the floor slabs of Runway D at Tokyo International Airport with a UHPFRC volume of approx. 26,000 yd^3 (20,000 m^3).

Thus far, UHPFR has rarely been used with sprayed placement, and forming the outer shell of a structure with sprayed UHPFRC is a novel challenge. This article outlines the experimental method developed and used to form the outer shell of a structure with sprayed UHPFRC.

We focused on columns as the target structure. This formless construction method requires a core material that is easy to install and remove. Air tubes were adopted as the core material. Figure 2 shows the installation of the air tubes. The thickness of the member was 16 x 16 in. (400 × 400 mm), and the thickness of UHPFRC was 1.6 in. (40 mm). The height of the columns was 59 in. (1500 mm).

In this experiment, a mortar pump (squeeze type), maximum discharge rate 8 yd^3/hr (100 L/min) and a delivery hose with a diameter of 2 in. (55 mm) were used.

Fig. 2: Installation of air tubes

Fig. 3: Spraying of UHPFRC on air tubes

Fig. 4: Removal of the air tubes

The diameter of the tip nozzle was 0.6 in. (15 mm). The sprayed material was required to stick on vertical surfaces without sagging. To this end, a non-alkali hardening accelerator was added at the nozzle.

Figure 3 shows the spraying of UHPFRC. The material adhered to the vertical surfaces of the air tubes without sagging, and coverage of the sprayed material to the required thickness and height of 5 ft (1.5 m) was achieved without problem.

Figure 4 shows the removal of the air tubes that was easily accomplished.

As the next steps, reinforcing bars will be set and SCC will be cast inside the outer shell. The structural performance will be evaluated by flexural strength testing.

***Satoru Kobayashi** is a senior researcher for Kajima Technical Research Institute based in Japan. He graduated from Hiroshima University where he studied the durability of concrete. He is highly skilled in concrete, for example, self-compacting concrete, anti-washout underwater concrete, dam concrete, and shotcrete. Recently his research project focuses on the new application method of UHPFRC and various ways to use it at the construction site effectively in order to improve the durability of the structure and the productivity of the construction process.*

Dealing with COVID-19 in Construction

By Ted W. Sofis

This year, 2020, we have been challenged in a manner unlike anything we have experienced in America since the 1918 influenza pandemic that killed millions worldwide. The coronavirus (COVID-19) was identified in Wuhan, China, after initially being reported as a cluster of pneumonia cases in December 2019. Despite efforts to contain the virus, it rapidly spread to Italy and the rest of Europe and eventually the United States. As a result, on February 26, the first cases of COVID-19 began to appear in the Seattle, Wash. area. Acting rapidly, many state governors issued emergency restrictions and stay-at-home orders. Across America we all watched the coronavirus task force briefings and New York Governor Andrew Cuomo's morning broadcasts, as the response unfolded in especially hard-hit New York. In Pennsylvania we were issued stay-at-home orders by our Governor Tom Wolf for all but life-sustaining businesses. Which resulted in PennDOT closing down construction projects. In the months that followed, state governors began to reopen their economies. With the return to work there are protocols and procedures we will need to follow to keep our crews safe and well. Below are some guidelines and information that I hope you will find helpful.

Intent of Program

COVID-19 is an easily transmitted disease, especially in group settings. It is essential that positive actions be implemented to slow or stop the spread of the virus to safeguard the public safety. Construction is vital to our nation's economy. Recognizing this, we need to find ways to accomplish our work while not endangering our employees. This requires several precautions to protect our workers, their families, and members of the community. It is necessary that all businesses in the construction industry conducting person-to-person activities follow the directives and requirements of their state governments. Other local political units or privately owned companies may elect to impose more stringent requirements. In such cases we must adhere to the client or owner's requirements.

Recommended Guidelines

- Follow all applicable provisions that your State government has provided for business safety measures.
- Requiring that every person present at a work site wear a face mask or face coverings.

Fig. 1: Social distancing with mask inside

Fig. 2: Hand Sanitizer and Disinfectant Wipes

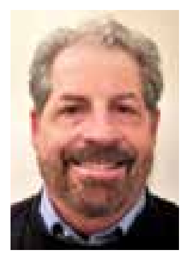
Fig. 3: Social distancing with mask outside

- Establish protocols for action to be taken when cases or probable cases of COVID-19 are discovered or whenever people in the company could have possibly been exposed to someone who may have the virus.
- Require social distancing with a 6 ft (2 m) minimum distance between workers, unless the safety of the workers makes an exception necessary, (for example, team lifting.)
- Follow other Department of Health (DOH) and Centers for Disease Control and Prevention (CDC) guidance.
- Provide hand washing stations at appropriate locations on your job sites, such as building entrances, break areas, offices, trailers and job site egress areas.
- Implement cleaning or sanitizing protocols at all construction sites and projects. Identify and regularly clean and disinfect areas that are high risk for transmission. Establish requirements to clean common areas and regularly trafficked areas periodically.
- Ensure all gatherings are limited to no more than the maximum gathering size mandated by the state where your project is located. Maintain 6 ft (2 m) social distancing at all times when required to meet, even when meeting outside.
- Use virtual meetings and distribute information electronically whenever possible.
- Stagger shifts, work breaks, work areas, and different trades, wherever feasible, to minimize the number of workers on site.
- Limit tool sharing and sanitize tools or equipment if they must be shared.
- Employ jobsite screening based on CDC guidance to determine if employees should be working. Prohibit employees with any symptoms of Covid-19 from working. Encourage any sick employees to stay at home.
- Prohibit unnecessary visitors to any project or work site and limit the number of supplier deliveries.
- Limit access to enclosed spaces as much as possible.
- Ensure workers are traveling to and from the jobsite in separate vehicles. Whenever possible, make sure that they do not share a vehicle.
- Identify a Coronavirus Safety Officer for each project or work site, or (on a large-scale project) for each contractor or subcontractor at the site. The primary responsibility of the Safety Officer is to convey, implement and enforce the social distancing and other requirements of the company program for the protection of employees, suppliers, and other personnel at the site.

Fig. 4: Face mask protection in close proximity

Fig. 5: The respiratory protection worn during gunning operations fulfills the COVID-19 face mask directive.

Ultimately, as a contractor, I realize the difficulties involved in implementing and following coronavirus guidelines, while at the same time trying to efficiently perform and complete our projects. The reality is that we have no other option. This pandemic is so widespread and highly contagious that it forced the shutdown of our nation's economy for months. Nothing like this has ever happened before in our lifetimes. To ignore this, we jeopardize the lives of our employees and their families. For the safety of everyone involved and the communities where we live, we need to get through this together. A vaccine for COVID-19 will be developed and therapeutic medications for treating the virus will become available. In the interim, we need to find ways to be safe and productive. I hope that you find these guidelines helpful. More importantly, it is my hope that all of you and all of your employees make it through this construction season safely and in good health.



__Ted Sofis__ and his brother, William J. Sofis Jr., are the Principal Owners of Sofis Company, Inc. After he received his BA in 1975 from Muskingum College, New Concord, OH, Ted began working full time as a shotcrete nozzleman and operator servicing the steel industry. He began managing Sofis Company, Inc., in 1984 and has over 40 years of experience in the shotcrete industry. He is a member of various ASA committees and an ACI Shotcrete Nozzleman Examiner for shotcrete certification. Over the years, Sofis Company, Inc., has been involved in bridge, dam, and slope projects using shotcrete and refractory installations in power plants and steel mills. Sofis Company, Inc., is a member of the Pittsburgh Section of the American Society of Highway Engineers (ASHE) and ASA.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Alfond W2 Ocean Engineering Lab Tank

By Mason Guarino

In 2013, South Shore Gunite (SSG) was approached by the Cianbro Corporation and the University of Maine in Orono, ME, to help with the construction of a new research facility. SSG previously worked with the University on a swimming pool project with another construction company. With their demonstrated high levels of safety and quality of the final product, the University and Cianbro felt comfortable deciding that SSG would be a good fit for the new project. The project was a research tank 100 ft (30 m) long, 30 ft (9 m) wide and 20 ft (6 m) deep with 2 ft (0.6 m) thick walls and a 3 ft (0.9 m) thick floor. The facility would help the University conduct research on offshore equipment, initially focusing on offshore wind farms although the research tank would be capable of much more when complete.

The construction schedule originally put tank construction in the summer but with typical construction delays it ended up getting pushed into the fall with completion of the tank ending up in winter-time. Orono, ME is close to Bangor, ME and gets very cold and snowy in the winter. The project posed many challenges from the start, including value engineering, meeting the University's and general contractor's elevated safety requirements as well as building the tank when the weather was not going to cooperate.

The original design anticipated conventional form-and-pour construction. SSG worked with the GC and engineer to show them how shotcrete could save money and move the project along faster. The shotcrete process reduced forming requirements, eliminated construction joints within the wall, and generally moved the project along faster by significantly reducing the time that conventional form-and-pour construction would have required with extensive form work and multiple construction joints. The GC was also concerned about working with a large crew inside a 20' deep tank. Even safe egress was an issue as it would be roughly three flights of scaffolding stairs or more, plus a ladder to get from the bottom to the top. Add that to more scaffolding or manlifts along with the delivery line for a large concrete pump. As a result, form-and-pour presented too many potential risks for working inside the tank. The last major hurdle would be winter conditions. While most of the tank was scheduled to be constructed during conditions suitable for pouring concrete, winter came on very quickly.

In considering the shotcrete placement option, the first challenge was how to construct the tank as safely as possible. Of concern were the safety issues for a quick escape or extraction if something happened while working inside the tank. SSG proposed forming the inside of the walls and shooting the tank from the exterior. This method ensured that no one had to be inside the tank after the forming process was complete. During the forming process multiple doors could be left open in the formwork until everyone was outside of the tank. Installing the forms on the inside of the tank allowed SSG to ensure the results would be perfect. Shooting from the outside added another safety concern. Since the floor slab extended beyond the outside of the tank wall, it created a tripping hazard. The team concluded that whenever possible, the GC would backfill to maintain a relatively level working area.

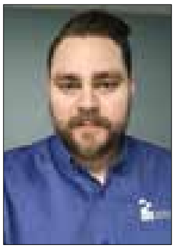
The shotcrete process also eliminated the need for construction joints that form-and-pour would have required. The tank concrete had to be watertight with no internal finishing, membrane, or coating. Eliminating all the construction joints in the wall eliminated the potential for leakage at the joints. The concrete floor was cast and the interface at the joint between the wall and the floor thoroughly roughened to allow the shotcrete to create a monolithic joint. The engineers also asked SSG to add a Xypex concrete admixture to the shotcrete mixture. Shooting from the outside also reduced cost as SSG only had to finish the top 4 ft (1.2 m) of the structure that would be exposed to view. SSG decided to shoot the tank with scissor lifts. We used two scissor lifts on site, one for the nozzlemen and blow pipe operator, and one for supervision and verifying the correct thickness was achieved. Since most of the exterior tank wall was to be unfinished, SSG shot the tank up to 4 ft from the top and demobilized. Creating an exceptional finish is very difficult from scissor lifts since it's difficult to have ready access everywhere when needed. For safety, scheduling and performance reasons, the tank was backfilled so we could work from ground level for the top 4 ft of the wall and provide a high-quality finish. While SSG was off site after demobilizing, the GC backfilled the tank.

The site soils required the excavation to be 24 ft (7.3 m) deep, 120 ft (37 m) long and 50 ft (15 m) wide with excavation sloping up at a 1:1 slope to keep the safe throughout the shotcrete phase. The size of the excavation kept the GC from doing most other work around the tank, so they were all for backfilling as early as possible. Properly backfilling this large excavation took some time to complete, and by the time the GC was ready for SSG to return, winter had completely set in. SSG now had to complete the high-quality finish work in freezing temperatures. The GC ended up building what was essentially a tunnel around the perimeter that would be heated for us to work in. The remainder of the shotcrete work was done in a couple weeks despite the frigid temperatures in the middle of Maine.

After the shotcrete work was complete, the tank was covered and the rest of the building erected. Interior markings on the walls were added later to support the research needs. A movable floor was installed to allow adjustments to the depth of the tank to model different depths of an ocean floor. One end of the pool had a wave machine installed and a sliding wall of fans was installed to simulate wind loads that may be expected in the ocean.

This project was featured in Engineering News-Record (ENR) soon after completion and specifically mentioned shotcrete. The facility has also been featured in the news many times for their research supporting different offshore wind turbine installations around the world. More information on what the facility is capable of can be found at https://composites.umaine.edu/key-services/offshore-model-testing/.

In summary, despite the challenging conditions in a deep excavation and enduring cold Maine weather, SSG proved that shotcrete placement was a great alternative to a form-and-pour approach. Shotcrete reduced the cost, provided savings in schedule, and produced a completely watertight concrete tank. The quality of shotcrete materials with proper placement have created a research facility that will serve the University of Maine for decades to come.



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 Institute of Technology with his BS in construction management in 2009. Guarino currently serves as Treasurer on ASA's Executive Committee, Chair of ASA's Pool & Recreational Shotcrete Committee, and is an ACI Certified Nozzleman.*

Iron Mountain Ski Lift

By Ben Byerly and Michael Klemp

Thorcon was hired by Replay Resorts to repair a previously stabilized slope, a terminal cutback retaining wall, near the Iron Mountain Ski Lift in "The Colony at White Pine Canyon" in Summit County, Park City, UT. Originally, the slope was stabilized with a helical and geo-grid system to protect the Iron Mountain Ski Lift that is directly below the cut slope.

The original repair was done in 2010 with typical construction methods used in the area and began to show signs of failure in 2017. Thorcon was hired to provide an analysis of the existing slope repair condition and innovate and execute a design-build solution with longer service life than the previous design. One of the client's requirement criteria for the solution was to not detract from the natural beauty surrounding the ski resort. In essence, a repair that does not look like a repair and blends into the natural landscape.

Several aspects of this project made it a complex endeavor. First, the existing tiered wall faces had dropped from the original repair creating a very narrow access for equipment to excavate, test, drill, reinforce, spray Shotcrete and sculpt the new repair. Second, due to the orientation of the slope and the elevation, controlling the seasonal runoff and large amounts of natural water was critical to the longevity of the new repair. This required a runoff control system that incorporated top of wall swales and drainpipes running from each terrace to the next behind the wall facing while controlling the final discharge at the very bottom of the wall system and away from the lift base.

Fig 2: Structural layer into sculpted architectural layer

Thorcon enlisted the services of EV Studio for the engineering and worked hand-in-hand to formulate a system to achieve all of the criteria goals of the design and client. The project used some of the existing anchors (that were proof tested) along with new soil nail anchors and reinforcing steel. Shotcrete was placed then sculpted and stained to create the final architectural finish. The construction also needed to include the drainage system at the top and bottom of the walls to manage the seasonal runoff.

All sculpting is hand carved and textured by hand. This was completely free formed and needed the artist and nozzleman working together as a team to build out different sections of the wall face then hand

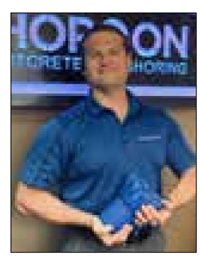
Fig 1: Iron Mountain ski lift

Fig 3: Finished product

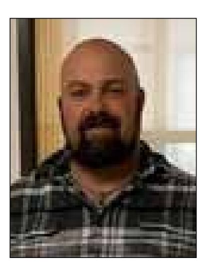
carving the surface to mimic the natural rock formations of the existing topography. After the carving and hand texturing were completed, the entire wall face was stained by hand with multiple colors to achieve a natural looking rock face with varying colors and patterns just as found in natural rock formations.

Thorcon installed a total of 45,000 ft^2 (4200 m^2) on 4 tiered walls with 328 new soil nail anchors and 1,717 yd^3 (1313 m^3) of 4000 lb/in^2 (28 MPa) shotcrete to deliver the clients structural integrity, durability and vision. Thorcon achieved all of the critical objectives with our trade partners EV Studio, Williams Form Engineering, Geneva Rock and HD Supply. This project is also the Grand Prize winner in Scofield's Heavy/Highway concrete category.

Fig 4: Drone shot completed wall system



__Ben Byerly__ is the Vice President of Thorcon Shotcrete and shoring, concentrating on the Operations side of management. He has been in the Management and the Construction Industry for over 10 years. Specializing on intricate building projects and high accountability Owners/GC's with little opportunity for errors. Working to create a productive team atmosphere and growing team members from within the company, to navigate the low availability of skilled labor in the Geotechnical field. He also focuses on building a sustainable business models and risk management tools to set Thorcon's path into the future.



__Michael E. Klemp,__ born and raised in Blackhawk, CO, is the owner of Thorcon Shotcrete and Shoring. He graduated from Colorado State University with a degree in Construction Management and currently has over 20 years in the construction industry, focusing on geotechnical work. Mike has been involved in hard rock and technical drilling his entire career. Large, complicated retaining and shoring wall systems are Mike's specialty, including structural shotcrete facing and sculpted architectural finishes, as well as complex and limited access foundation piles. Projects completed include mining, railroad, DOT, and private projects.

What to Look for in a Shotcrete Contractor?

By Lloyd Keller and Lorena Proietti

With the continuing evolution and acceptance of shotcrete in structural commercial concrete construction, attention to the critical components and procedures in the technology is needed to achieve the necessary structural requirements. There are a number of key requirements for any project to meet the expectations of the engineer of record, in addition to what a shotcrete contractor needs as their work plan to best achieve the requirements.

KEY ELEMENTS TO CONSIDER IN CHOOSING AND QUALIFYING A CONTRACTOR

Who has the background and experience for shooting structural shotcrete elements? Of course, each project has its own unique challenges and requirements. The type of project – whether it is a civil transportation system that requires an extended service life of 75 to 100 years; a water retaining structure that requires the shotcrete wall to be subjected to a water pressure; or a mass concrete structure requiring low exothermic heat generation are examples of a few of those challenges. The project may require extensive and densely spaced reinforcing steel, or it might be designed as a circular or curved shape requiring carefully controlled geometric controls and layout. The project might be in an area where local sourcing of equipment and personnel with the understanding and experience of proper shotcreting techniques is not readily available.

From a business perspective, the shotcrete contractor must have a background in management and personnel. ASA has developed a qualification program for structural shotcrete contractors. Currently there is an ASA Board of Directors Position Statement #1 entitled, *Shotcrete Contractor* and *Crew Qualifications*. The position statement outlines a number of key guidelines that the owner or specifier should consider when prequalifying shotcrete contractors prior to bidding. Some of the key items listed include:

1. Five years of experience as a licensed contractor.
2. Fifteen shotcrete projects of similar size, scope and shotcrete process used (dry or wet mix) successfully completed in those five years with proper documentation, including full contact information for owner/engineer/construction manager/general contractor, a project description, and a scope of work accomplished.
3. The ability to self-perform all shotcrete-related work and a minimum crew on hand and/or staff listed as part of the company (either employees or substitutes with a work history under the current business name) consisting of the following minimum experienced crew members:
   a. Shotcrete Foreman
   b. Nozzleman (at least one ACI Certified Nozzleman on the project)
   c. Wet-Mix Pump Operator or Dry-Mix Gunman
   d. Assistant Nozzlemen/Nozzlemen Trainees (blowpipe operators)
   e. Finishers
   f. Mixerman (for site batched concrete materials)
   g. Hose Tenders
4. Ownership of all necessary shotcrete-specific equipment to accomplish the job based on the project specific needs.
5. A certificate as a Business in Good Standing from the state or province that the company resides in.
6. A letter of bonding capacity from the bonding company or a letter of credit.
7. Company insurance in good standing, meeting all state or provincial minimum requirements, including, but not limited to, general liability and workers compensation.

Fig. 1: Shotcrete samples being tested with shear vanes

Fig. 2: Shotcrete semi-adiabatic cube cast for thermal monitoring

8. ASA Sustaining Corporate or Membership
9. Ability to demonstrate that company construction support staff (safety, general superintendent, project managers and construction managers) has educational session credits through an industry-appropriate continuing education program specifically addressing shotcrete design, construction or administration sessions such as World of Concrete, ACI and ASA conventions and ASA meetings.
10. An office, shop or business office (with an address).
11. References (including those from the fifteen projects identified in Item #2)
12. Affiliations
13. Full disclosure of any criminal or fraudulent rulings for shotcrete work against former or current company owners in a 5-year period.

EQUIPMENT AND MAINTENANCE

A company is only as good as its people and the equipment needed to perform the installation. Proper certification for the personnel is very important, however, if the labor force is not provided with the proper tools and well maintained equipment, production and performance will be seriously impacted. It would be wise to inquire whether or not the company has an equipment division that is responsible for supply all of the tools necessary for each and every day's work requirements. Also, ask if there is a shop or facility that takes in and services the pumps and other equipment needed on a daily basis. Check to see if there are equipment maintenance logs to review and if the maintenance division ensures that there is adequate standby equipment in the event of a breackdown on a project.

The list of questions that should be asked can seem endless. Additional areas of consideration are as follow:

1. Innovative approach - Has the company demonstrated a capacity to be a valuable contributor to the construction process? Are they able to provide well thought out strategies and options for development of a work plan that enables the project to proceed in a cost-effective manner with expedited construction time or enhancements to the schedule?
2. Supply chain partners - Does the company perform in a collaborative manner and actively engage in planning sessions to coordinate timing and deliveries to best suit all partners involved? This is especially important in busy locations where schedules are impacted by traffic congestion during rush hour, noise considerations due to adjacent residential areas or construction material suppliers like ready-mix concrete producers are operating at or near full capacity during particular hours.
3. Industry leaders and involvement - Does the company participate actively in local or national construction associations? Is there an active involvement of their leadership to ensure collaboration and understanding of each stakeholder on the project, recognizing concerns and constraints with the goal of working towards a practical solution to any constraints imposed from either parties during the construction process?

Fig. 3: Representative mockup of 1.2 m thick, heavily reinforced wall

Fig. 4: Shotcrete nozzleman shooting project mockup

4. Effective communication to the Engineering and Architect Community - Is the leadership of the company actively accessible to the architectural and engineering community? Do they participate in formalized association-related technical sessions and workshops either through associations or at the workplaces of the major architects and engineers?

QUALITY AND SAFETY

Quality and safety are two of the most important factors to ensure successful shotcrete placement. A benchmark is set on both of these points to make sure that the project engages a qualified and experienced shotcrete contractor, with a proven track record of building similar structures and having the correct equipment and crew for the project. During the initial meetings with the contractor, focus on the contractor's commitments to ensuring that the utmost quality and safety guidelines are adhered to by all parties involved. During construction, it may make sense to engage a qualified third-party inspector to act as a second set of eyes and help ensure the approved procedures are being followed. Jobsite safety and quality assurance involve constant communication between all stakeholders as well as proper tracking of personnel, procedures, and documentation.

In addition, the technical performance of the project would need to be confirmed with the aid of concrete mixture design development and hardened materials properties testing. Preconstruction mockups used to verify the performance of the crews by demonstrating their abilities to place and fill the reinforced elements with a dense shotcrete material that fully wraps around the reinforcing steel and fills areas around and adjacent to embedded accessories like electrical conduit and shoring anchors etc. is a given requirement. Hopefully, the above mentioned items and recommendations will enable you to adequately choose a qualified shotcrete company that will ensure your project meets the necessary requirements to achieve quality and success.

Lloyd Keller *is the founder of Research and Development and Quality Control for EllisDon Construction in Mississauga, Ontario. He is an American Concrete Institute (ACI) fellow and participates in numerous committees for ACI and CSA Group (CSA) in Canada. He was educated at BCIT in Canada specializing in Civil and Structural Engineering Technology. His research efforts have been over the last number of years focused on Self Consolidation Concrete (ACI 237) and the prediction of formwork pressure. Shotcrete for structural installations and the control of exothermic heat generation with the utilization of high-volume supplementary cementing materials is also an area of research over the last few years.*

Lorena Proietti *has a Civil Engineering degree from Ryerson University, Toronto, Canada and has 10 years of experience working in the Construction Sciences Division at EllisDon Corporation. In her role, Lorena provides technical support to a variety of projects nationwide, focusing on concrete and material technologies. In the last few years, the use of shotcrete for structural applications in Canada has increased and Lorena has been at the forefront of understanding this technology to be able to service those projects. She is an active member of ACI and continues to work on advancing standards on both ACI and CSA.*

PULLMAN

PULLMAN

With the construction of its first 100 ft (30 m) high chimney at a coal-fired power plant in 1902, PULLMAN established itself as a specialty contractor that knew how to tackle the tough jobs. More than a century later, we have developed a diverse offering of specialty contracting services for the oil and gas, power generation, civil infrastructure and commercial sectors.

SAFETY 24/7 – KNOW IT, LIVE IT

Safety 24/7 is an integral part of a PULLMAN employee's personal commitment to his or her own safety, as well as to the safety of friends, family and co-workers. This commitment creates a culture of safety on our job sites, in our manufacturing facilities, offices, and in our private lives.

PULLMAN'S DEDICATION TO SAFETY

Our commitment to safety goes beyond our employees—it extends to our subcontractors, customers, the general public and the structure itself. For each project, we implement a site-specific safety plan, training plan and communications program. Our program is the most comprehensive in the industry.

FRONTLINE SAFETY STRATEGIES

- High-level management and technician/craft involvement
- A project-specific safety committee
- Continuous task hazard analysis
- Safety observation processes
- Regularly scheduled job site safety audits
- Continuous improvement planning and execution

Fig. 1: Setup and form work for mock-up of an architectural shotcrete project.

Fig. 2: Shotcrete application using dry-gun shotcrete process on architectural arch panels.

Fig. 3: Finished architectural shotcrete arch panels.

Fig. 4: Shotcrete fireproofing on beams and columns in FCCU.

WHAT MAKES US UNIQUE?

PULLMAN is a full-service specialty contractor with a trained, union workforce, in-house engineering and professional project management team. Our experienced team works with the client to determine the correct repair, while maintaining the needed schedule and budget.

PULLMAN specializes in shotcrete placement of site-batched sand and cement, pre-packaged dry-mix shotcrete products and refractories in the industrial and commercial markets. We perform these services throughout the US and abroad with offices in the following areas:

- Detroit
- Kansas City
- New York
- Toronto
- Philadelphia
- Pittsburgh
- San Francisco

SERVICES

- Concrete Repair
- Shotcrete
- Grout Injection
- Refractory
- Fireproofing
- Building Envelope Restoration
- Strengthening
- Moisture Control & Waterproofing
- Force Protection
- Historic Restoration
- Pipe Rehabilitation
- Post-Tensioning Repair
- Corrosion Control & Protection

PULLMAN
Pullman SST, Inc
Philadelphia Regional Office
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Swedesboro, NJ 08085
877-701-5236
www.pullman-services.com

Fig. 5: Refinery fireproofing repairs

Fig. 6: Typical industrial shotcrete set-up for dry-mix process fireproofing

Fig. 7: Building envelope work on historical restoration project

Fig. 8: Refinery crew cutting back freshly gunned shotcrete fireproofing

South Shore Gunite Pool & Spa, Inc.
Quality Pools And Spas Since 1975

South Shore Gunite Pools & Spas, Inc. (SSG), is owned and operated by Bob Guarino out of Billerica, MA. Bob started working on swimming pools in the early 70's and has yet to stop. Starting as a reinforcing placement subcontractor, Bob soon saw that he could subcontract for more than just his main pool builder. Through the 80's, Bob grew what then was Guarino's Swimming Pools into one of the largest pool subcontractors in New England, at one point installing reinforcing bar in over 1000 pools a year. One of the primary pool builders Bob worked for was South Shore Gunite. When the owner of South Shore Gunite was retiring Bob purchased the company and no longer was simply a subcontractor. At that point, SSG was performing swimming pool excavation, plumbing, reinforcing, masonry, renovation, and service. In 1998, SSG started to grow and added the ability to self-perform all its own dry-mix shotcrete work. In the early 2000's, SSG got into interior finishes which was the final piece to be a 100% self-performing pool builder. To this day the only thing SSG subcontracts is electrical work.

Fig. 1: University of New Hampshire

Bob was one of the first nozzlemen to become ACI-certified nozzlemen in Streetsboro, OH. He also participated in ASA as much as he could until the demand of the business became too great. Eventually, due to the rapid growth of the business, he was unable to continue active participation in ASA but remained a big supporter of ASA and quality shotcrete for the industry.

SSG has grown into one of the largest pool builders in the country. We regularly rank in the Top 15 for pool construction and Top 5 for swimming pool service. SSG engages over 200 employees during the busier parts of the year and about 100 employees through the slower parts of the year. As an industry pacesetter, SSG leads with a lifetime transferrable structural warranty on their residential swimming pools. It isn't a secret that we provide this excellent warranty through good, solid shotcrete placement practices.

SSG is one of the largest commercial pool builders and we have some special characteristics. New

Fig. 2: Brown University Pool

Fig. 3: Residential Pool

Fig. 4: Shear Wall Project

Fig. 5: Washington Bridge Concrete Repair

England's pool season is only three months for most public entities such as municipalities, YMCAs, country clubs, yacht clubs, etc., SSG developed a rather unique marketing strategy for our region to offer a complete removal and replacement of commercial pools, guaranteeing that they would be fully completed during their closed winter season and ready to open up on time as usual in the spring. SSG has the resources to comfortably provide this service to at least six facilities at a time. The quality and customer service provided has many of our past customers so satisfied that many commercial contracts are negotiations and not open bids.

SPECIALIZED SHOTCRETE GROUP

In 2012, SSG incorporated wet-mix shotcrete into the business with its higher production rates. The ability to shoot commercial pools in half the time was very helpful and allowed us to undertake more projects in a given time. As a result, SSG's sister company, Specialized Shotcrete Group (SSG Shotcrete), was born to support this increase in production. SSG Shotcrete started marketing and building non-swimming pool work. With Mason Guarino at the helm of SSG Shotcrete, the sister company has grown to an annual volume of about $3 million in non-swimming pool shotcrete work and continues to grow. SSG Shotcrete has successfully completed many diverse projects including bridge repair, dam repair, seismic retrofit work, architectural concrete repair and many other services that can benefit from shotcrete application. SSG Shotcrete is growing to be a premier shotcrete contractor in New England by leveraging lessons learned in the pool industry and managing scheduling opportunities which come with seasonal work.

SOUTH SHORE GUNITE

12 Esquire Rd
North Billerica, MA, 01862
Phone: 800-649-8080
Website: ssgpools.com

SHOTCRETE CONVENTION & TECHNOLOGY CONFERENCE

Call for Presentations – ASA 2021 Shotcrete Convention and Technology Conference

ASA announces a Call for Presentations for the ASA 2021 Shotcrete Convention and Technology Conference. Our 2021 Convention will take place February 21 – 23, 2021, at the Sonesta Resort, Hilton Head, SC.

ASA Conventions provides a unique opportunity to explore shotcrete applications and innovations, as well as future advancements. We encourage those active in shotcrete construction, engineering, education, equipment, materials and R&D who are interested in sharing their expertise, insights and accomplishments in the wide variety of shotcrete placement applications our industry enjoys, to submit presentations for consideration. Each individual presentation will be scheduled for a 50-minute duration, including a short Q&A opportunity for the audience.

Topic areas include (but aren't limited to):

- Water Features
- Value Engineering
- New Construction
- Repair, Rehabilitation and Repurposing
- Geotechnical and Underground
- Architectural
- Advances in Materials and Equipment
- Sustainability

Your presentation submission should include the title of the proposed presentation, speaker information and a short (less than 100 word) abstract. Submissions must be received by September 1, 2020, to be reviewed by the ASA Technical Committee. Please direct submissions and/or questions to Charles Hanskat at 248.983.1701 or Charles.Hanskat@Shotcrete.org.

ASA 2020 Fall Committee Meetings

Due to ongoing concerns regarding the COVID-19 pandemic, the health, well-being and safety of everyone are our highest priorities. ASA is carefully reviewing and evaluating several options for our Fall Committee Meetings. These include virtual meetings, limited face-to-face attendance with options for virtual participation, and virtual committee meetings potentially in combination with a dinner or networking reception in Raleigh, NC for those attending ACI's Fall Concrete Convention. Thank you for your patience and support as we work towards a solution that would accommodate both ASA's Committee work along with the benefits of social and networking opportunities. Sign up for our eNewsletter, "What's in the Mix," for the latest updates: www.shotcrete.org/enews.

asa OUTSTANDING SHOTCRETE PROJECT Awards

ASA Outstanding Shotcrete Project Awards Program

2020 online application for the ASA Outstanding Shotcrete Project Awards Program is now available on the ASA website. Projects must be submitted by Thursday, October 1, 2020.

The ASA Outstanding Shotcrete Project Awards Program recognizes excellence and innovation in projects where shotcrete placement played a significant role. Our awards program strives to recognize and celebrate all the various markets where shotcrete placement has proven to be a practical, creative and cost-effective method for constructing or repairing with strong, durable concrete.

ASA's Annual Outstanding Shotcrete Project Awards Program helps to confirm and exemplify the exceptional advantages of shotcrete placement of concrete. Shotcrete inherently has many sustainability advantages, facilitating creativity, efficiency and flexibility in placement. Showcasing these attributes while highlighting shotcrete's role in the success of your project are key components of projects who win. Projects can be submitted in the following six categories:

- Architecture & New Construction
- Infrastructure
- International Projects
- Pool & Recreational
- Rehabilitation & Repair
- Underground

Visit www.shotcrete.org/ASAOutstandingProjects to start your application. The deadline for submissions to be entered is Thursday, October 1, 2020. For more information or questions contact Tosha at Tosha.Holden@shotcrete.org or (248) 983-1712.

ASA Welcomes Tosha Holden

ASA is pleased to welcome Tosha Holden to the team as the new Editorial and Marketing Manager of ASA. With the recent association management transition and growing number of programs at ASA, we are excited to have Tosha onboard! Tosha will be primarily responsible for ASA's marketing activities such as social media, the monthly eNewsletter "What's in the Mix," and *Shotcrete* magazine. In addition to these tasks, she will also be assisting with the Outstanding Project Awards program.

Tosha's industry experience includes serving as ACI's Chapter Activities Senior Coordinator, where her main focus was the Excellence in Concrete Construction Awards program and her previous position as the Membership and Marketing Director at the Arthroscopy Association of North America. She completed her master's degree in Integrated Marketing Communications from Roosevelt University, Chicago, IL.

NEW ASA MEMBERS

SUSTAINING CORPORATE MEMBERS

EdenCrete
Littleton, CO
www.edeninnovations.com
Primary Contact: Robert Cavaliero
rcavaliero@edeninnovations.com

Maple Site Solutions Inc.
Cambridge, ON Canada
www.maplesitesolutions.ca
Primary Contact: Jason Chow
jason@maplessi.ca

CORPORATE MEMBERS

BASF Master Builders
Portland, OR
www.basf-admixtures.com
Primary Contact: Jim Lindsay
jim.lindsay@basf.com

FORTA Corporation
Grove City, PA
www.fortacorp.com
Primary Contact: William Coursen
info@fortacorp.com

Franklin Silo Repair
Reinholds, PA
Primary Contact: Ephraim Renno
eph@franklinsilorepair.com

Holland Aquatics
Longwood, FL
www.holland-aquatics.com
Primary Contact: Brett Holland
brett@holland-aquatics.com

Michels Pipe Services a div of Michels Corporation
Watertown, CT
www.michels.us
Primary Contact: Paul Mallory
pmallory@michels.us

Professional Shotcrete Ltd.
Acheson, AB Canada
www.reachcsg.com
Primary Contact: Jace Linman
jlinman@reachcsg.com

Quality Pools Group
Fort Mill, NC
www.qualitypoolsgroup.com
Primary Contact: Randolph Rivas
isaac@qualitypoolsgroup.com

Robert H Ward & Associates
S Chicago Heights, IL
Primary Contact: Blake Rago
shotcreterjr@hotmail.com

SUSTAINING CORPORATE ASSOCIATE

Grover Vargas
King, A Sika Company, Tampa, FL

David Medeiros
Maple Site Solutions Inc., Cambridge, ON Canada

CORPORATE ADDITIONAL INDIVIDUALS

Susan Tiber
FORTA Corporation
Grove City, PA

INDIVIDUAL

Robert Thomas
Construction Engineering Labs Inc
Pearl City, HI

Isabelle Fily-Pare
Interventions SWATcrete Inc.
Val-d'Or, QC Canada

PUBLIC AUTHORITIES & AGENCIES

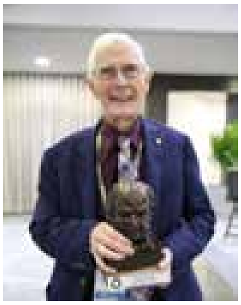
Emery Tyler
NIOSH - Spokane Mining Research Division
Spokane, WA

STUDENT

Mallikarjun Hulagabali
Gujarat, India

Harvey W. Parker, Ph.D., P.E, Awarded Lifetime Achievement Award

International Tunneling & Underground Space Association (ITA) Recognizes Career Spanning More than Five Decades



Dr. Harvey W. Parker was awarded the Lifetime Achievement Award from the International Tunneling Association & Underground Space Association (ITA) at the ITA Tunneling Awards Conference in Miami, Florida on November 18, 2019. The crowd gave a standing ovation in recognition of his five decades of tunneling. Dr. Parker served as President of the ITA from 2004 – 2007, as well as ITA's official representative and spokesperson for Sustainable Development to the United Nations.

The award was given in honor of his significant contributions, in the United States and around the world, to signature tunneling projects through innovation, leadership and expertise. Starting his focus on innovation early in his career, he pioneered the development of steel fiber shotcrete in 1972. He continued this innovative approach to engineering through specific projects including the Mount Baker Ridge Tunnel in Seattle, Washington, the largest soil tunnel in the world, and in metro systems across the United States including Los Angeles, Washington D.C., New York, Boston, and Seattle.

Dr. Parker has always believed in giving back to his industry through service and leadership. Over the course of his career, in addition to his work with ITA, he was Chairman of several organizations including the US National Committee on Tunneling Technology, the Underground Technology Research Council, the Underground Shotcrete Subcommittee for American Concrete Institute Committee. He authored or co-authored more than 60 publications, including a paper on Innovations in Tunnel Support Systems.

About Dr. Harvey W. Parker: Dr. Parker received his Ph.D in Civil Engineering with a Minor in Geology from the University of Illinois Urbana-Champaign, Master's Degree in Civil Engineering from Harvard University, and B.S. in Civil Engineering from Auburn Polytechnic Institute (now known as Auburn University). He has held adjunct or visiting teaching positions at University of Illinois and Columbia University. He continues his work as a geotechnical and tunnel engineer with Harvey Parker & Associates.

GCP Applied Technologies Inc. Amends Existing Stockholder Rights Plan

Will Bring Plan to Stockholder Vote at 2020 Annual Meeting Plan Does Not Apply to Fully Financed Tender or Exchange Offers that Treat All Stockholders Equally

GCP Applied Technologies Inc. (NYSE: GCP) ("GCP") announced today that its Board of Directors has approved an amendment of its stockholder rights plan. The current rights plan, adopted in March 2019, was scheduled to expire on March 14, 2020. The amendment approved by GCP's Board of Directors extended the final expiration date of the plan to March 14, 2023, subject to stockholder's approval of the rights plan at GCP's 2020 annual meeting of stockholders.

The amendment also raises the level of beneficial ownership for a person or group to become an "Acquiring Person" (as defined in the amendment) to 20% of GCP's outstanding shares of common stock. If a stockholder's beneficial ownership on March 15, 2019 was at or above 20%, that stockholder's existing ownership percentage would be grandfathered, but the rights would become exercisable if the stockholder increases its ownership percentage by 0.001% or more.

The amendment of the rights plan is intended to enable all GCP stockholders to realize the full potential value of their investment in GCP and to protect GCP and its stockholders from efforts to obtain control of GCP that are inconsistent with the best interests of GCP and its stockholders. GCP's Board of Directors adopted the rights plan in 2019 in response to a rapid and significant accumulation of GCP's outstanding common stock by 40 North Management (together with its affiliates, "40 North"), GCP's largest stockholder, and the possibility that 40 North would accumulate a potentially controlling position in GCP without paying a control premium to all stockholders. 40 North had previously received clearance under the Hart-Scott-Rodino Act allowing it to acquire up to almost 50% of GCP's common stock. GCP's Board of Directors has determined that circumstances continue to warrant GCP maintaining the protections afforded by the 2019 rights plan.

The rights plan also provides the GCP Board of Directors with time to make informed decisions that are in the best interests of GCP and its stockholders and does not deter the GCP Board of Directors from considering any offer that is fair and otherwise in the best interests of GCP stockholders. The rights plan continues to provide several recognized stockholder-friendly features, including being subject to stockholder approval at GCP's 2020 annual meeting of stockholders and an exception for fully financed offers that are open for at least 60 business days, are made for all GCP shares and treat all stockholders equally.

The amended rights plan is effective immediately and, if approved by stockholders at GCP's 2020 annual meeting, will expire on March 14, 2023. If stockholders do not approve the rights plan, it will expire following the 2020 annual meeting.

The amendment will be filed with the Securities and Exchange Commission.

Advisors

Evercore is serving as GCP's financial advisor and Wachtell, Lipton, Rosen & Katz is serving as legal advisor.

About GCP Applied Technologies

GCP is a leading global provider of construction products technologies that include additives for cement and concrete, the VERIFI® in-transit concrete management system, high-performance waterproofing products, and specialty construction products. GCP Products have been used to build some of the world's most renowned structures. More information is available at www.gcpat.com.

Additional Information

GCP intends to file a proxy statement and proxy card with the U.S. Securities and Exchange Commission (the "SEC") in connection with its solicitation of proxies for its 2020 Annual Meeting of Stockholder (the "2020 Annual Meeting"). GCP Stockholders are strongly encouraged to read the definitive proxy statement (and any amendments and supplements thereto) and accompanying proxy card when they become available as they will contain important information. Stockholders may obtain the proxy statement, any amendments or supplements to the proxy statement and other documents as and when filed by GCP with the SEC without charge from the SEC's website at www.sec.gov.

Certain Information Regarding Participants

GCP, its directors and certain of its executive officers may be deemed to be participants in connection with the solicitation of proxies from GCP's stockholders in connection with the matters to be considered at the 2020 Annual Meeting. Information regarding the ownership of GCP's directors and executive officers in GCP stock is included in their SEC filings on Forms 3, 4, and 5, which can be found through the SEC's website at www.sec.gov. More detailed and updated information regarding the identity of potential participants, and their direct or indirect interests, by security holdings or otherwise, will be set forth in the proxy statement to be filed with the SEC. These documents can be obtained free of charge from the sources indicated above.

Cautionary Statements Regarding Forward-Looking Information

This communication includes certain forward-looking statements within the meaning of the Private Securities Litigation Reform Act of 1995. These statements are based on the current expectations or beliefs of management of GCP and are subject to uncertainty and changes in circumstances. Actual results may vary materially from those expressed or implied by the statements herein due to changes in economic, business, competitive, technological and/or regulatory factors, and other factors affecting the operation of the businesses of GCP. More detailed information about these factors may be found in filings made by GCP with the Securities and Exchange Commission, including Annual Reports on Form 10-K and Quarterly Reports on Form 10-Q. GCP is under no obligation to, and expressly disclaims any such obligation to, update or alter forward-looking statements, whether as a result of new information, future events, or otherwise.

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SHOTCRETE CALENDAR

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

OCTOBER 5 – 7, 2020	**ICRI Fall Virtual Convention** Full schedule on website. www.icri.org
OCTOBER 2020	**ASA Fall 2020 Virtual Committee Meetings** Date(s) for our online committee meetings are not yet finalized. Check calendar for most updated schedule. www.shotcrete.org/calendar
OCTOBER 25 – 29, 2020	**The ACI Virtual Concrete Convention and Exposition – Fall 2020** Full schedule to follow. www.aciconvention.org
NOVEMBER 11 – 13, 2020	**International Pool I Spa I Patio Expo 2020** Mandalay Bay Convention Center | Las Vegas, NV www.poolspapatio.com
NOVEMBER 12, 2020	**Quality Shotcrete – How to Recognize It When You See It** International Pool | Spa | Patio Expo Mandalay Bay Convention Center | Las Vegas, NV www.shotcrete.org
DECEMBER 6 – 9, 2020	**ASTM International Committee C09, Concrete and Concrete Aggregates** Renaissance Orlando at SeaWorld | Orlando, FL www.astm.org
JANUARY 19 – 22, 2021	**World of Concrete 2021** Las Vegas Convention Center | Las Vegas, NV www.worldofconcrete.com
FEBRUARY 21 – 23, 2021	**2021 ASA Shotcrete Convention & Technology Conference** Sonesta Resort | Hilton Head, SC www.shotcrete.org
SEPTEMBER 2021	**MINExpo INTERNATIONAL® 2021** Dates TBD| Las Vegas, NV www.minexpo.com
JUNE 17 – 24, 2022	**North American Tunneling Conference** 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.

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 http://shotcrete.org/pages/products-services/technical-questions.htm.

Question: *I have a 24 in (600 mm) thick shotcrete wall that will have to be scanned for voids. The project has been struggling to locate a local expert who has the capability to scan this thick of a wall. In addition, this new 24 in thick shotcrete wall was dowelled and made "as one unit" together with an existing 24 inches thick cast in place wall. What technique should I use to get the right proportion?*

Answer: Shotcrete is a placement method for concrete. Thus, all non-destructive testing (NDT) applicable to concrete walls would be usable on your wall. However, it is difficult to get good results with a scanning system for heavily reinforced concrete walls of your thickness. Impact Echo and Impulse Response are two one-sided techniques that can provide good results for a portion of the 24 in thickness though would likely not be able to scan the entire depth. Ultrasonic Pulse Velocity is a potential if you can access both sides of the wall. For one-sided investigation at greater depth you may be able to use a MIRA system. It is sophisticated tomographic system that says it can test from 50mm to 800mm (32 in) thickness. There are national consulting firms that provide these investigation systems. Each requires a highly trained, experienced operator so be sure to verify the firm can document successful experience with the method.

Question: *I would like to ask if there are any articles, references, etc, which reference procedures to determine the maturity of the concrete applied via shotcrete? Basically, how to generate the validation curves?*

Answer: Shotcrete is a placement method for concrete. Thus, generating the maturity curves would be based on the concrete mixtures. There are several online resources about the maturity method. One that discusses production of the curves is from the Minnesota DOT and available in PDF format at www.dot.state.mn.us/materials/concretedocs/MaturityMethodProcedure.pdf.

Question: *We are working on a repair/renovation project in Boston. A long-concealed wall next to an adjacent property is now visible as the adjacent property is being renovated. We have been told that our wall must have a 2-hour fire rating. Our wall is composed of CMU masonry and exposed structural steel members. Applying shotcrete to the CMU and steel is a good solution for several reasons. Would you provide shotcrete specifications that will have a 2-hour fire rating on CMU and structural steel?*

Answer: Shotcrete is a placement method for concrete. Thus, the fire resistance for shotcrete placement is the same as concrete. The primary reference for fire resistance of concrete is ACI 216.1-14(19) Code Requirements for Determining Fire Resistance of Concrete and Masonry Construction Assemblies.

Question: *We are working on a large infrastructure project in New York state. We have access and approval issues for a new concrete mixture design. Our understanding is we can specify a Pre-Bagged or Pre-Packaged Shotcrete mix for a wet-mix application. Is this the correct terminology? Are there companies that produce this type of product?*

Answer: We see both Pre-Bagged and Pre-Packaged terminology used. ASTM C1480 / C1480M - 07(2012) uses the rather unwieldy "Standard Specification for Packaged, Pre-Blended, Dry, Combined Materials for Use in Wet or Dry Shotcrete Application." Most suppliers of packaged dry concrete materials for shotcrete have formulations designed for wet-mix applications. You can find our corporate members who supply packaged materials on our website in the Buyers Guide (shotcrete.org/BuyersGuide), select the Category, "Shotcrete Materials-Mixture Sales" and the Subcategory, "Wet Mix."

Question: *I'm interested in any information you can provide about recommended expansion/contraction joint spacing for lazy river concrete flumes.*

Answer: Shotcrete is a placement method for concrete. As the lazy river is a long concrete trough that is intended to be functionally watertight, the best guidance is ACI, 350-06 *Code Requirements for Environmental Engineering Concrete Structures*. As the predominate stresses in the horizontal direction result from shrinkage and temperature, Section 7.12.2.1 provides guidance on joint spacing based on the provided reinforcement ratio in the concrete section. The closer the movement joints, the less reinforcement required. Chapter 5 of ACI 350.4R-04, *Design Considerations for Environmental Engineering Concrete Structures*, has guidance on design of joints for water containing structures to help maintain water tightness.

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