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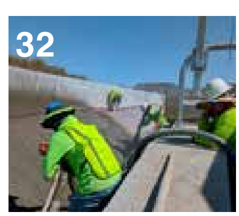
FEATURES



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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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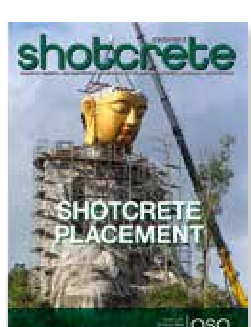

COVER PHOTO: *Lifting parts of the head for a Buddha statue. See the full story on Pg. 10.*


YOUR DURABLE
UNDERGROUND PARTNER.
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MAPEI

Must Be Present to Win

By Jason Myers

As I think back on the most recent American Shotcrete Association (ASA) convention in Santa Fe and immediately following American Concrete Institute (ACI) Convention in Chicago, it makes me grateful and honored for the friendships, knowledge, discussions, arguments, and food and beverages that I have shared with my ASA colleagues. As the ASA convention was wrapping up, I was in a discussion with a first-time attender of the convention, and he was amazed at the knowledge that was shared, the interactions of the various contractors, and the networking and information that was discussed in an effort to promote and enhance the shotcrete industry. He was highly impressed by the leaders of the shotcrete industry who gathered together to be industry-focused and not self-focused. These experiences show that the importance of ASA goes back to the old mantra of "Must be Present to Win".

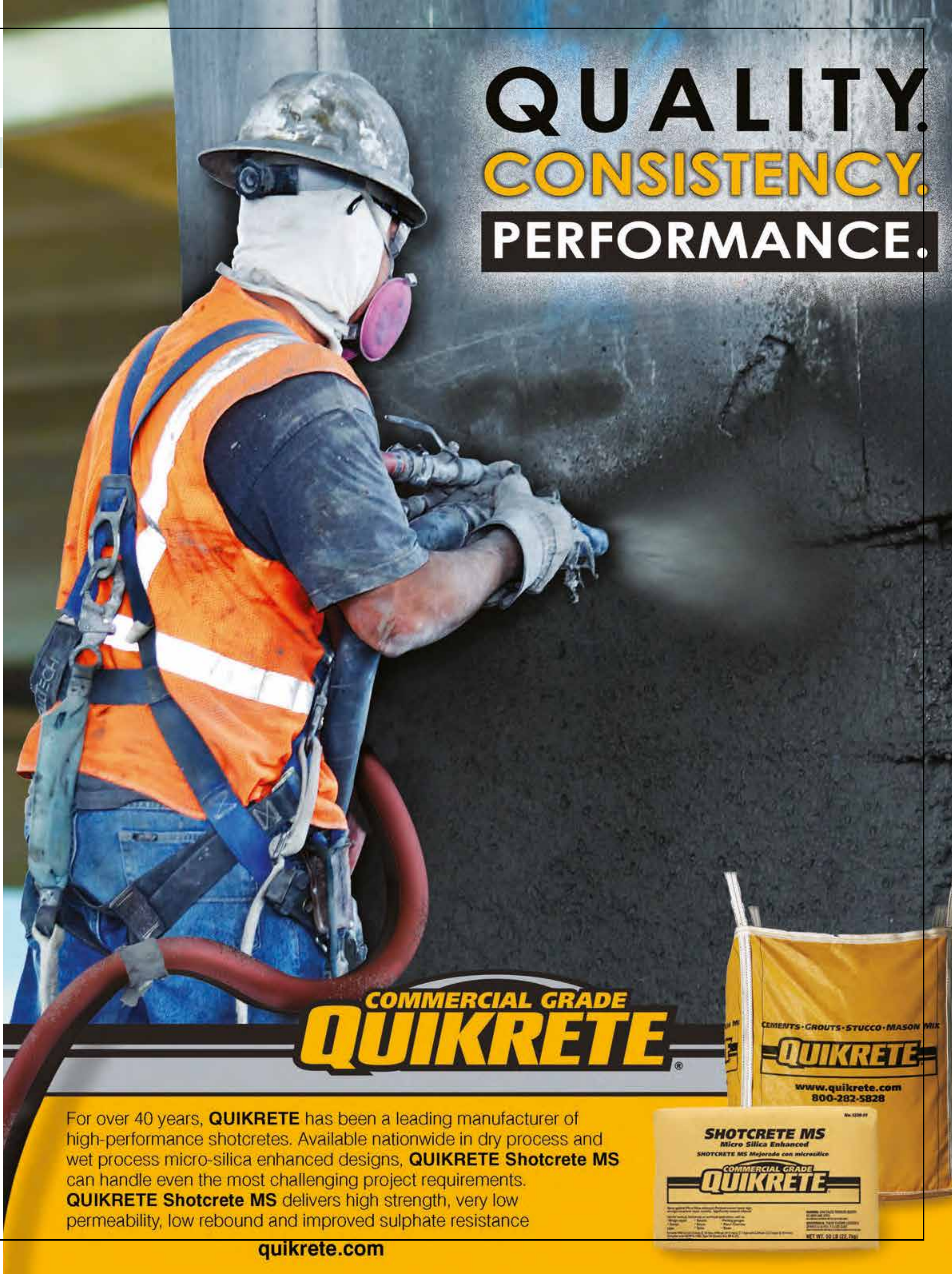
This past year, the Membership Committee conducted a survey to analyze what benefits our membership value. The results were discussed in Santa Fe, and despite the wide range of shotcrete usage, different types of members, and various needs of the organization, it was interesting that every survey noted that the importance and value of ASA is in the interpersonal relationships that occur within the group and the knowledge that is shared. What the members see as the greatest value is the conversations, contacts, and education that occur just by hanging out with other members of the shotcrete industry.

It was also amazing to read how many people first began attending ASA events because of an invitation from an ASA forefather. All of this shows that in today's attempt to have the latest electronic gadget or the newest podcast or video, the true value that people seek is in the relationships and interpersonal interactions that we are created to seek. Once again "Must be Present to Win".

Another value that members cherish is the education, knowledge, and credibility that ASA provides: I did not attend a single educational presentation at Santa Fe that I did not learn something from. So often today when we try to self-educate, we start to read an article or watch a video, but quickly fast forward through it because we think that we know it all and it's just a repeat of previous knowledge. When in this type of situation with my children, I always tell them to "Look for the nugget." It may appear that it is the same information retaught, but there's always something new to discover if you pay attention to the information. At the last ASA Convention, I walked away with an ore cart of nuggets, which just proves the mantra true again. On the surface it might appear to be easier to read the latest article, but the value of the ASA is in the knowledge that we share, discuss, and refine together, which then leads to all of its members having greater credibility in our industry.

One unique aspect and value of the ASA is that an essential goal of the membership is trying to elevate the industry with better shotcrete placement. So often, trade organizations are about trying to keep the status quo or trying to make competitors look bad. Numerous comments in the membership surveys discussed the value of ASA's role in forging acceptance of shotcrete placement through education of engineers, shotcreters, and their companies, thus elevating the standards of shotcrete placement throughout the industry. Through proper engineering at the beginning, and higher quality standards, the entire level of acceptance and use in the concrete construction industry is increased. The ASA membership is about not cheating the process, but collaborating together to increase the shotcrete standards throughout the industry. It is human nature to look at a project and tear it down for what is wrong with it — but it works better for everyone to discuss from the beginning how to design and build, and ultimately building to a higher standard. How is this done and accomplished? By being part of the conversation.

As I discussed in my previous **President's Message**, the value of ASA has been given to us by our shotcrete forefathers. They have laid a tremendous foundation that we are building upon. We owe the credibility that we presently enjoy to that foundation laid for us — but, as the previous article also stated, "Where are you serving?" Are you involved, or are you waiting for someone else to maintain that foundation? Only by active participation can we all succeed and continue to grow the usage and credibility of the shotcrete industry; and the only true way to accomplish this? "Must be Present to Win."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COMMITTEE CHAIR MEMO

Informing the Market, Making a Difference

By Ryan Oakes

The pool and skatepark industries continue to evolve, and with that evolution comes both progress and pressure. In recent years, we have seen the effects of rapid growth, increased demand, and a widening range of experience levels across those designing and building pools. As an industry, we are no longer in a position where we can rely on tradition or fragmented knowledge — we must continue to define and reinforce what quality construction truly means.

Within the American Shotcrete Association (ASA), the Pool & Skatepark Committee (formerly the Pool and Recreational Shotcrete Committee) has remained focused on that objective. Through continued collaboration, publication, and engagement with our industry partners, we are working to ensure that shotcrete remains not only relevant but properly understood and correctly applied.

Most recently, the committee published Position Paper #8: *Steel Reinforcement for Shotcrete Pools*. This paper represents a significant step forward in clarifying best practices around reinforcement, an area that is often assumed to be understood, yet is frequently misapplied in the field. It stands as an important resource for engineers, contractors, and designers seeking to build durable, long-lasting concrete pools.

In parallel with our publication efforts, our members continue to contribute to *Shotcrete* magazine. In the second quarter of 2025, the magazine featured a pool-focused issue that addressed several key topics within our industry. Of particular note was **the discussion around why pools crack** — a subject that is too often oversimplified. The article helped frame cracking not as a singular failure, but as the result of design decisions, construction practices, material behavior, and restraint conditions. This type of technical clarity is essential if we are to move beyond surface-level explanations and toward meaningful improvement in how pools are designed and built.

Looking ahead, the committee has formed a task group to develop Position Paper #9, to address proper control of rebound and trimmings in shotcreted pools. These are subjects that are encountered daily in the field, yet are inconsistently understood and, at times, debated. In the case of rebound, there is a broader body of research within the shotcrete industry that clearly defines its characteristics and limitations. The application of that knowledge to pool construction, particularly regarding durability, bond, and long-term performance, is an area where greater clarity is needed. Our intent is to approach this work with a research-driven, science-based perspective, grounded in both existing literature and field experience.

In the case of trimmings, the discussion can be more contentious. As with many long-standing practices, there are differing opinions rooted in habit, experience, and interpretation. These are precisely the types of topics that our committee is positioned to address — not to create unnecessary division, but to provide clear, technically

ASA POOL & SKATEPARK COMMITTEE

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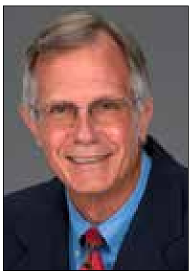
William Drakeley | Drakeley Pool Company LLC supported guidance that advances the quality of construction across the industry.

In addition to our technical work, we have updated the name of our committee to the Pool & Skatepark Committee. This change is not a shift in direction, but rather a more accurate reflection of what we have long represented. Shotcrete placement has played a critical role in the development of both pools and skateparks, and it is important that members of the skatepark community recognize that they have a place within ASA and within this committee.

As we continue forward, our focus remains the same: To raise the standard of construction, to support our industry through education and technical guidance, and to ensure that the structures we help create are built to perform for not just years, but generations.

Strategic Alliances

By Charles S. Hanskat, P.E., F.ACI, F.ASCE, ASA Executive Director



Since our inception in 1998, we have made a distinct mark on the concrete construction market. Through our direct, dedicated member involvement in a variety of engineering, design, and construction-oriented standards development organizations, we have advanced the recognition and acceptance of shotcrete placement for quality concrete construction. In our outreach efforts, we have already been working with committees at the following organizations:

- American Concrete Institute (ACI)
- International Concrete Repair Institute (ICRI)
- ASTM International, American Railway
- Maintenance-of-Way Association (AREMA)
- Underground Construction Association (UCA) of the Society for Mining & Exploration (SME)

Our connections with these organizations enhance and increase our Association and shotcrete's visibility in the concrete construction world, and this year, we've added affiliations with three other concrete-related groups. They include:

Skate4Concrete

SKATE4CONCRETE (WWW.SKATE4CONCRETE.COM)

The Skate4Concrete mission is to dispel the belief that a successful career can only be achieved by going to college. Skate4Concrete provides a place where it is easy to explore entry-level careers in concrete that set the stage where the skate community can craft their own career path.

Skate4Concrete has established a certification program that allows individuals to explore opportunities in the concrete construction market. The curriculum focuses on concrete construction within the Construction, Engineering, and Manufacturing CTE pathways, and students gaining their certification will have direct understanding of the importance and stability of a concrete career.

PRO™

An ACI Center of Excellence for Advancing Productivity

PRO – AN ACI CENTER OF EXCELLENCE FOR ADVANCING PRODUCTIVITY (WWW.CONCRETEPRODUCTIVITY.ORG)

PRO's mission is a catalyst for solving the barriers of constructability to advance concrete construction productivity. PRO will collaborate with contractors, designers, and materials suppliers to identify and resolve issues that negatively impact productivity in concrete construction. Through the development and dissemination of construction productivity knowledge, such as training for structural designers, industry-wide collaboration efforts, measurement and validation of progress toward increased constructability, and more, PRO and its members aim to advance new technologies and processes that improve productivity beyond historic levels.

> "Through a collaborative approach, PRO aims to optimize labor and time against materials by improving structural design and construction processes."
>
> \- Phil Diekemper, Executive Director, PRO

WHO DOES PRO WANT TO GET INVOLVED?

- Industry leaders and associations seeking to advance concrete design and construction
- Innovative individuals that share PRO's vision
- Companies seeking to improve employee expertise and business results
- Concrete contractors facing complex obstacles

Since shotcrete placement inherently provides greater efficiency for concrete construction, our involvement in their "Constructability Blueprint" document is beneficial to both ASA and Pro, and truly the entire industry. We will work with PRO to develop a chapter that directly addresses shotcrete placement.

P+EX: CENTER OF EXCELLENCE FOR CONCRETE PRESERVATION AND SERVICE LIFE EXTENSION (WWW.PEXCOE.ORG)

P+Ex is a non-profit organization created to focus on the sustainability benefits of preserving and extending the life of concrete structures. Shotcrete placement offers a distinct benefit for the quality and durable repair of concrete structures of all types. This makes participation with P+Ex a natural outreach for ASA, as shotcrete is a significant part of our members' work.

P+Ex MISSION: To drive global awareness, education, tools, and actions to preserve and extend the service life of concrete structures to ensure a sustainable built environment

P+Ex VISION: To promote and lead "Concrete Preservation and Service Life Extension Initiatives" to contribute to sustainable solutions for society

As a developing organization, their initial strategies include:

- Identify and quantify the benefits of service life extension
- Develop channels to communicate the benefits of preservation and service life extension
- Expand national and international conversation to increase engagement around the sustainability of concrete structures

ICRI – D(AI)LE SYSTEM (WWW.ICRI.ORG/RESOURCES/MEET-DAILE)

Finally, we will be supplying portions of our website shotcrete knowledge base to ICRI's closed generative AI system, D(ai)le. Here's their introduction to D(ai)le:

> Hello, I'm D(ai)le!
> I'm your new best friend for all things concrete repair. Tired of digging through documents? I'm here to do the heavy lifting for you! I've devoured all the content from ICRI's world — think ICRI.org, technical guidelines, webinars, and issues of the Concrete Repair Bulletin. I'm powered by the latest insights and ready to dish out the info you need to get the job done right.

The system puts most of ICRI's documents into an LLM that can be queried, like using ChatGPT or Perplexity, but the replies are based only on vetted ICRI technical information. We anticipate supplying much of our shotcrete knowledge (already freely available on our website) as PDFs that the system analyzes for inclusion in the chat results. This will likely include our FAQs, past *Shotcrete* magazines, certification information, and the article archive.

D(ai)le is designed to provide limited responses to the public, but ICRI members can take full advantage of its capabilities by logging in through the website to see the more extensive responses. You don't have to be an ICRI member to try the limited application, though: Go try it out at the link above!

Though ICRI information often includes shotcrete placement, adding ASA's shotcrete knowledge can help provide more accurate and complete responses. We are also investigating ways that ASA members may access the more detailed responses.

LEVERAGING ASA AND SHOTCRETE EXPOSURE WITH AFFILIATED ORGANIZATIONS

Our interaction with many concrete-related groups provides us with much greater visibility, not only for our Association, but also for shotcrete placement in concrete construction. This leverage of our message (without additional financial impact) is a winning combination for ASA and the associations who work with us.

Buddha Statue

By Peter Epperson

It was 2015, and I was imagining retirement. I had been a shotcrete contractor for almost 40 years. My company, Pacific Gunite, had primarily worked with thin shell concrete and ferrocement since 1986, and for those 40 years, we'd been building ferrocement water tanks for some of the thousands of people on our island who depend on rain catchment for their water supply. I had always loved the job, but working in an area that averages over 180 in. (4600 mm) of rain per year has special challenges (never mind living on an island where 18-year-olds take early retirement, presenting significant labor challenges). But then I got a call from a local Buddhist monastery: They asked if our company would build them a 110 ft (34 m) tall concrete statue of the Buddha. It would be the tallest statue of Buddha in the Western Hemisphere. How could I say no? I forgot all about retirement.

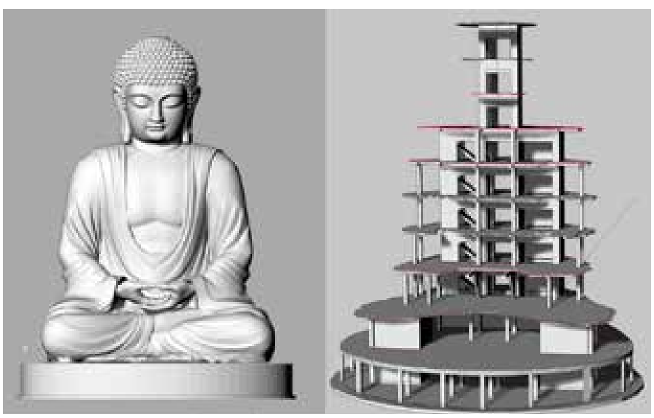


Fig. 1: Concept design of statue and interior support

Fig. 2: Head on steel frame

Ferrocement is almost unknown in Western countries. It has a reputation for being labor intensive, but that is an unfortunate and inaccurate assessment: The water tank construction technique we employ is relatively quick and easy, and a much more affordable alternative to conventional concrete tanks. Our designs don't usually follow the exact definition of ferrocement. I prefer the term "Thin Shell Concrete". The idea is the same — there is a much higher steel-to-concrete ratio than in typical concrete construction. Our 60,000 gal (230,000 l) tanks have a wall thickness of just 2 in. (50 mm).

The monastery had no design for the desired statue, just a concept. After two years of design, engineering, and permitting, we began construction. Planning began with the purchase of three different 3D models of the Buddha. Elements of the three models were combined to design the statue that the monastery envisioned. Working with a couple of engineer friends (T.P. Singh of Construction Research Technologies in Delhi and Ray Keuning in Hawaii), we created the design of the structural components of the statue .

Above our 15 in. (380 mm) thick concrete foundation, we decided on a solid 4 in. (100 mm) thick concrete floor every 10 ft (3 m) in elevation and a 12 in. (300 mm) thick central concrete core that also extended from grade to the top. Concrete posts, beams, and shear walls supported the floor slabs.

We discussed how we would shape the exterior for some time until I saw a YouTube video that showed a CNC plasma cutter in action. Using our 3D design software, it was simple to define section drawings, or profiles, anywhere along the statue's exterior and turn those shapes into files that the CNC cutter could work with. Plates of 5 ft x 10 ft x 0.25 in. (1.5 m x 3 m x 6 mm) stainless steel were cut to shapes 1.5 in. (38 mm) wide, and each piece was numbered. Then, like a giant puzzle, the vertical pieces were welded to anchors embedded in the concrete floors, and horizontal profile pieces were added to the verticals. A stainless steel wire mesh was added to the inside and outside of the profiles to complete the armature. The final total wall thickness for the exterior of the statue came to no less than 2.5 in. (65 mm).

Fig. 3: Adding mesh to armature

Concrete for the entire exterior of the statue was hand mixed for better control and to alleviate scheduling concerns with ready-mix delivery of concrete.

The monastery requested a statue that would last for 1000 years. As long as the statue gets a new coat of paint every 25 years, I think that it will. We used MMFX reinforcing bar for the floors and core structure. The concrete mix was 4000 psi (28 MPa) with Cortec anti-corrosion additive, silica fume, and 6 lb/yd^3 (3.5 kg/m^3) of PVA fibers. Our aggregate was crushed basalt, which is inherently very strong. Our core samples always tested well over the 4000 psi goal, and many samples were over 10,000 psi (69 MPa). We hand mixed all 30,000 ft^2 (2800 m^2) of the exterior of the statue with the same mixture of sand only and no coarse aggregate. All steel other than the MMFX rebar was 316 stainless steel.

The earlier pours on the lower floors were the largest, and we used a boom pump. Upper floors were placed with a Schwing 750 line pump or a small Reinert 536 pump. The exterior spraying of the statue used a Putzmeister peristaltic squeeze pump. We have always used peristaltic pumps for our thin-shell concrete surfaces. They can be turned down low for spraying thin layers or to a higher RPM for pumping up to 1 in. (25 mm) of material. Even though it is considered a low-pressure pump, the Putzmeister had no problem pumping up to the 110 ft elevation. It's a low-volume pump with a maximum output of 8 yd^3 (6 m^3) per hour at a 4-in. slump. At the nozzle there is minimal pulsing and very smooth shotcrete spraying.

As each 10 ft level was completed, work to create the armature for the exterior began. The vertical stainless profiles were welded to anchors cast into the floor slabs.

Fig. 4: "Condor" manlift

Horizontal profile pieces were then welded to the verticals every 30 in. (750 mm) to both stabilize the armature and help define the shape. A layer of 0.5 in. (13 mm) welded wire mesh was attached to the inside of the armature and a layer of 0.25 in. mesh to the outside. If more detail was needed anywhere, additional steel rods were added to the profile pieces. For areas where there were many tight curves, we would use woven mesh instead of welded mesh to maintain the desired shape. We would shotcrete a reinforcing layer of concrete inside and out to cover the steel. The final finish coat would come later.

Most of the statue was finished directly onto the structural framework. Because of the detail required for the head of the statue, and because of its elevation, we decided to create the head on a steel frame on the ground and lift the finished pieces with a crane. Due to the location of the statue being in a very rainy location, a removable 30 ft^2 (2.8 m^2) 'umbrella' covered the steel framework space where we would build the head.

The head was comprised of nine separate parts, which were bolted together on our ground-level frame. Upon completion, they were lifted into position at the top of the statue, where each piece would then be bolted through the floor and welded to steel brackets previously cast into the concrete floor slabs. In addition to the face, the back of the

Fig. 5: Armature with mesh and 0.375 in. steel rods for better definition and finished mortar layer

neck, and the two ears, we also had to make the five parts that comprised the top of the head, or scalp, which included 400 curls. These curls have symbolic significance, and presented their own challenge, as they couldn't be created with our CNC cut armature approach.

There were 16 different size curls. We made a separate polyurethane mold for each size curl. Each curl had steel reinforcement with exposed tabs that could be welded to the larger section of each of the five scalp parts. Our Rhino 3D software once again proved invaluable when we needed to calculate the weight and center of gravity for each piece to create appropriately sized lifting frames for the crane. A Grove 50-ton (45 tonnes) crane had no problem positioning all of the parts.

Lifting all of the parts that make up the head and fitting them into their final positions was obviously something that required careful planning. In any construction project, surprises can happen. When you have an expensive crane on the job, one might expect to be concerned and even lose a little sleep. We initially anticipated two days to complete the first lift that included the face, both ears, and the back of the neck. As it turned out, things went flawlessly, and we were done by lunchtime the first day! As the pieces were lifted to their final positions, I looked toward the ground and saw several monks looking up with their hands in prayer. Perhaps success depends on more than just calculations

Fig. 6: Hands, before and after

Fig. 7: Lifting parts of the head

Fig. 8: The completed statue

and planning. There were two more crane days as the other parts of the scalp were completed. They also went smoothly.

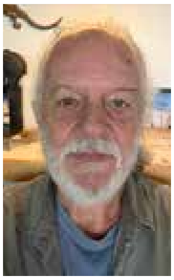
Fortunately, the monastery located a military surplus manlift with a 125 ft (38 m) reach and load capacity large enough for our project. This beast was essential in aiding scaffold erection as well as helping people get to those hard-to-reach places that needed work. Finding the perfect tool at an incredible price was just one of the many pleasant surprises that came along with this job, and it will continue to earn its keep with occasional cleaning and maintenance after construction.

Like the head, the hands were also built on the ground level. With everything ready, it was time to finish and place the hands. We called the crane back for a final lift. Then, as a finishing touch, a series of 12-ft (3.6 m) lotus petals surrounds the base of the statue. Fiberglass molds of the lotus petals were made and the petals were shotcreted with our concrete mixture one at a time. Touchups at the seams gave the surround a clean, homogenous look. The concrete portion of the project was now complete. Two coats of polyurethane paint were then applied over the entire surface.

The statue was completed in 2024 after 7 years of construction, mostly by seven of my employees and three monks from the monastery. The monks took on some of the more arduous tasks: One of them ran the CNC cutter and produced a few thousand pieces of the steel that shaped the statue. Another monk became the daily project coordinator. He also painted the entire statue by himself. A third made the fiberglass molds that were used to create the surround at the base of the statue.

I had many workers come and go, but a core group stayed with the project to completion. My crew, which were primarily concrete placers and finishers at the beginning of the job, left with some new skills. Four of them are now also certified welders, and they all handled enough formwork lumber that they could join a carpenters' union.

My retirement has finally arrived, and this statue was my swan song. Although I take some credit for this accomplishment, I was never one of those that had to erect scaffolding in the rain or deal with the myriad of things that can go wrong while mixing and pumping and placing concrete. What a job!



Peter Epperson *owned and operated Pacific Gunite on the big island of Hawaii from 1986 to 2024. The company always valued the creative potential of concrete, often taking on challenging projects and preferring to take a carefully considered chance rather than declining an offer for fear of failure. Peter is retired now, but two of his sons operate their own concrete businesses in the area. They carry the tradition by building lifetime water tanks, swimming pools, and other imaginative creations.*

Advances in Silicate Accelerators for Shotcrete

By Vicky Sidorkiewicz and Michael McDonald

INTRODUCTION

Sodium silicate has long history of use in construction and geotechnical applications due to its versatility and reliable performance. In shotcrete placement, sodium silicate solutions were widely used as alkaline rapid-set accelerators from the 1960s through late 1990s, most commonly in wet-mix systems for tunnel linings and ground support.

Typical dosages were relatively high (13-17% by mass of cement), which often led to reduced long-term compressive strength. This limitation helped drive the development of alkali-free accelerators, which offered improved handling and more consistent performance.

Today, the industry is transitioning toward low carbon cements blended with higher levels of Supplementary Cementitious Materials (SCMs) or non-reactive calcium carbonate filler. These changes require accelerators formulated to react effectively with both the cement and the SCMs.

This article highlights new silicate-based accelerators that have shown promising results in field trials and can complement the use of low carbon cement. Compared with historical dosage rates, these modified silicates are used at lower concentrations, further improving overall cost economics relative to alkali-free accelerators.

SILICATE: KEY PROPERTIES AND SAFETY OVERVIEW

Silicates are inorganic, non-toxic, non-carcinogenic, and non-volatile. They are recognized as safe for food contact applications and are NSF certified for drinking water systems. Conventional sodium silicates are alkaline, and the preferred grade for shotcrete applications has a pH of ~11.2. This moderate alkalinity requires proper handling practices and PPE to prevent skin and eye contact. However, with greater use of remotely manipulated shotcrete nozzling equipment, the risk of direct exposure has been significantly reduced.

While a pH of 11.2 is high, it falls within the typical pH range for many soaps and detergents. In relation to cement and other alkaline accelerators — particularly sodium aluminate — sodium silicate has much lower alkalinity:

- Sodium silicate pH: ~11.2
- Cement mortar pH: ~12.5
- Sodium aluminate pH: ~13.5

As the principal safety concerns associated with alkaline accelerators arise from their pH and alkali content, a low alkali silicate accelerator containing roughly half the alkali content of conventional silicates is a safer and more effective alternative (Table1). Reducing the alkalinity, makes sodium silicate more reactive and allows a wider dosage window with less risk of introducing excess sodium into the cement.

Properties	Conventional sodium silicate	Novel, high ratio sodium silicate
SiO_2:Na_2O	3.2	4.5
Total Solids	37%	25%
Silica as SiO_2	28.7%	20.3%
Alkali as Na_2O	8.9%	4.7%
pH	>11.3	~11
Viscosity	180 cp	60 cp

Table 1: Silicates — Typical Properties

LOW-ALKALI SODIUM SILICATE ACCELERATOR

Shotcrete placement in underground construction must develop rapid set and high-early-age strength. This is typically achieved using set accelerators, which modify early cement hydration, especially reactions associated with C_3A and C_3S.

Soluble sodium silicate provides rapid setting by reaction with calcium in the cement paste to form solid calcium silicate. Over time, this precipitate transforms into a hydrated calcium silicate gel (Prudencio 1996), like the gel produced during hydration of clinkers in the cement.

While conventional silicate accelerators can enhance cement hydration and increase early-age strength, they have been reported to reduce later-age strength (Prudencio 1998).

A novel sodium silicate with a low alkali and a high SiO_2/Na_2O ratio (originally developed for select geotechnical and oil field applications) was evaluated as a shotcrete accelerator in both laboratory and field tests. The objective of the study was to determine whether the novel low alkali high ratio silicate accelerator can maintain early strength benefits while reducing the tendency for later age strength


Spraying the panels and outdoor curing

loss during curing that is often observed with conventional silicate accelerators (Elsayed, Soliman, El Naggar 2023).

TEST PROGRAM OVERVIEW & RESULTS

A wet-mix concrete mixture with portland limestone cement (GUL) and microsilica (MS), a w/cm of 0.43, and a polycarboxylate high-range water reducer was shotcreted into panels and cored for testing. The baseline mixture proportions are shown in Table 2.

Four accelerated shotcrete mixtures and a control were compared: Novel, low-alkali sodium silicate A1 at 4% and 6%, conventional sodium silicate A2 at 6%, and AF-alkali-free aluminum sulfate-based accelerator at 6% (accelerator dosage by binder mass).

Concrete was shotcreted into field panels. Panels were protected immediately after spraying, then cured using a wet burlap and protected with heated outdoor measures. Cores were later transferred to a humidity chamber until tested.

Cores were tested for compressive strength, and the results after 7, 14, and 28 days of curing are shown in Fig. 1. The novel low-alkali silicate (A1) outperformed the conventional silicate accelerator (A2) at all curing ages and exhibited a significantly reduced tendency for lower later age strength observed with conventional silicate

Composition	Weight (kg/m^3)
GUL Cement	410
Microsilica	40
Concrete sand	1,693
Air(entrained)	4.2
Water	194
High-Range Water Reducer	2

Table 2: Concrete Mixture Design

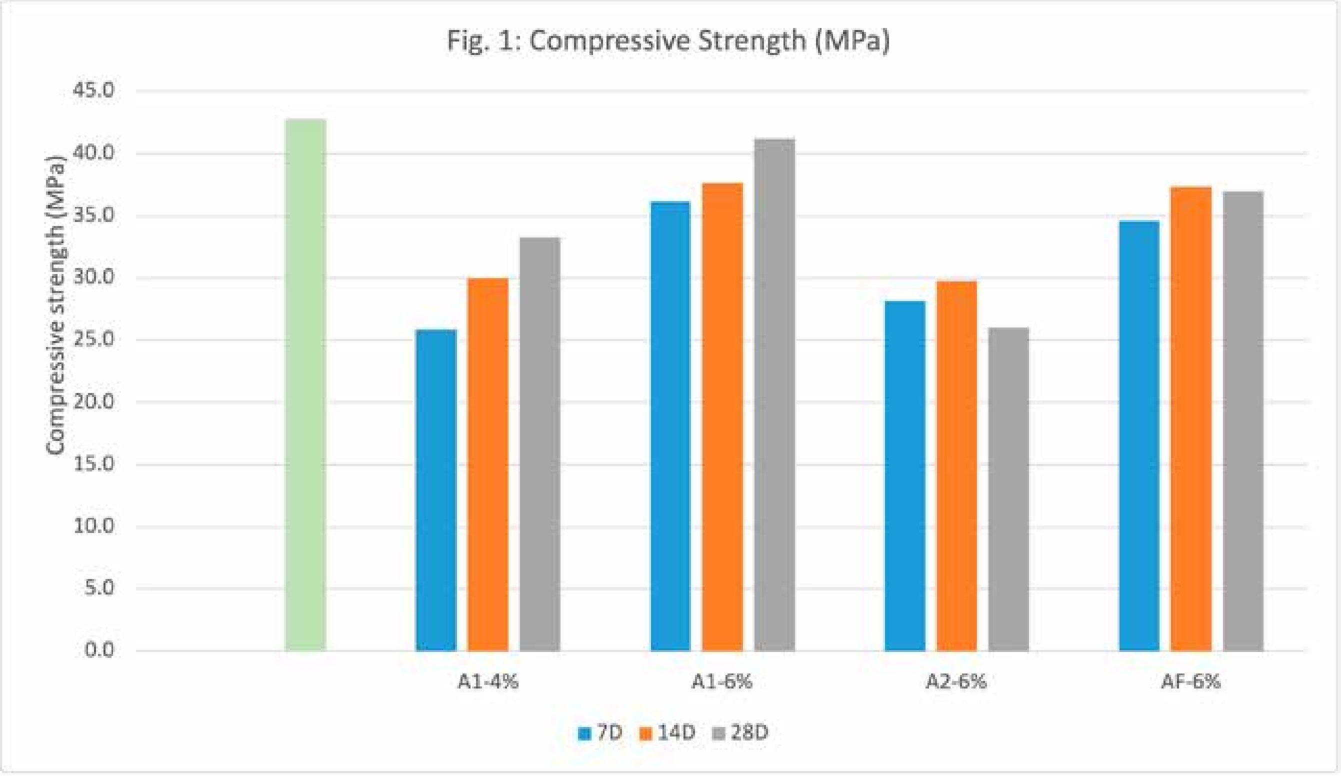


Fig. 1: Compressive Strength (MPa) Chart; A1 - novel low alkali sodium silicate; A2 - conventional sodium silicate; AF - Alkali free, aluminum sulphate based

accelerators. At a 6% dosage, the low alkali silicate (A1) and the alkali free accelerator (AF) demonstrated comparable compressive strength at both early and later ages.

These results support additional testing to optimize dosage and to evaluate performance across other concrete mixture designs.

ALUMINUM MODIFIED SILICATES

A major challenge facing our industry is the increasing amount of supplementary cementitious material in portland limestone cement and the resulting strength development. The next innovative sodium silicate is an aluminum-modified silicate, where a reactive aluminum end group is attached to the silicate molecule. The presence of aluminum reduces sodium mobility and introduces additional mechanisms that promote the setting of both cementitious and pozzolanic components.

In this study, panels were also shotcreted using the aluminum-modified sodium silicate (AAAS) and compared against two versions of a commonly used alkali-free accelerator. AAAS achieved over 3 MPa (450 psi) compressive strength in 30 minutes. Fig. 2 illustrates the compressive strength at 7 and 28 days. Additional field trials are scheduled to further confirm the performance and to optimize dosage levels.

CONCLUSIONS

New silicate accelerators have demonstrated strong performance in preliminary field tests and are now being evaluated at lower dosage levels than those historically used.

Low alkalinity silicate has gained industry attention as a potential solution to long-term strength loss, while also offering opportunities to further enhance other key performance properties in shotcrete mixes. Aluminum-modified silicates have notably enhanced strength development of shotcrete produced with a low-carbon cement.

Ongoing laboratory and field work will continue to assess the performance of new silicate accelerators across a wide range of shotcrete mix designs and field conditions. This work will support greater use of more cost-effective formulations where performance criteria are met.

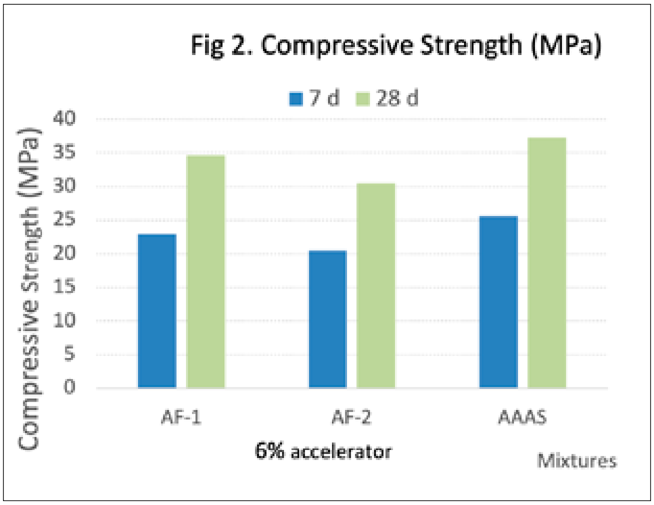


Fig. 2: Compressive Strength (MPa) at 7 and 28 days

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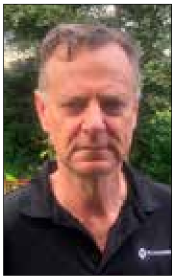

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blastcrete X-40D

Automated Shotcrete Application in Tunnelling

By Igor Schweiggl, Rainer Antretter, Alex Sellemond, Norbert Fügenschuh, and Peter-Rolf Dietrich

INTRODUCTION AND DEVELOPMENT

The tunnelling industry has again been working toward the automation of shotcrete application for some years now, after research and development stalled around 2005. Robots had been developed with the capability of applying a consistent thickness of shotcrete onto uneven surfaces. However, doing so did not improve the waviness of the original substrate, and the cost and limited possibilities to use such machines brought further development to a halt.

Stricter requirements regarding the waviness and accuracy of the shotcrete surface, coupled with a growing shortage of skilled shotcreters, necessitated further development. Such automation has the potential to address several fundamental challenges associated with conventional, manually controlled shotcrete spraying.

One of the primary objectives during shotcrete placement is to achieve a surface that is as smooth as possible and as close as possible to the specified geometry. In practice, however, the nozzle is usually controlled manually via remote control while the operator is positioned at some distance from the spraying location. Limited visibility and the strong dependence on operator experience often make it difficult to consistently meet the increasingly strict quality requirements for tunnel profiles.

Deviations from the geometry frequently result in extensive and costly rework, such as milling/grinding operations or manual surface corrections using repair mortars. These activities can significantly affect construction time and project costs and may even jeopardize the overall economic success of a project.

Against this background, a joint development project between BeMo Tunnelling GmbH and a development team from Vision Metrics GmbH was launched in February 2023. The goal of this collaborative effort was to develop a control system for fully automated shotcrete placement, to test it under real construction site conditions, and ultimately use the system on BeMo sites and to rent it out to third parties.

The basis for development was a conventional shotcrete robot originally designed for manual nozzle guidance via remote control. As part of the project, the machine was equipped with additional sensors and a newly developed control system (Fig. 1).

After completion of the mechanical and electronic modifications, development of the control software began, accompanied by initial practical tests. The first trials were carried out in a specially constructed test tunnel (Fig. 2) to evaluate fundamental functions and control logic under controlled conditions.

As development progressed and the core functional principles were successfully validated, further tests were gradually moved to real tunnel environments. During this testing phase, continuous adjustments were made to control parameters, hardware components, and the overall workflow. Through this iterative development process, the original concept evolved into a robust and practical solution suitable for construction site operations.

Fig. 1: Retrofitting the control system on an existing machine

Fig. 2: Test setups of the artificial tunnel profiles for the initial tests

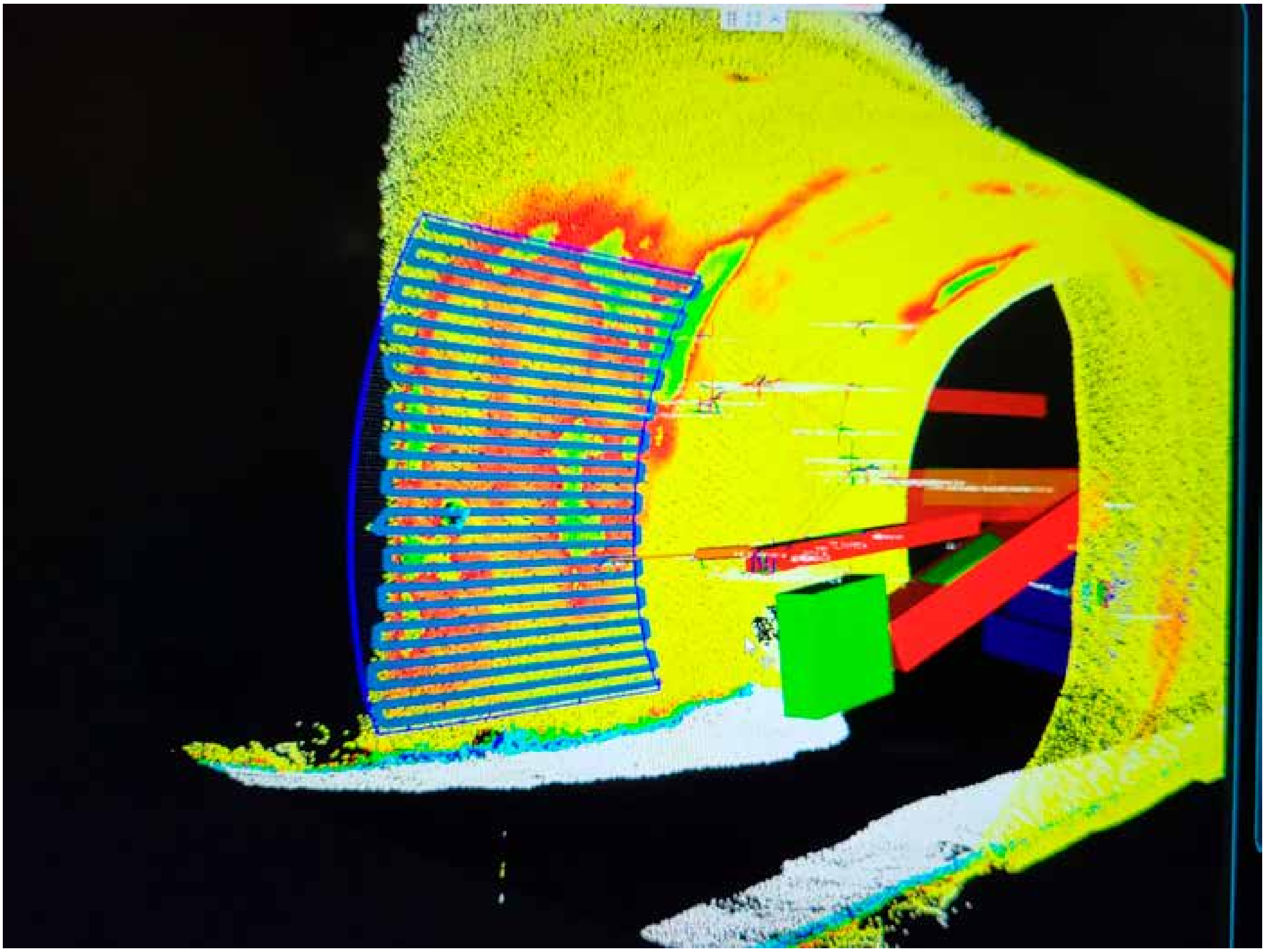


Fig. 3: Visualization of the tunnel scan, the machine position, the selected area, and the planned spraying path

WORKFLOW OF THE AUTOMATED SHOTCRETE PROCESS

To better understand the overall concept, the final workflow of the automated shotcrete process is described below. The process can be divided into the following consecutive steps.

SURFACE SCAN

At the beginning of the process, the machine must receive information about the locally required layer thicknesses. For this purpose, a three-dimensional scan of the existing tunnel surface is created before the spraying process begins. No scanning is performed during spraying; all geometric information required for the automated application is derived from the previously recorded surface scan.

The scan itself is not performed by the spraying machine but by conventional surveying instruments such as 360-degree laser scanners or total stations. After optional in post-processing, the data is imported into the machine control system.

During spraying, the required layer thickness is achieved while maintaining a constant spraying rate, typically between 10 to 16 yd^3/hr (8 and 12 m^3/hr). Instead of adjusting the material flow, the system controls the applied thickness by varying the movement speed of the robotic arm, and therefore the nozzle. Lower travel speeds result in thicker layers, while higher speeds produce thinner layers.

An important advantage of this approach is that surveying can be performed independently of the spraying operation. Tunnel sections can therefore be scanned in advance, for example, the day before spraying, reducing waiting times and improving the overall construction workflow.

MACHINE POSITIONING

In addition to the layer thickness information, the machine must also know its exact position in space. This is achieved by surveying the machine into the same coordinate system used for the surface scan. By aligning both datasets within a common coordinate system, it ensures the calculated layer thicknesses are applied at the correct positions in the tunnel.

SELECTION OF THE SPRAYING AREA

In the control software, both the machine and the point cloud of the surface scan are now georeferenced within the same coordinate system. The current machine position and the scanned tunnel surface are visualized accordingly (Fig. 3). Based on this representation, the operator can define the spraying area to be processed and select an appropriate parameter set for the control system that is adapted to the layer to be applied (for example, nozzle distance to the surface or spacing between spraying lines).

PATH CALCULATION AND START OF SPRAYING

After the spraying area has been selected, the control software automatically calculates a suitable spraying path. This calculation determines both the movement trajectories of the robotic arm and the corresponding travel speeds required to apply the locally required layer thickness.

Once the calculation is completed, the operator manually moves the robotic arm into a suitable position close to the starting point of the spraying path (shown in Fig. 3). The compressor and the concrete pump are then started, followed by the activation of the accelerator pump to initiate the automatic spraying process.

By positioning the nozzle to the invert and after some seconds spraying onto it, a stable shotcrete cone forms indicating appropriate accelerator dosing (the correct accelerator dosage rate has been determined previously during the pre-construction testing procedure of the concrete mixture). This allows the operator to visually assess the correct consistency of the concrete and to start the automatic spraying process.

A particularly critical aspect of continuous spraying operations is repositioning the machine and creating a smooth transition to the previously sprayed area. Within the control system, this has been addressed by designing the spraying paths so that transitions between adjacent spraying fields remain as inconspicuous (geometrically smooth) as possible.

However, achieving a homogeneous surface appearance does not depend solely on precise machine control. Other factors, such as accurate machine positioning, proper surveying, the properties and consistency of the concrete mixture, and the dosage rate of the accelerator also play an important role.

INFLUENCE OF CONCRETE CONSISTENCY AND ACCELERATOR DOSAGE

Throughout the course of the project, it became increasingly evident that the quality and consistency of the shotcreted concrete mixture have a decisive influence on the spraying result. In automated spraying, the requirements for the material properties are even higher than in manual nozzle operation, because the machine cannot visually assess the spray pattern and therefore cannot adjust the nozzle guidance during application.

Consequently, the system is not able to adjust the nozzle guidance based on the appearance of the freshly shotcreted concrete, for example, by increasing the nozzle distance to better distribute a mixture that is too fluid. For this reason, the correct adjustment of the material parameters before the automated spraying process begins is essential. It is therefore the operator's responsibility to ensure that both the concrete delivery rate and the accelerator dosage are correctly set before the spraying cycle begins.

In general, two key factors interact in this context: The quality of the concrete mixture and the dosage rate of the accelerator.

CONCRETE QUALITY

The term concrete quality encompasses several properties of the shotcreted mixture that together influence the spraying result.

Fig. 4: The appearance of sprayed surfaces when the shotcrete mixture is too fluid; a clearly visible pattern can be observed, which is often undesirable

SLUMP

A key parameter is the slump of the concrete. For shotcrete placement, a balance must usually be found between pumpability and sufficient stability once applied. The slump must remain consistent to ensure a uniform finish.

If the slump is too low, the required pumping pressure increases significantly. At the same time, the delivery rate becomes irregular, which can lead to fluctuations in the concrete flow at the nozzle. These fluctuations are directly reflected in the spray pattern and can negatively affect the surface quality (Fig. 4).

If the slump is too high, the concrete may exhibit inconsistent flow on the application surface because it does not set quickly enough. In such cases, the geometric accuracy of the applied layer may still be acceptable, but the visual appearance of the surface often does

Fig. 5: A sprayed area with good concrete quality; the pattern is still visible, but significantly less pronounced

not meet the required standards.

If the slump is within the optimal range, the spray pattern that would otherwise be visible also disappears from the surface (Fig. 5). However, some unevenness may remain in the lower part of the sprayed area if the start-up phase of the concrete and accelerator pump was not carried out with sufficient care, and the correct ratio of concrete to accelerator has not yet been established in the shotcrete stream.

ADMIXTURES AND FIBERS

Chemical admixtures and reinforcing fibers can also significantly influence the properties of shotcrete. Depending on the type and amount of these components, the pumping behavior and spraying characteristics of the concrete may change.

WORKABILITY TIME

Another important factor is the workability time of the concrete. Long transport distances or delays in the construction process may lead to noticeable differences in spraying quality between the beginning and the end of discharging a truck mixer. For this reason, careful coordination of site operations is essential to minimize waiting times after the concrete has been mixed.

Due to the large number of influencing factors in shotcrete placement, an initial calibration of the machine with the concrete to be sprayed needs to be carried out before the first operation. During this calibration, the machine parameters are adjusted to match the specific concrete mixture used on site.

ACCELERATOR

In addition to concrete quality, the accelerator dosage also plays a crucial role in the appearance of the sprayed surface. The accelerator dosage should always be adjusted to the concrete consistency and the layer thickness being applied. If the dosage is too low, parts of the fresh shotcrete layer can break away from the surface. Because the automated system does not receive feedback about such defects without an additional surface scan, these areas will usually need to be repaired manually afterward. This can also have implications for work safety.

Further, when the nozzle is flushed between spraying cycles, it is essential that the accelerator line is properly refilled before the next spraying operation begins. This ensures that the accelerator is mixed with the concrete

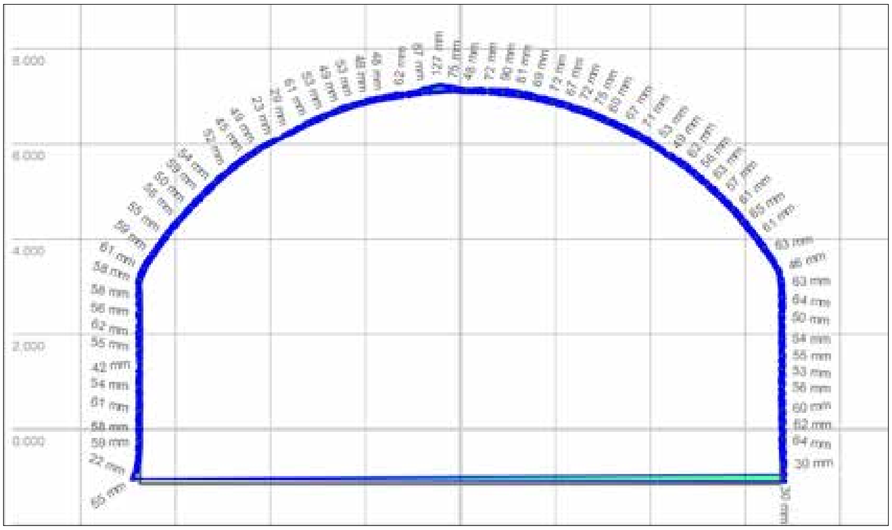


Fig. 6: Values indicate the applied layer thickness at each comparison point, ranging from 0.9 in. to 5.0 in. (23 mm to 127 mm)

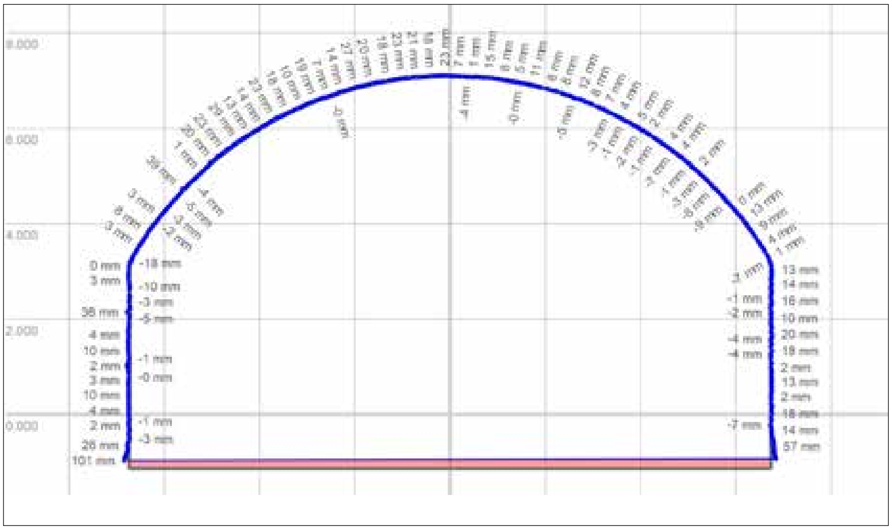


Fig. 7: Values indicate the deviation from the target profile at each comparison point, ranging from approximately -0.9 to +0.9 in

Fig. 8: Surface appearance during the execution of the automatic spraying process

Fig. 9: An even shotcrete surface, achieved using the automated spraying system

from the very beginning of the pumping process. Otherwise, the first sprayed lines can appear insufficiently set, because the concrete initially reaches the surface without sufficient accelerator.

It should be noted that these aspects are not specific to automated spraying but are equally important in conventional manual shotcrete application.

RESULTS FROM FIELD APPLICATION

Initial deployments of the automated shotcrete system in a tunnel environment have demonstrated that the developed solution is suitable for practical use. In most cases, deviations of approximately ± 0.9 in. (± 23 mm) from the specified design profile could be achieved.

Fig. 6 illustrates how the system is able to locally adapt the applied layer thickness. More material is applied in areas where the existing surface deviates significantly from the design profile, while areas closer to the design profile receive a thinner layer.

In the example shown, the applied layer thickness varies between approximately 0.9 in. and 5.0 in. (23 mm to 127 mm). This clearly demonstrates the system's ability to locally adapt the amount of material in order to reach the requirements of the target profile.

A further evaluation of the achieved surface geometry (Fig. 7) shows the actual deviations from the design profile after the spraying process. Apart from a few isolated outliers, the resulting surface remains within a tolerance range of approximately ± 0.9 in.

In addition, the visual appearance of the sprayed surface indicates that the automated process produces a uniform and even surface with very few visible irregularities (shown in Figs. 8 and 9).

CONCLUSION

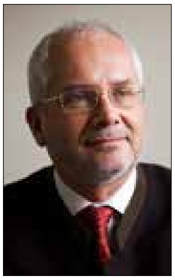
The development demonstrates that automated shotcrete application in tunnelling is technically feasible and can be successfully implemented under appropriate conditions. Certain challenges can also be mitigated at the design stage, for example, by avoiding sharp geometric transitions in the tunnel profile.

By combining precise surveying, digital process planning, proper design, and automated nozzle guidance, automated shotcrete placement can be performed more reproducibly and with much better geometric accuracy (waviness) than in purely manual operations. In particular, the system enables high accuracy in layer thickness across the entire tunnel profile, including the crown. This makes the method particularly suitable for applications with strict geometric tolerances, as well as for layers that require an even surface with minimal waviness, such as smoothing layers for waterproofing installation, shotcreted final linings, and tunnel rehabilitation (e.g. projects where existing tunnel final linings get replaced by shotcrete placement).

Soon, efforts will be made to incorporate control of the concrete pump into the control system to refine its capabilities. Further, a high-precision automatic calibration system for determining the spray robot's position will be implemented. This will save time when repositioning the machine.

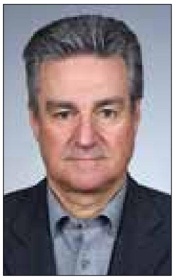
The system and the spraying robot are already being rented to interested customers for suitable applications, including training provided by application engineers. A patent application has been filed for the main features of the control system.

__Igor Schweiggl__, M.Sc. is an application engineer at BeMo Tunnelling GmbH, focusing on the development and implementation of automated shotcrete application in tunnelling. He holds a master's degree in environmental and process engineering and has been closely involved in advancing robotic spraying technologies from concept to field application. His work combines practical tunnelling experience with a strong background in surveying and process optimization. He has contributed to the successful deployment of automated shotcrete systems on construction sites, with a focus on improving surface quality, geometric accuracy, and overall process efficiency in tunnel construction.

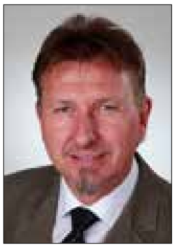


Dipl.-Ing. __Norbert Fuegenschuh__ holds a master's degree in civil engineering from University of Technology in Graz, Austria (1989). He started working for BEMO Tunnelling in Innsbruck, Austria in February of 1990, and is still employed by BEMO, having gathered 36+ years of experience in SEM/ NATM tunneling. Norbert has worked as project manager, tunnel manager and NATM/ SEM, and shotcrete specialist on tunnel projects in Germany, Sweden, Canada, and the U.S. In his current position as head of BEMO's North America subsidiary, he is based in Vienna, Virginia.

__Alexander Sellemond__, M.Sc. is the system engineer and managing director of Vision Metrics GmbH in Munich, specializing in the development of camera-based measurement technology. He holds a master's degree in electrical and information engineering from the Technical University of Munich, with a focus on power electronics and image processing. His professional background spans hardware and embedded software development, with experience at MTU Aero Engines, Siemens Corporate Technology in Munich, and in freelance engineering for startups and enterprise companies. His work combines expertise in computer vision, artificial intelligence, software engineering, and electronic system design.



Mech. Eng. __Rainer Antretter__ is employed with BEMO Tunnelling as head of the Mechanical Department, where he started in 1983. His early responsibilities included design of construction site facilities, water supply, wastewater disposal systems, excavation and muck-handling equipment concepts, design of rail-based mucking systems, tunnel ventilation systems, and compressed-air tunnelling systems. Appointed Deputy Head in 1996, he contributed to strategic and operational development and completed training to an HSE expert. Since 2006, he has served as Head of Plant Department, overseeing profitability, capital expenditure, and plant-related contracts while leading multidisciplinary engineering teams. He also provides expertise for international know-how transfer services with core expertise in mechanical systems for tunnelling, and he is driving the development of automated concrete spraying technology.



Dipl.-Ing. (FH) __Peter Dietrich__ is a senior tunnel engineer and project engineer at BeMo Tunnelling GmbH with more than 30 years of experience in the tunneling industry. He has extensive expertise in SEM/NATM tunneling and shotcrete-supported excavation, gained through numerous complex infrastructure projects in Europe, North America, and Asia. His work includes project management, construction supervision, and technical consulting in challenging ground conditions, particularly in urban environments. He has been involved in international know-how transfer projects and the implementation of advanced tunneling methods, contributing to safe and efficient excavation processes and high-quality shotcrete application in modern tunnel construction.

Fire-Spalling Resistant Dry-Mix Shotcrete

FOR THE REHABILITATION OF THE LOUIS-HIPPOLYTE-LA FONTAINE TUNNEL

By Christine Poulin and Cody Fournier

INTRODUCTION

Since 1967, the bridge-tunnel Louis-Hippolyte-La Fontaine has been one of the most critical transportation arteries for one of Canada's busiest cities. Located in Montreal, Quebec, this unique structure combines a 1500 ft (460 m) bridge and an immersed tunnel almost a mile long (1.5 km), passing over Charron Island and then under the St. Lawrence River (Fig. 1) (La Presse Canadienne, 2017). This crucial artery has played a central role in supporting daily mobility, economic activity, and regional connectivity with up to 120,000 daily commuters (La Presse Canadienne, 2022).

Fig. 1 (ABOVE and BELOW): Drone captures of the bridge-tunnel Louis-Hippolyte-La Fontaine. Photo credit: OIQ (n.d.).

With over 50 years in service, the *Ministère des Transports et de la Mobilité Durable* of Quebec (MTMD) has initiated a major rehabilitation program to extend the Louis-Hippolyte-La Fontaine tunnel's service life by approximately 40 years. The Renouveau La Fontaine consortium, formed by Pomerleau and Vinci Construction (Dodin QC and Eurovia QC), was awarded the contract. Construction began in 2021 and is scheduled for completion in 2027 (Gouvernement du Québec, 2026).

The rehabilitation includes full structural restoration of the tunnel and upgrades to meet current fire protection standards. To satisfy performance requirements for road tunnel fire resistance, the MTMD and Renouveau La Fontaine selected fire and spalling resistant concrete as the primary protective solution.

Sika Canada played a significant role in meeting these specifications, particularly in the refurbishment work inside the tunnel's two ventilation towers, each consisting of two reinforced concrete shafts (Fig. 2). Dry-mix shotcrete placement with fire induced spalling resistance was selected as the optimal solution due to the towers' complex geometry, their constrained location within the tunnel, and the required sequencing of repair operations.

Thanks to the collaboration of the various project stakeholders, including the specialized shotcrete contractor Groupe LB (formerly known as FDDF), Sika Canada succeeded in developing the only fire resistant dry-mix

Fig. 2: Ventilation towers of the Louis-Hippolyte-La Fontaine tunnel. Photo credit: La Presse (2024).

shotcrete capable of meeting the project's stringent fire protection requirements. This article examines in detail the project's specific challenges, the technical requirements, the materials and technologies deployed, and the results achieved to satisfy the owner's criteria.

PLACEMENT METHOD SELECTION

The ventilation towers of the Louis-Hippolyte-La Fontaine tunnel were among the most challenging components to rehabilitate within the project. Their curved geometry, dense reinforcement, and the limited clearance inside the shafts significantly increased the complexity of the repairs (Fig. 3).

One of the initial repair approaches involved the use of a conventional form-and-pour approach together with the addition of a passive protection panel to ensure fire-spalling resistance of the structure. However, due to the irregular shapes of the structures, the very limited working space on the scaffolding, and the tight schedule for completing the rehabilitation, this approach was deemed impossible. Shotcrete placement was the only viable solution for carrying out the work successfully.

The wet-mix process was first considered by Renouveau La Fontaine. However, the low volumes per sequence, the heavy equipment required, and the restricted access

Fig. 3 (ABOVE and BELOW): Views of one of the severely damaged shafts undergoing repair inside the tunnel. Photo credits: La Presse (2024) and Sika Canada (2024).

Fig. 4 (ABOVE and BELOW): Preconstruction mock-ups with dry-mix shotcrete for the encapsulation of reinforcement and Sika® Galvashield® galvanic anodes. Photo credit: Sika Canada (2023).

within the tunnel significantly constrained work inside the shafts and limited the use of ready-mix concrete. A small on-site batching plant with smaller pumping equipment and pre-packaged wet-mix shotcrete could have been an alternative. However, the wet-mix process using a rapid-set accelerator for overhead applications, including those at the base of the shafts on this project, was not permitted by MTMD due to concerns related to durability and placement quality. Given these constraints, dry-mix shotcrete was the only placement method capable of meeting the project's requirements.

Upon selecting this placement method, several preconstruction mock-ups were requested during the preliminary phase of the project by the MTMD and Renouveau La Fontaine to demonstrate the effectiveness of shotcrete placement in encapsulating the heavy reinforcement and the cathodic protection system integrated into the rehabilitation design (Fig. 4).

These successful tests demonstrated the ability of high velocity shotcrete placement to thoroughly encapsulate complex reinforcement configurations and the embedded galvanic anodes. The mock-ups clearly highlighted how the energy of the shotcrete impact produced full consolidation

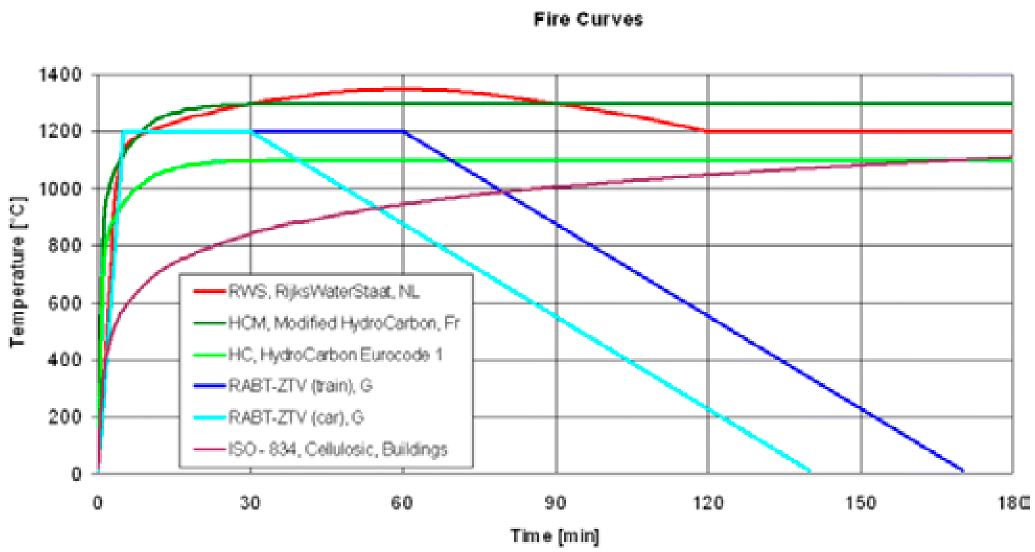


Fig. 5: Depiction of the various industry-recognized fire curves as a function of exposure time and test temperature. Figure credit: Promat (2020).

around both the reinforcing steel and the cathodic protection components, ensuring durable, continuous contact within the in place concrete.

PROJECT REQUIREMENTS

According to the design criteria established in the MTMD's material standard 3101 (2021), several key performance characteristics of the shotcrete material had to be validated to obtain approval from the MTMD, such as:

- Compressive strength of 5176 psi (35 MPa) at 28 days
- Air content between 3.5% and 7.0%
- Maximum air void spacing factor of 0.012 in. (300 µm)
- Chloride ion penetration below 1500 coulombs

In addition, to comply with fire-resistance requirements, the material also had to meet the Modified Hydrocarbon (HCM) fire curve performance criteria specified in the CETU Technical Guide (2017) and in accordance with standard NF EN 13381-3 (AFNOR, 2015). Mainly recognized and used in France for road tunnels, the HCM fire curve represents the evolution of temperature over a period of 120 minutes on elements that may be exposed to a fire reaching a maximum temperature of 2400°F (1300°C) due to the burning of petrochemical fuels (petrol, oil, chemical tankers, etc.). For this project, the exposure duration was increased to 180 minutes.

Several other fire scenario curves exist across various international standards and guidelines. The HCM curve is among the most stringent for fire protection requirements. Fig. 5 presents a comparison of several recognized fire curves as a function of time and temperature, including the HCM curve specified for this project.

As part of the rehabilitation project for the Louis-Hippolyte-La Fontaine tunnel, the laboratory appointed to perform the HCM fire curve tests was the *Centre d'Études et de Recherches de l'Industrie du Béton* (CERIB) established in France, in accordance with the recommendations of the CETU Technical Guide. CERIB operates as an industrial technical center specializing in research, innovation, and material qualification for infrastructure works (CERIB, 2026).

SHOTCRETE MATERIAL AND SAMPLING

The specific requirements of the project leveraged Sika Canada's expertise in developing a dry-mix shotcrete material optimized for fire performance and, more specifically, for mitigating explosive spalling. A dedicated mix was formulated to withstand the severe fire conditions anticipated in the Louis-Hippolyte-La Fontaine tunnel.

The dry-mix shotcrete mixture design included GU cement, silica fume, air entrainment, a maximum aggregate size of 0.375 in. (10 mm), conforming to ACI PRC-506 (2022) Grade 2, nonreactive aggregates, and microfiber designed to reduce fire-spalling, dosed at 5.77 lb/yd^3 (2 kg/m^3) (Fig. 6).

These specially designed fibers play a critical role in reducing fire induced spalling. When exposed to elevated temperatures (approximately 328°F [165 °C]), the fibers melt and expand within the concrete. This process generates a network of microcracks that facilitates vapor movement and relieves internal moisture pressure. In addition, the melting of the fibers significantly increases the pore connectivity, allowing internal water vapor to dissipate more effectively through the cementitious matrix. As a result, the buildup of

Fig. 6: Close-up views of the fibers in Sika® Fibermesh® 150F, a fiber designed to prevent explosive fire spalling in concrete. Photo credit: Sika Canada (2023).

moisture pressure inside the concrete is mitigated, thereby enhancing the concrete's stability and integrity under extreme thermal loading (Smith & Atkinson, 2009).

The project specified tests were used to validate the performance of the shotcreted mixture and the effectiveness of the fiber technology. In accordance with NF EN 13381-3, a large flat panel 12.8 × 10.5 × 0.41 ft (3.9 × 3.2 × 0.125 m) was prepared on June 6, 2022, to serve as a full scale test specimen.

The panel seen in Fig. 7 incorporated a reinforcement configuration representative of in service conditions, along with twelve thermocouples positioned 4 in. (100

Fig. 7: Preparation of the panel with dry-mix shotcrete King® MS-D1 FSR for the HCM fire curve testing by the contractor Groupe LB. Photo credit: Sika Canada (2022).

Test	Standard	Age / Cycles	Units	Project Requirement	Result
Compressive Strength	CSA A23.2-14C	1 day	psi (MPa)	2176 (15.0)	3508 (24.2)
		7 days	psi (MPa)	3626 (25.0)	5221 (36.0)
		28 days	psi (MPa)	5076 (35.0)	6938 (47.8)
Bulk Resistivity	CSA A23.2 26C	28 days	ohm·ft (ohm·m)	1640 (500)	1221 (372)
Air Content	CSA A23.3-4C	—	%	3.5 – 7.0	6.7*
Spacing Factor	ASTM C457	—	in (μm)	0.012 (300)	0.008 (206)
Absorption (Immersion & Boiling)	ASTM C642	—	%	8.0	2.6
Permeable Void Volume	ASTM C642	—	%	17.0	5.9
Rapid Chloride Penetration	CSA A23.2-23C	56 days	Coulombs	1500	212 *(Very Low)*
Freeze–Thaw Resistance	ASTM C666	300 cycles	% durability factor	—	100
Salt-Scaling Resistance	ASTM C672	56 cycles	lb/ft² (kg/m²)	—	0.02 (0.1)
Fire Resistance	CETU Technical Guide, and NF EN 13381-3	180 minutes, at 2372 °F (1300 °C)	—	HCM fire-curve	Passed

Table 1: Compilation of the test results obtained for the King® MS-D1 FSR shotcrete mix for the Louis-Hippolyte-La Fontaine tunnel project.
**Air content testing conducted in accordance with ASTM C457*

mm) from the exposed face to monitor the thermal evolution during testing.

After the panel was fabricated, it was shipped by sea to the CERIB laboratory in France, arriving on Sept. 2, 2022, to undergo the fire resistance test. The test setup consists of a furnace in which the panel, supported horizontally on two bearings, is exposed to a fire scenario representative of an HCM curve thermal loading.

RESULTS AND DISCUSSION

Based on the tests carried out for this project, the dry-mix shotcrete material formulated for fire spalling resistance met all project requirements, including the spalling resistance test under the HCM fire curve. The detailed results are presented in Table 1 (see previous page).

The mix achieved a 28-day compressive strength of 6938 psi (47.8 MPa) exceeding the minimum strength criteria established by the MTMD. The hardened concrete exhibited 6.7% entrained air, achieving a well-distributed air void structure with a spacing factor of 0.008 in. (206 μm). The absorption after boiling (2.6 %) and permeable void volume (5.9 %) were consistent with acceptable placement quality as defined by established in situ performance indicators, including those presented by Morgan & Jolin (2022).

Durability testing demonstrated compliance with project requirements. Chloride ion penetration was classified as *very low*, and the air entrainment system provided robust resistance to freeze–thaw cycling as well as to surface scaling in the presence of de icing salts. Additionally, the bulk resistivity of 1221 ohm-ft (372 ohm-m) supports compatibility with the cathodic protection systems implemented as part of the tunnel rehabilitation program.

The incorporation of an appropriate fiber was fundamental toward achieving the required fire spalling resistance under HCM curve thermal loading. As reported by CERIB (2023), a test is considered successful when the concrete exhibits no evidence of fire induced spalling, including delamination, surface breakout, or loss of cover concrete from the exposed face. Fig. 8 depicts the condition of the shotcrete panel before and after the fire exposure. The results confirm that this mixture produced the first dry-mix shotcrete system verified to meet the HCM fire spalling resistance criteria.

CONCLUSION

The Louis-Hippolyte-La Fontaine tunnel in Montreal is still today currently undergoing work to extend its service life by an additional 40 years. For this project, the two ventilation towers composed of two reinforced concrete shafts presented significant challenges due to their complex geometry and a constrained workspace. These constraints necessitated the use of dry-mix shotcrete as both a repair and fire protection material (Fig. 9 - see next page).

Upgrading the fire resistance performance of these structures required the application of a shotcrete capable of mitigating fire induced spalling under the severe thermal conditions represented by the HCM fire curve (180 minutes, at 2400°F [1300°C]). The incorporation of properly engineered microfibers was essential for reducing the risk of explosive spalling by enabling vapor pressure relief within the concrete matrix during rapid heating.

The coordinated efforts of the Renouveau La Fontaine consortium, the contractor Groupe LB, and the MTMD ensured the successful execution of this project. The fire resistance tests conducted by CERIB confirmed that the dry-mix shotcrete material used in this project is, to date, the only mixture of its type verified to meet HCM fire curve performance criteria. The shotcrete material developed for the Louis-Hippolyte-La Fontaine Tunnel, in accordance with MTMD requirements, constitutes today a proven new technology for future infrastructure projects requiring comparable fire protection performance.

Fig. 8: HCM testing panel before (LEFT) and after (RIGHT) being exposed to 2372°F (1300°C) for 180 minutes. No visible damage was reported after testing. Photo credit: CERIB (2023).

Fig. 9: Result of the rehabilitation of one of the towers using fire-spalling resistant dry-mix shotcrete King® MS-D1 FSR. Photo credits: Sika Canada (2024) and Groupe LB (2026).

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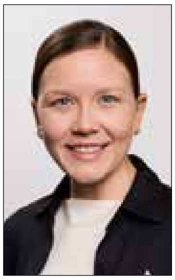

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Shotcrete Placement in a Constrained Corridor

EXECUTION STRATEGIES FROM THE I-17 FLEX LANES PROJECT

By Jeff Araiza

On large infrastructure projects, shotcrete placement is rarely defined by design drawings alone. Instead, production is dictated by access, logistics, terrain, and the ability of field crews to adapt in real time. That reality was on full display during BAM Shotcrete's work on the Interstate 17 Flex Lanes project in Arizona.

Spanning multiple locations between Anthem and Black Canyon City, the project required shotcrete installation across slopes, drainage channels, bridge structures, and median protection zones, often directly adjacent to live interstate traffic. From December 2024 through September 2025, BAM Shotcrete placed approximately 2465 yd^3 (1,885 m^3) of shotcrete and grout across 12 distinct work areas.

While the scope varied by location, the consistent challenge across the project was not the material itself, but how to place it efficiently and safely under constantly changing field conditions. This article focuses on the placement strategies, equipment decisions, and field adaptations that allowed production to continue across a highly constrained highway corridor.

Fig. 1: Night shotcrete application under a bridge for slope stabilization and erosion control project

PLACEMENT DRIVEN BY ACCESS, NOT DRAWINGS

On paper, shotcrete placement is typically defined by thickness, reinforcement, and finish requirements. In the field, especially on a project like I-17, placement strategy was driven first by how crews could physically access the work area. Crews were routinely working alongside active traffic lanes, beneath bridge structures, on slopes approaching 1:1 (45°), and within washes and drainage channels with limited entry points.

Because of this, placement sequencing could not follow a single standardized approach. Instead, each location required its own strategy based on terrain, staging constraints, and safety considerations. In many cases, crews had to determine whether to work top-down or bottom-up on slopes, how to break areas into manageable sections, and where to position hose lines to maintain consistent material flow.

The key takeaway from this project is that successful shotcrete placement in constrained environments starts with access planning, not production planning.

MANAGING LONG HOSE RUNS AND MATERIAL FLOW

One of the most consistent production challenges across the project was the distance between staging areas and placement zones. Because equipment often could not be positioned directly at the work face, hose lengths reached up to 800 ft (240 m) in some areas. These extended runs introduced challenges such as maintaining consistent pump pressure, preventing material segregation, coordinating communication between pump operators and shotcreters, and managing hose routing across uneven terrain.

To address this, crews focused on pump consistency and clear communication. The Reed B50HP and Reed C50HP pumps provided reliable output, but maintaining steady flow over long distances required experienced operators who could anticipate fluctuations before they affected placement quality. Hose routing was also critical: Lines were positioned to minimize sharp bends and elevation changes where possible, reducing pressure loss to maintain a consistent stream at the nozzle.

For contractors working in similar environments, long hose runs should be treated as a primary planning factor because they directly impact placement quality and production efficiency.

Fig. 3: Shotcrete crew placing concrete on reinforced slope protection along a highway embankment in Arizona

Fig. 2: Rebar installation on a steep slope for the upcoming shotcrete application and erosion control system

EQUIPMENT STRATEGY FOR MOBILITY AND PRODUCTION

Given the number of locations and varying access conditions, mobility was just as important as production capacity. BAM Shotcrete utilized a RAM 5500 flatbed truck with a bed-mounted air compressor towing Reed B50HP and C50HP shotcrete pumps. This setup allowed crews to move efficiently between work zones while maintaining consistent output.

Because the project included work ranging from 2 in. to over 24 in. (50 mm to over 600 mm) thicknesses, equipment needed to handle both light slope protection as well as heavier structural placements without requiring reconfiguration. The mobile setup also allowed crews to adapt quickly when site conditions changed or when access points shifted due to ongoing construction.

ADAPTING PLACEMENT TO VARIABLE THICKNESS REQUIREMENTS

The project required a wide range of shotcrete thicknesses depending on application, from thin slope protection to thicker structural sections around bridge columns and spillways. Rather than treating these as separate types of work, crews approached them as variations within a single placement system and adjusted techniques accordingly.

For thicker placements, maintaining material stability and preventing sloughing required careful nozzle control and layering. For thinner sections, consistency and finish quality became the primary focus. Crews adjusted nozzle angle, application rate, and section size based on field conditions — an adaptability which allowed the same crews and equipment to perform efficiently across multiple scopes without slowing production.

FINISHING BASED ON FUNCTION

Finishing requirements were driven by functional needs such as drainage and surface performance. Specified finishes included nozzle finish, float finish, and light broom finish. Each finish was selected based on the requirements of the installation area and integrated into the placement process, improving efficiency and reducing the need for additional work after placement.

ACCESS CONSTRAINTS AND WORK AREA SETUP

Access conditions varied significantly across the project. Crews relied on temporary dirt access roads where available. In areas without access roads, work required coordination with the general contractor to implement lane closures or shift operations to nighttime hours. On slopes approaching 1:1 (45°), articulating boom lifts were used to safely position crews and maintain proper placement angles. These strategies required ongoing adjustments as conditions changed throughout the project.

WORKING IN A LIVE TRAFFIC ENVIRONMENT

Working alongside active interstate traffic introduced additional challenges related to safety and coordination. Crews implemented strict safety protocols, including high-visibility personal protective equipment, clearly marked

Fig. 4: Shotcrete crew applying concrete over rebar for wash lining and slope stabilization in desert terrain

equipment, and additional traffic-control measures such as cones and signage. In many cases, work was performed at night to reduce traffic exposure and improve safety. Coordination with ADOT and the general contractor was essential to maintaining safe and efficient operations.

Mix Design Adjustments in Desert Conditions

All concrete and grout materials were supplied by CalPortland. No accelerator was used on this project, however, hydration stabilizers were used when needed to maintain workability and control set times.

In hot weather, crews used chilled water, ice, and, when needed, a retarder to keep mixture temperatures under control. These adjustments ensured consistent placement quality despite challenging environmental conditions.

Controlling Overspray and Protecting Surfaces

Overspray was controlled through careful placement and protective measures. Crews used heavy-mil plastic tarps and plywood shields to protect adjacent finished surfaces when necessary. Material usage was managed closely to minimize waste and maintain efficiency throughout the project.

Quality Control in the Field

Quality control included regular testing and inspection. Test panels measuring 24 × 24 × 6 in. (600 × 600 × 150 mm) were produced every 50 y^3 (38 m^3) or as required. These panels were tested by a third-party agency to verify strength and compliance with project specifications.

Lessons Learned from Field Execution

Frequent field changes and design adjustments were one of the most consistent challenges encountered during the project. In some cases, crews arrived on site to find that installation requirements had changed from the original plans. This required immediate adjustments to placement strategy and sequencing.

The ability to adapt quickly while maintaining quality was critical to project success. For contractors working on similar projects, it is important to expect changes and build flexibility into both planning and execution.

Conclusion

The I-17 Flex Lanes project demonstrates the importance of execution in shotcrete placement. Access constraints, long hose runs, variable terrain, and evolving project conditions all influenced how work was performed in the field. By focusing on mobility, communication, and adaptability, BAM Shotcrete successfully completed more than 2,465 yd^3 (1,885 m^3) of shotcrete and grout work across 12 locations.

This project reinforces that successful shotcrete placement is not just about material selection, but about how that material is placed under real-world conditions.

Fig. 5: Finished shotcrete wall with uniform texture and proper compaction for structural slope stabilization

Fig. 6: Completed shotcrete slope protection under a highway overpass for long-term erosion control and durability

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Key Disciplines for Advancing as a Shotcreter

FROM OPERATOR TO CONSCIENTIOUS SHOTCRETE EXPERT

By Raúl A. Bracamontes

Shotcrete performance is often attributed to concrete mixture design, equipment, or materials. Field experience consistently demonstrates, however, that the most influential factor in the final quality of shotcrete is the shotcreter (formerly nozzleman). This article outlines the key disciplines that allow a shotcreter to evolve from a mechanical operator into a conscientious technician — one who actively interprets fresh material properties, reduces rebound, improves compaction, and optimizes productivity in real time.

In shotcrete placement, significant effort is devoted to optimizing mixture proportions, selecting cementitious materials and admixtures, and ensuring the quality of equipment (gun, pump, compressors, delivery system, etc.). While these factors are critical, numerous field evaluations have shown that the greatest variability in shotcrete quality originates from the human factor: Two shotcreters could work with the same concrete mixture, the same equipment, and under identical environmental conditions, yet produce markedly different results.

According to CCS-4: "The [shotcreter] is the craftsman that physically directs the shotcrete placement of the concrete. The [shotcreter] has final responsibility for the quality of the placed shotcrete and is an extremely important member of the shotcrete crew. The [shotcreter] must have an understanding of the materials, equipment, safety procedures, and the proper placement techniques to produce high quality, durable concrete."

Fig. 1: Two cores (by two different shotcreters with the same concrete mixture) produce two very different results

The difference lies not in the materials or equipment, but in the shotcreter's level of awareness, technical discipline, and ability to respond to visual feedback during application. Understanding and cultivating these disciplines are essential for improving both structural performance and construction efficiency.

FROM OPERATOR TO EXPERT: A SHIFT IN MINDSET

Many entry-level shotcreters operate in what can be described as an automatic mode — repeating learned movements without continuously evaluating the results of their actions during shotcrete placement. While experience may refine these movements over time, automatic execution alone does not guarantee quality.

An experienced, expert-level shotcreter, by contrast, works with constant situational awareness. They observe the behavior of the material during placement, adjust their technique in real time (distance, angle, layer thickness, etc.), and critically evaluate the placement, taking immediate corrective actions. This represents not only a technical progression, but also a cognitive shift — from performing a task to managing a process — which raises an important question: Who is responsible for training the shotcreter? On many projects, shotcreters are expected to learn primarily through experience in the field, often without structured guidance or formal instruction. However, given the direct impact of shotcreter performance on shotcrete placement quality, training should be a shared responsibility among contractors, supervisors, engineers, and industry organizations. Effective training programs must combine theoretical knowledge, hands-on practice, and continuous evaluation to ensure that shotcreters develop not only manual skills but also a deep understanding of the material and the process they control.

DISCIPLINE OF SELF-OBSERVATION

The first and most important discipline is recognizing the visual cues of quality while shooting. Shotcrete application is a dynamic process, and the operator must continuously evaluate indicators such as material consistency, rebound levels, surface appearance, degree of compaction, reinforcement encasement, and control of overspray.

During shotcrete application, several visual indicators confirm proper placement and consolidation. A slightly glossy surface, produced by adequate compaction with sufficient paste at the receiving surface, is one of the most reliable signs of correct application. Reinforcing steel should remain visible and clean during spraying, without voids or shadowing behind the bars. The material should progressively encapsulate the reinforcement, allowing it to be fully surrounded before being completely covered.

Shotcreters have the opportunity and the responsibility to make real-time adjustments to the placement process when any change is observed in material workability, water content (for dry-mix shotcrete), material velocity and impact energy, or nozzle distance and angle. Continuous control of rebound and overspray is essential, as any change here is often the earliest warning sign of a reduction in application quality. Immediate response allows for corrections to be made before defects become embedded in the structure. Without continuous and attentive observation of one's performance, errors will often go unnoticed until inspection or testing, at which point corrective action is costly and inefficient.

DISCIPLINE IN EQUIPMENT CONTROL

Shotcrete can be applied manually or using remotely-controlled nozzle systems, depending on project requirements. The principles of control remain the same.

In hand spraying, the shotcreter secures the hose between the legs, as the leg muscles are strongest and best able to resist the reaction forces generated by pumping. The hose should not be carried on one side or over the shoulder. Instead, the operator uses their body to counteract the thrust produced by the high-pressure stream. The shotcreter does not 'carry' the hose, but controls the nozzle's direction, maintaining proper distance and perpendicularity to the receiving surface. By stabilizing the hose with their legs and body, the operator can make rapid adjustments to nozzle angle, distance, and velocity, ensuring consistent placement, compaction, and minimizing rebound.

Fig. 3: A shotcreter using proper form for shotcrete placement

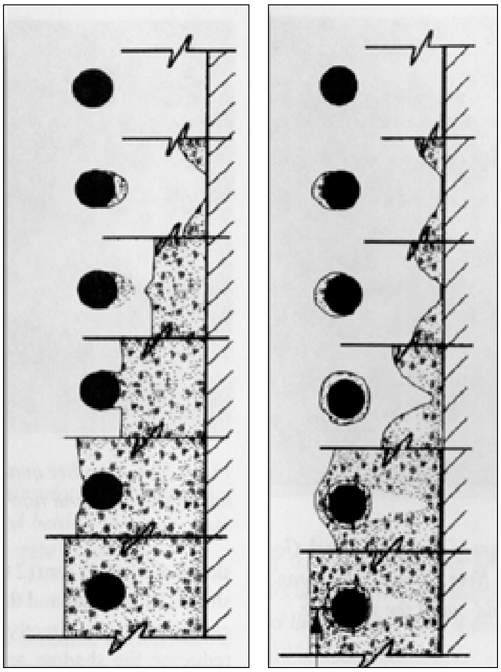

Fig. 2: Visual signs of shotcrete placement with rebar — correct placement (LEFT), incorrect placement (RIGHT) Credit: ACI PRC 506-22

Equipment control is an extension of operator control. The shotcreter must maintain consistent command of key variables such as nozzle angle, standoff distance, material velocity, spray pattern, and adjustments to air, water, and accelerator dosage (if used). Maintaining a nozzle angle nearly perpendicular to the receiving surface promotes maximum impact with resulting in-place compaction and reduces rebound.

At the same time, the shotcreter must continuously evaluate the behavior of the concrete at the moment it strikes the receiving surface. The appearance, texture, and response of the material upon impact provide immediate feedback on whether the application parameters are correct or require adjustment.

Expert shotcreters develop the muscle memory and spatial awareness needed to control these variables precisely and consistently, allowing them to make rapid, almost instinctive corrections while maintaining uniform placement and high-quality consolidation.

DISCIPLINE OF SUSTAINED ATTENTION

Concentration is one of the most underestimated factors in shotcrete quality. The placement process demands continuous attention to visual, auditory, and tactile cues. The shotcreter is the first to detect changes in material behavior or equipment performance, such as variations in spray sound, surface texture, or rebound trajectory.

Loss of attention often results in immediate defects — poor compaction, shadowing behind reinforcement, or uneven thickness. Maintaining full attention throughout spraying is therefore not merely a matter of professionalism but an essential requirement for quality placement.

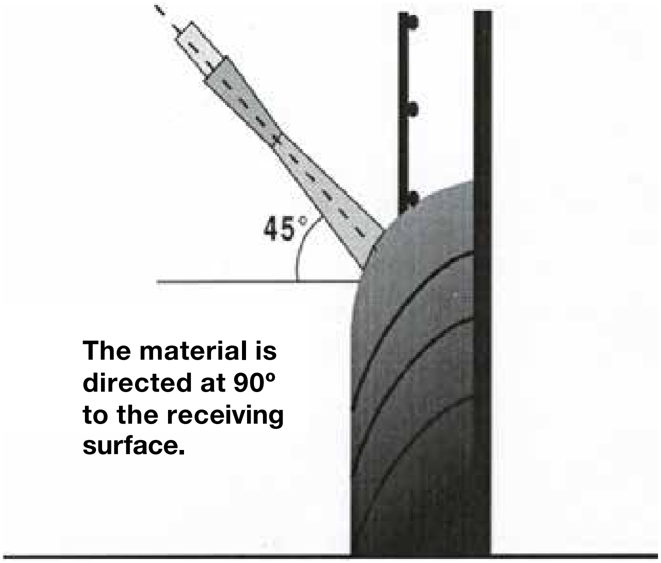

Fig. 4: Bench shooting

SHOTCRETE PLACEMENT TECHNIQUES

There are two primary methods for placing shotcrete: Bench shooting and vertical layer placement. Each method involves specific techniques, and the shotcreter must understand the principles and applications of both.

Bench shooting is typically used in thick walls or heavily reinforced sections. In this method, the shotcrete placement is applied at an angle of approximately 45 degrees to the receiving surface, which itself acts as the temporary 'bench'. This approach allows the shotcreter to apply thicker layers efficiently, control rebound, and ensure proper compaction. Bench shooting is particularly effective on inclined or thick sections where vertical application would be difficult or inefficient.

Vertical layer placement involves building up shotcrete directly on vertical or near-vertical surfaces, layer by layer, from bottom to top. This method requires careful control of nozzle angle, distance, and material cohesion to prevent slumping, sagging, or uneven thickness.

A skilled shotcreter knows when to employ each technique based on project geometry, wall thickness, surface conditions, and structural requirements. Understanding the differences ensures efficient placement, proper compaction, and high-quality adhesion regardless of orientation.

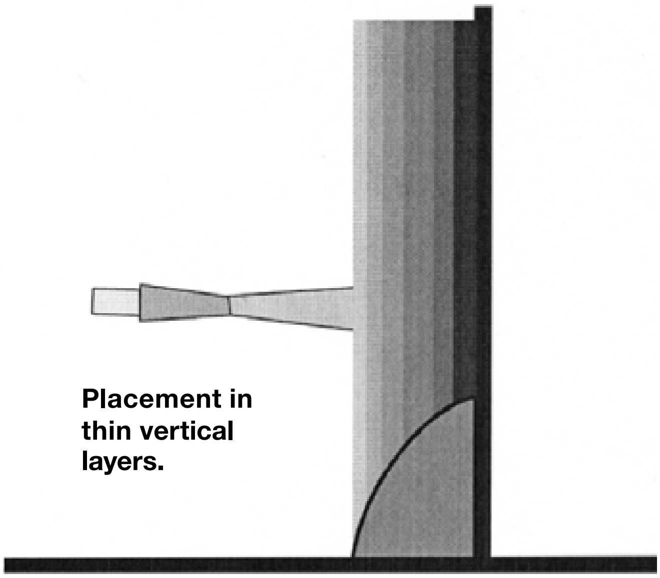

Fig. 5: Vertical layers

DISCIPLINE IN READING THE SHOTCRETE PLACEMENT

Shotcrete placement is not painting the surface with concrete. The shotcrete process is a quality concrete placement technique that communicates its condition through visible and measurable signals. An experienced shotcreter learns to interpret these cues in real time and adjust application parameters accordingly.

A sandy or dull, opaque

Fig. 6: Sandy or dull, opaque surface during placement

Fig. 7: Distance results from left to right — good distance, too far, and too close

surface finish typically indicates insufficient impact energy, incorrect nozzle angle, or inadequate water content. Properly applied, the surface should exhibit a slightly glossy relatively smooth appearance, reflecting adequate compaction and paste coverage.

Surface texture should be slightly rough, generally indicating that the nozzle is at the correct distance. Too close, and the material hits with excessive force, forming crater like depressions. Too far, and the paste loses velocity, resulting in poor compaction. Craters, therefore, serve as practical distance indicators.

Surface waviness indicates that the nozzle is at too steep an angle, causing lateral flow rather than uniform compaction. Persistent waves can allow the stream to act like sandblasting, eroding or removing previously placed shotcrete. Maintaining a nozzle angle near perpendicular ensures proper compaction, uniform thickness, and secure adhesion.

Rebound levels are closely tied to placement quality. Skilled shotcreters maintain low rebound through proper control of nozzle angle, distance, and impact energy. High rebound signals deficiencies in application technique and requires immediate corrective action.

The ability to recognize these visual cues and respond immediately is a defining characteristic of expert-level shotcrete placement. Shotcreters continuously interpret material behavior and adjust their technique to maintain consistent quality and structural performance.

UNDERSTANDING THE MATERIAL

A shotcreter should not be limited to mechanical execution; they must understand the material. Knowledge of water-cement ratio, accelerator function, air content, mixture consistency, temperature effects, and early hydration behavior provides a scientific basis for decision-making.

How can a shotcreter understand concrete? Understanding shotcrete placement goes beyond theoretical knowledge alone; it requires direct interaction with the concrete under real job-site conditions. Hands-on experience allows the shotcreter to observe how the material responds to variations in water content, air pressure, nozzle angle, and impact energy. However, practical experience must be supported by a solid theoretical understanding of concrete.

A shotcreter who combines field experience with technical knowledge is better equipped to recognize changes in material behavior, adjust placement technique in real time, and communicate effectively with

Fig. 8: Wrong angle shooting results in surface waviness

engineers and supervisors when site conditions require modifications. This integration of theory and practice transforms the shotcreter from a simple operator into a knowledgeable technician capable of contributing to quality control and process optimization.

As an old construction saying goes:

> "To make good concrete, you must study hard, leave the office and visit the job sites, get your shoes dirty, put your hands in the material, and treat it with respect and care. It is the only language this remarkable material understands."

This motto, commonly shared among field engineers in the late 1990s, captures the essence of experiential learning and the intimate relationship between the shotcreter and the material.

DISCIPLINE IN QUALITY CONTROL

Expert shotcreters integrate verification into daily work. This includes checking applied thickness, observing test panel performance, reviewing core results, and comparing outcomes against specifications. By connecting field practice with laboratory and inspection results, shotcreters refine their technique based on objective data rather than subjective impressions.

DISCIPLINE OF CONTINUOUS IMPROVEMENT

Experience alone does not guarantee expertise. Repetition without reflection can reinforce poor habits as easily as good ones. Expert shotcreters actively analyze errors, adjust methods, and strive for consistency in every application. Mistakes are inevitable, but repeated errors indicate a lack of discipline rather than a lack of experience. A distinct advantage of shotcrete placement is that errors are not hidden inside a form, but readily visible. This allows the shotcreter to fix the problem before it becomes hard concrete.

CONCLUSION

The evolution of a shotcreter from operator to expert depends not only on time in the field, but on the quality of practice and the disciplines that guide it. Structured training, continuous skill development, self-observation, equipment control, sustained attention, material understanding, quality control, and a commitment to continuous improvement form the foundation of professional shotcrete application.

Ultimately, shotcrete placement quality is not determined solely by mixture design or at the batching plant — it is defined at the nozzle, on the receiving surface. The development of shotcreters who operate with awareness, discipline, and technical understanding is one of the most effective ways to elevate the standard of shotcrete placement in concrete construction. For this reason, proper training, qualification, and ongoing evaluation of shotcreters are essential to achieving consistent and reliable shotcrete performance.

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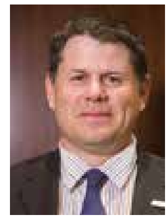

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Disciplinas clave para avanzar como lanzador de concreto

DE OPERADOR A EXPERTO CONSCIENTE EN CONCRETO LANZADO

Por Raúl A. Bracamontes (Traducción al español editada por Raúl A. Bracamontes)

El desempeño del concreto lanzado a menudo se atribuye al diseño de la mezcla, al equipo o a los materiales. Sin embargo, la experiencia en campo demuestra consistentemente que el factor más influyente en la calidad final del concreto lanzado es el lanzador (anteriormente llamado boquillero). Este artículo describe las disciplinas clave que permiten a un lanzador evolucionar de operador mecánico a técnico consciente: uno que interpreta activamente el comportamiento del material fresco, reduce el rebote, mejora la compactación y optimiza la productividad en tiempo real.

En la colocación de concreto lanzado, se dedica un esfuerzo significativo a optimizar las proporciones de la mezcla, seleccionar materiales cementantes y aditivos, y garantizar la calidad del equipo (equipo de concreto lanzado vía seca, bomba, compresores, sistema de transporte, etc.). Aunque estos factores son críticos, numerosas evaluaciones en campo han demostrado que la mayor variabilidad en la calidad del concreto lanzado se origina en el factor humano: Dos lanzadores pueden trabajar con la misma mezcla de concreto, el mismo equipo y bajo condiciones ambientales idénticas, y aun así producir resultados marcadamente diferentes.

Según CCS-4: “El lanzador es el artesano que dirige físicamente la colocación del concreto lanzado. El lanzador tiene la responsabilidad final sobre la calidad del concreto colocado y es un miembro extremadamente importante del equipo. El lanzador debe comprender los materiales, el equipo, los procedimientos de seguridad y las técnicas adecuadas de colocación para producir concreto duradero y de alta calidad.”

Fig. 1: Dos núcleos (realizados por dos lanzadores diferentes con la misma mezcla de concreto) producen resultados muy distintos.

La diferencia no radica en los materiales o el equipo, sino en el nivel de conciencia del lanzador, su disciplina técnica y su capacidad para responder a la retroalimentación visual durante la aplicación. Comprender y desarrollar estas disciplinas es esencial para mejorar tanto el desempeño estructural como la eficiencia constructiva.

DE OPERADOR A EXPERTO: UN CAMBIO DE MENTALIDAD

Muchos lanzadores en etapas iniciales operan en un modo automático, repitiendo movimientos aprendidos sin evaluar continuamente los resultados de sus acciones durante la aplicación del concreto lanzado. Aunque la experiencia puede refinar estos movimientos con el tiempo, la ejecución automática por sí sola no garantiza calidad.

En contraste, un lanzador experto trabaja con conciencia situacional constante. Observa el comportamiento del material durante la colocación, ajusta la técnica en tiempo real (distancia, ángulo, espesor de capa, etc.) y evalúa críticamente su propia aplicación, tomando acciones correctivas inmediatas. Esto representa no solo una progresión técnica, sino también un cambio cognitivo: pasar de ejecutar una tarea a gestionar un proceso. Esto plantea una pregunta importante: ¿quién es responsable de la capacitación del lanzador?

En muchos proyectos, se espera que los lanzadores aprendan principalmente mediante la experiencia en campo, a menudo sin guía estructurada ni instrucción formal. Sin embargo, dado el impacto directo del desempeño del lanzador en la calidad del concreto lanzado, la capacitación debe ser una responsabilidad compartida entre contratistas, supervisores, ingenieros y organizaciones del sector. Los programas efectivos deben combinar conocimiento teórico, práctica en campo y evaluación continua para asegurar que los lanzadores desarrollen no solo habilidades manuales, sino también una comprensión profunda del material y del proceso que controlan.

DISCIPLINA DE LA AUTOOBSERVACIÓN

La primera y más importante disciplina es la capacidad de reconocer las señales visuales de calidad durante la ejecución del trabajo.

La aplicación del concreto lanzado es un proceso dinámico, y el lanzador debe evaluar continuamente indicadores como la consistencia del material, los niveles de rebote, la apariencia de la superficie, el grado de compactación, el recubrimiento del acero de refuerzo y el control del rocío.

Durante la aplicación, diversos indicadores visuales permiten confirmar una colocación y consolidación adecuadas. Una superficie ligeramente brillante, resultado de una adecuada compactación con suficiente pasta en la superficie de recepción, es uno de los signos más confiables de una correcta aplicación. El acero de refuerzo debe permanecer visible y limpio durante la proyección, sin vacíos ni sombras detrás de las barras. El material debe encapsular progresivamente el refuerzo, permitiendo que quede completamente rodeado antes de cubrirlo en su totalidad.

Los lanzadores deben ser capaces de realizar ajustes en tiempo real —en fracciones de segundo— cuando se observan cambios en la trabajabilidad del material, contenido de agua (en mezcla seca), velocidad de proyección, energía de impacto o distancia y ángulo de la boquilla. El control continuo del rebote y del rocío es esencial, ya que cualquier incremento en estos fenómenos suele ser una de las primeras señales de desviaciones en la calidad de la aplicación.

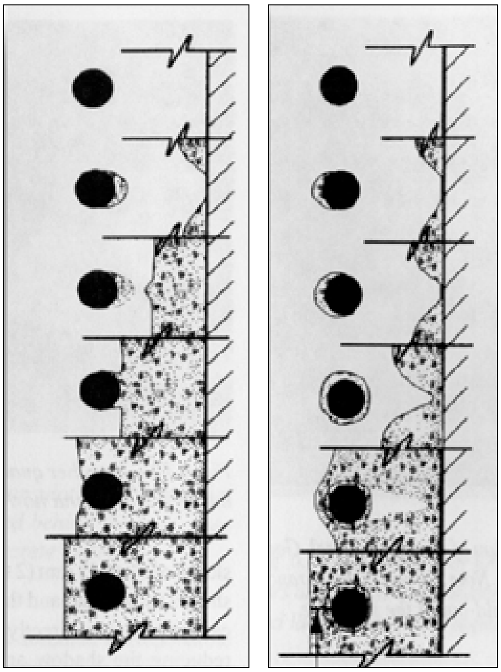

Fig. 2: Señales visuales de colocación con refuerzo: correcta (IZQUIERDA) e incorrecta (DERECHA).

Fig. 3: Lanzador utilizando una postura adecuada para la colocación de concreto lanzado.

Sin una observación continua y atenta del propio desempeño, los errores suelen pasar desapercibidos hasta la inspección o el ensayo, momento en el cual su corrección resulta costosa e ineficiente.

DISCIPLINA EN EL CONTROL DEL EQUIPO

El concreto lanzado puede aplicarse manualmente o mediante sistemas de boquilla controlados de forma remota, dependiendo de los requerimientos del proyecto. Los principios de control, sin embargo, son los mismos.

En la aplicación manual, el lanzador asegura la manguera entre las piernas, ya que los músculos de las piernas son los más fuertes y adecuados para resistir las fuerzas de reacción generadas por el sistema. La manguera no debe apoyarse sobre el hombro ni cargarse a un lado. El operador utiliza su cuerpo para contrarrestar la fuerza del chorro a alta presión. El lanzador no “carga” la manguera, sino que controla la dirección de la boquilla, manteniendo la distancia y perpendicularidad adecuadas respecto a la superficie de recepción.

El control del equipo es una extensión del control del operador. El lanzador debe mantener un dominio constante de variables clave como el ángulo de la boquilla, la distancia de proyección, la velocidad de avance, el patrón de proyección y los ajustes de aire, agua y acelerante (cuando se utilice). Mantener un ángulo cercano a la perpendicular con respecto a la superficie de recepción favorece una mejor compactación y reduce el rebote.

Al mismo tiempo, el lanzador debe evaluar continuamente el comportamiento del concreto en el momento del impacto. La apariencia, textura y respuesta del material proporcionan retroalimentación inmediata sobre si los parámetros de aplicación son adecuados o requieren ajuste.

Los lanzadores expertos desarrollan la memoria muscular y la conciencia espacial necesarias para controlar estas variables de manera precisa y consistente, lo que les permite realizar ajustes rápidos y casi instintivos mientras mantienen una colocación uniforme y una alta calidad de compactación.

DISCIPLINA DE LA ATENCIÓN SOSTENIDA

La concentración es uno de los factores más subestimados en la calidad del concreto lanzado. El proceso de aplicación exige atención continua a señales visuales, auditivas y táctiles.

El lanzador es el primero en detectar cambios en el comportamiento del material o en el desempeño del equipo, como variaciones en el sonido de proyección, en la textura de la superficie o en la trayectoria del rebote.

La pérdida de atención suele traducirse en defectos inmediatos: mala compactación, sombras detrás del refuerzo o espesores irregulares. Mantener la atención plena durante toda la aplicación no es solo una cuestión de profesionalismo, sino un requisito técnico fundamental para asegurar la calidad.

TÉCNICAS DE COLOCACIÓN DE CONCRETO LANZADO

Existen dos métodos principales para la colocación del concreto lanzado: proyección en bancada y colocación por capas verticales. Cada método implica técnicas específicas, y el lanzador debe comprender los principios y aplicaciones de ambos.

La proyección en bancada se utiliza típicamente en muros de gran espesor o en secciones con alta densidad de refuerzo. En este método, el material se aplica con un ángulo aproximado de 45 grados respecto a la superficie de recepción, la cual actúa como una “banca” temporal. Este enfoque permite colocar capas más gruesas de manera eficiente, controlar el rebote y asegurar una adecuada compactación.

La colocación por capas verticales consiste en construir el concreto lanzado directamente sobre superficies verticales o casi verticales, capa por capa, de abajo hacia arriba. Este

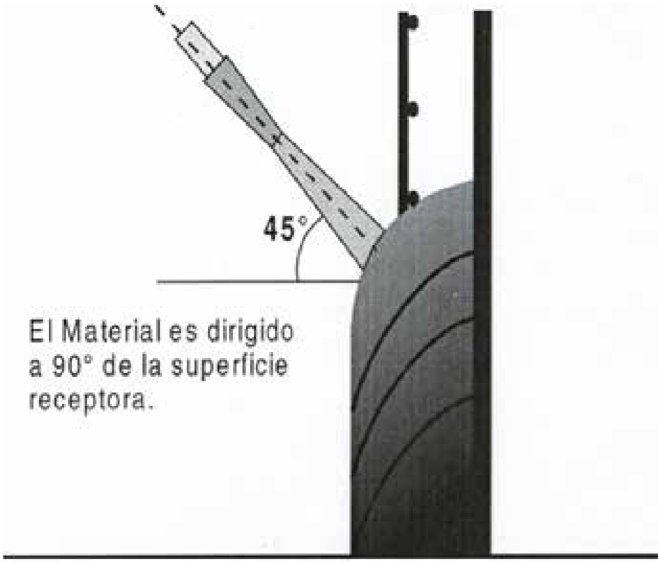

Fig. 4: Proyección en bancada

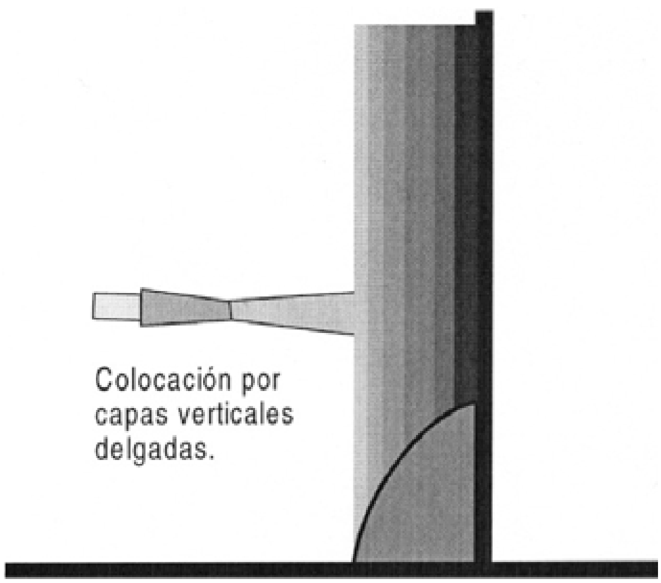

Fig. 5: Capas verticales

Fig. 6: Superficie arenosa u opaca durante la aplicación

Fig. 7: Resultados de distancia: adecuada, muy lejos y muy cerca

método requiere un control cuidadoso del ángulo de la boquilla, la distancia y la cohesión del material para evitar deformaciones, deslizamientos o espesores irregulares.

Un lanzador competente sabe cuándo emplear cada técnica en función de la geometría del elemento, el espesor del muro, las condiciones de la superficie y los requisitos estructurales.

DISCIPLINA EN LA LECTURA DEL CONCRETO LANZADO

La colocación de concreto lanzado no es un proceso de "pintar" una superficie. Es un proceso de colocación de concreto que comunica su condición a través de señales visibles y medibles.

Una superficie arenosa, opaca o sin brillo generalmente indica energía de impacto insuficiente, ángulo incorrecto de la boquilla o contenido inadecuado de agua (en mezcla seca). Cuando se aplica correctamente, la superficie debe presentar una apariencia ligeramente brillante, reflejo de una adecuada compactación y cobertura de pasta.

La textura superficial debe ser ligeramente rugosa, lo que generalmente indica una distancia adecuada de la boquilla. Si la distancia es demasiado corta, el material impacta con exceso de energía y forma cráteres. Si es demasiado lejos, el material pierde velocidad, reduciendo la compactación.

La ondulación superficial indica que el ángulo de proyección es demasiado inclinado, provocando flujo lateral en lugar de compactación uniforme. Ondulaciones persistentes pueden permitir que el chorro actúe como un proceso erosivo, removiendo material previamente colocado.

El nivel de rebote está estrechamente relacionado con la calidad de la colocación. Niveles elevados indican deficiencias en la técnica y requieren corrección inmediata.

COMPRENSIÓN DEL MATERIAL

El lanzador no debe limitarse a la ejecución mecánica; debe comprender el material.

El conocimiento de la relación agua-cemento, la función del acelerante, el contenido de aire, la consistencia de la mezcla, los efectos de la temperatura y el comportamiento de hidratación temprana proporciona una base científica para la toma de decisiones.

Fig. 8: Ondulación superficial por ángulo incorrecto

La comprensión del concreto lanzado va más allá de la teoría: requiere interacción directa con el material en condiciones reales de obra. La experiencia práctica, combinada con conocimiento técnico, permite al lanzador reconocer cambios en el comportamiento del material, ajustar la técnica en tiempo real y comunicarse eficazmente con ingenieros y supervisores cuando las condiciones del proyecto lo requieren.

Como señala un antiguo principio de la industria:

> "Para hacer buen concreto, hay que estudiar, salir a la obra, ensuciarse los zapatos, meter las manos en el material y tratarlo con respeto. Es el único lenguaje que este material entiende."

DISCIPLINA EN EL CONTROL DE CALIDAD

Los lanzadores expertos integran la verificación en su trabajo diario. Esto incluye el control de espesores aplicados, la evaluación de paneles de prueba, la revisión de núcleos y la comparación de resultados con las especificaciones del proyecto.

Al vincular la práctica en campo con los resultados de laboratorio e inspección, los lanzadores pueden perfeccionar su técnica con base en datos objetivos.

DISCIPLINA DE MEJORA CONTINUA

La experiencia por sí sola no garantiza la excelencia. La repetición sin reflexión puede reforzar malos hábitos.

Los lanzadores expertos analizan errores, ajustan métodos y buscan consistencia en cada aplicación. Los errores son inevitables, pero su repetición indica falta de disciplina.

Una ventaja del concreto lanzado es que los errores son visibles de inmediato, lo que permite corregirlos antes del endurecimiento.

CONCLUSIÓN

La evolución de un lanzador desde operador hasta experto depende no solo del tiempo en campo, sino de la calidad de la práctica y de las disciplinas que la guían.

La capacitación estructurada, el desarrollo continuo de habilidades, la autoobservación, el control del equipo, la atención sostenida, la comprensión del material, el control de calidad y el compromiso con la mejora continua constituyen la base de una aplicación profesional del concreto lanzado.

En última instancia, la calidad del concreto lanzado no se define en la planta de producción, sino en la boquilla, sobre la superficie de recepción.

El desarrollo de lanzadores que operen con conciencia, disciplina y conocimiento técnico es una de las formas más efectivas de elevar el nivel de la construcción con concreto lanzado.

Por esta razón, la capacitación, certificación y evaluación continua de los lanzadores son esenciales para lograr un desempeño consistente y confiable.

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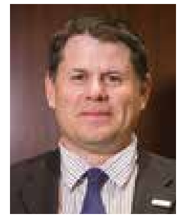

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SHOTCRETE INSPECTORS WANTED
Shotcrete Projects with ACI-Certified Shotcreters Need ACI-Certified Shotcrete Inspectors

The Art of Coastal Resilience

SHOTCRETE RESTORATION AT THE GERALDINE R. DODGE ESTATE

By Dana Alan Lilly

OVERVIEW

This article details the technical restoration of a historic seawall in Rockport, Maine, designed to withstand intense Atlantic wave action. The project showcases how modern engineering can preserve coastal history while enhancing structural integrity.

The Geraldine R. Dodge Estate, situated on a prominent granite outcropping in Rockport, Maine, has long stood as a testament to coastal architecture. However, the relentless energy of the North Atlantic had, over decades, severely compromised its primary line of defense: A historic granite seawall. The restoration of the seawall required a delicate balance between modern high-performance materials and the preservation of the rugged Maine aesthetic.

The technical challenge was twofold: Managing the extreme kinetic energy of wave impacts and addressing the hydrostatic pressures behind the seawall that typically lead to structural failure in coastal barriers. Our solution used a specialized dry-mix shotcrete application. The dry-mix process was chosen for its high velocity and superior compaction, which results in a significantly less permeable and more durable finished product compared to traditional form-and-pour concrete.

PHASE I: SUBSTRATE PREPARATION AND MECHANICAL ANCHORING

Before any material was applied, the existing granite ledge had to be meticulously prepared. We utilized high-pressure water blasting to remove salt deposits and organic growth.

Fig. 1: Cleaning the bottom of the seawall at low tide by fresh water blasting and securing a new "through drains" and placement of new galvanized 2 x 2 WWF, tied to epoxy set 6 in. galvanized anchor bolts on a 2 ft x 2 ft pattern

Fig. 2: The final stages of completing the backside drain system up to the top of the seawall

Fig. 3: The same procedure as in #1 was all in preparation of the dry-mix shotcrete placement at various thickness to provide a reasonable looking non troweled finish

Fig. 4: While working with the 8 ft (2.4 m) tides at various levels the shotcrete placement begins from bottom to top and over the wall down the backside to the newly installed filter fabric and crushed stone backside drainage feature to capture and safely remove the overwash drainage from extreme tides

To ensure a strong bond between the geological substrate and the shotcreted concrete shell, we installed a comprehensive anchoring system. This involved drilling and epoxy-setting 3/8 in. (10 mm) stainless steel threaded rods 6 in. (150 mm) deep into the bedrock. These were placed on a 12 in. (300 mm) grid, creating a mechanical 'key' that prevents delamination under the immense 'pulling' force of retreating waves.

PHASE II: HYDROSTATIC PRESSURE MANAGEMENT

One of the leading causes of seawall failure is the buildup of water behind the wall. Without relief, this pressure eventually pushes the wall outward. We integrated a series of 2 in. (50 mm) PVC weep holes and a backing drainage composite mat. This allows groundwater and overwash to cycle back to the sea without compromising the structural integrity of the wall.

PHASE III: THE SHOTCRETE MIX DESIGN

The shotcrete materials were a critical component of the project's success. We utilized a pre-bagged dry-mix enriched with 8% silica fume. The addition of silica fume reduces the permeability of the concrete to near-zero levels, which is essential in significantly delaying chloride-ion penetration and the subsequent corrosion of internal steel reinforcement.

We also incorporated synthetic macro-fibers throughout the mixture. These fibers provide three-dimensional reinforcement, offering superior toughness and crack control compared to traditional wire mesh, which is prone to corrosion in saltwater environments.

Technical Highlights

SUBSTRATE ANCHORING
To ensure a permanent bond between the new shotcrete and the existing ledge, we utilized 3/8 in. (10 mm) stainless steel threaded rods set 6 in. (150 mm) deep on a precise 12 in. (300 mm) grid.

HYDROSTATIC RELIEF
A critical component of the design is an integrated drainage system. This allows water trapped behind the seawall to escape safely, preventing the pressure build-up that often leads to blowouts or collapses.

HIGH-PERFORMANCE SHOTCRETE MATERIALS
We employed a dry-mix shotcrete material specifically designed for harsh marine environments. The mixture is enhanced with silica fume for low permeability and synthetic macro-fibers for superior crack resistance and toughness.

ARTISTIC FINISHING
Beyond structural strength, the project required an aesthetic touch. Our finishers used hand-sculpting techniques to mirror the natural stone textures and contours of the Maine coastline, making the restoration virtually invisible.

PHASE IV: ARTISTIC SCULPTING AND FINISH
Because the Dodge Estate is a historic property, a standard concrete finish was unacceptable. Our team of expert finishers used hand-sculpting tools to replicate the natural fissures, textures, and color variations of the surrounding Maine granite. By varying the nozzle distance and employing specialized carving techniques during the initial concrete set, we created a facade virtually indistinguishable from the natural coastline.

CONCLUSION
The finished structure now provides a high-strength, low-maintenance shield for the estate. This project serves as a case study for 'Coastal Resilience', proving that we can harden our infrastructure against rising sea levels and increased storm intensity without sacrificing the natural beauty of our historic shorelines.

Dana Alan Lilly *is a Senior Projects and New Business Development Director with over 45 years of experience in strategic planning and global project management. He has directed multi-billion-dollar civil, marine, and oil/gas installations across the US, Middle East, Africa, and the Russian Federation. Dana is an expert in EVG 3D Panel systems and high-performance shotcrete technologies, focusing on sustainable and resilient infrastructure.*

Introducing the Construction Mental Health Alliance

PROTECTING THE PEOPLE WHO BUILD OUR WORLD

By Joseph Whiteman

In construction, some of the most effective solutions start outside of the boardroom. They take shape in the field, coming from the people closest to the work — our craft professionals, supervisors, safety professionals, and company leadership, working through real challenges and learning from experience.

When those ideas are shaped through collaboration across roles and organizations, they evolve into practical tools that can be applied across all types of work and company sizes. That's exactly how the Construction Mental Health Alliance (CMHA) came to be.

AN INDUSTRY NEED; NOT A SINGLE-COMPANY SOLUTION

Over the past several years, the American Society of Concrete Contractors (ASCC) Safety & Risk Management Council (SRMC), a group of safety and operations professionals from across the concrete construction industry, has spent significant time discussing the evolving challenges facing the workforce. While hazards like falls, struck-by incidents, and equipment risks remain critical, it has become increasingly clear that mental health, fatigue, substance misuse, and overall worker well-being are just as important to address.

These aren't separate issues; they are directly connected to safety, performance, and the long-term sustainability of our workforce. Through these discussions, one theme consistently emerged: The industry isn't short on information or strong efforts, it's challenged by how fragmented those resources can be, and the difficulty in bringing them together in a way that is accessible, credible, and practical for the construction environment.

BUILT BY THE INDUSTRY, FOR THE INDUSTRY

What started as an SRMC-driven conversation has grown into a broader industry initiative. The Construction Mental Health Alliance (CMHA) is a collaborative effort developed by industry professionals, associations, and aligned partners who recognized the need for a more coordinated and practical approach to mental health and worker well-being in construction.

This isn't a top-down program or a one-size-fits-all solution. It's a resource shaped by:

- Contractors and safety professionals working in the field
- Input from multiple organizations across the industry
- Real-world challenges faced on jobsites every day

The goal is simple: Provide practical resources that help companies take meaningful, actionable steps to support their workforce.

A SHARED VISION FOR THE INDUSTRY

At its foundation, CMHA is guided by a clear vision:

> A safer, stronger, and more supportive construction industry where mental health, emotional well-being, and psychological safety are valued as highly as physical safety and embedded into every jobsite and every role.

This vision reflects a broader shift already underway across the industry which recognizes mental health not as a separate initiative, but as a fundamental component of safety, performance, and workforce sustainability.

A CENTRAL RESOURCE FOR WORKER WELL-BEING

At its core, CMHA serves as a centralized clearinghouse of curated resources, available at: **www.constructionwellness.org**. The platform brings together practical tools, guidance, and information focused on key areas impacting today's construction workforce, including:

- Mental health awareness and support
- Suicide prevention
- Opioid and substance misuse awareness
- Fatigue and recovery
- Head injury awareness and overall worker well-being

Rather than requiring companies to search across multiple sources, CMHA provides a single, credible location where these resources are organized and accessible. Most importantly, the content is designed to be practical and usable, supporting application across the entire organization, from the jobsite to the C-suite.

CONSTRUCTION MENTAL HEALTH ALLIANCE

CUTTING THROUGH THE NOISE

The resources available at **constructionwellness.org** are not aggregated at random — they are thoughtfully curated and vetted by industry professionals and organizations actively engaged in this space. The focus is on providing content that is:

- Relevant to construction environments
- Practical and applicable across all levels, from the jobsite to executive leadership
- Grounded in real-world experience

This approach helps ensure that those seeking information and support can do so with confidence, knowing they are accessing resources that have been reviewed, aligned, and built with the industry in mind.

A MODEL FOR SHARING WHAT WORKS

This approach is not entirely new for ASCC or the Safety & Risk Management Council. Several years ago, what began as an internal effort to better understand and evaluate head protection evolved into what is now known as the Hardhats to Helmets (H2H) initiative (see page 52). As that group dug deeper into the research and available data, it became clear that the information being developed had value well beyond a single organization.

Rather than keeping it internal, the decision was made to make those resources available to the broader construction industry, creating a centralized, accessible platform that could help drive informed decisions and improve worker protection across all sectors.

A similar path led to the development of the Construction Mental Health Alliance. What initially began as an effort within the SRMC (to support Total Worker Health concepts for ASCC members) quickly revealed something important: There was already a wealth of strong resources available across the industry. The need wasn't to reinvent programs or create new materials — it was to organize, vet, and connect people to what already exists in a meaningful and practical way.

That realization shifted the focus. It quickly became clear that this effort was bigger than any one organization. The challenges it aimed to address, and the approaches being developed, were shared across the entire industry.

Recognizing its broader value, the decision was made not to keep it internal, but to develop it as an industry resource, one which could support companies of all sizes and help advance a more consistent, unified approach to worker well-being.

In many ways, it reflected a simple reality: The need was too widespread, and the opportunity too important, to limit its reach. Much like H2H, it was designed to serve anyone looking to better support their workforce. At its core, this reflects a shared belief: *There should be nothing proprietary about helping workers become safer, healthier versions of themselves.*

A SHARED EFFORT ACROSS THE INDUSTRY

The American Shotcrete Association (ASA), along with other industry organizations, plays an important role in advancing safety and supporting its members. By sharing resources like CMHA, the ASA strengthens alignment across the industry and ensures that companies, regardless of size or specialty, have access to tools that can make a real difference.

This is not an ASCC-only initiative. It is a shared industry resource, built to support the construction community as a whole.

MOVING FORWARD

The challenges facing our workforce are complex. Efforts like CMHA represent a continued evolution in how we think about safety, recognizing the full scope of what it means to protect our people. Because safety today isn't just about managing hazards; it's about protecting the person behind the hard hat. It's about protecting the people who build our world.

LEARN MORE

To explore available tools and resources, visit:
www.constructionwellness.org

Joseph Whiteman*, CSP, CHST, is the Director of Safety Services for the American Society of Concrete Contractors (ASCC), bringing more than 20 years of construction safety experience to the job. He's had leadership roles with Turner Construction and Morley Construction, both with a strong focus on structural concrete. Joseph has supported ASCC's mission since 2018, helping contractors build safer jobsites and stronger safety cultures while leading and contributing to several industry-wide initiatives to advance worker safety, health, and total well-being. A U.S. Marine Corps combat veteran and Purple Heart recipient, he is also an advocate for mental health and suicide prevention in the construction industry. Joseph maintains CSP and CHST certifications and holds a degree in occupational safety and health.*

From Hard Hats to Helmets

THE EVOLUTION OF HEAD PROTECTION IN THE WORKPLACE

By Scott Greenhaus

In the realm of occupational safety, head protection has come a long way from its beginnings as a simple hard hat. The transition from hard hats to helmets represents a remarkable evolution in the goal of keeping workers safe in a wide range of industries. This article explores the history and technological advancements that have reshaped head protection, emphasizing the importance of safeguarding workers in the construction industry.

BIRTH OF THE HARD HAT

Hard hats made from leather, canvas, or steel first made their appearance in the early 20th century. The first hard hat patented in 1919 was called the "Hard Boiled® Hat" (Fig. 1) because of the steam used in the manufacturing process. The first designated "Hard Hat Area" enforced with the threat of dismissal was set up at the San Francisco Golden Gate Bridge construction site[1]. Hard hats were primarily used in the construction industry to protect workers from falling debris and head injuries. Over time, hard hats became more standardized and began to include suspension systems for added comfort and impact absorption. The iconic design, with a protective brim and a solid crown, became a symbol of safety in construction sites worldwide.

Fig. 1: Hard Boiled® Hat (Photos courtesy of WaveCel)

TRANSITION TO HELMETS

The transition from hard hats to helmets is marked by significant advancements in technology and materials. The concept of a helmet, while similar to a hard hat in terms of providing protection, brought several key improvements to the table. The primary distinctions between hard hats and helmets include:

1. **Improved Impact Resistance:** Helmets are designed with advanced impact-absorbing materials like high-density foam and polycarbonate shells, which provide enhanced protection against head injuries. This advancement is particularly crucial in industries where workers face high-impact risks, such as professional athletes, military personnel, and now construction crews (Fig. 2).

Fig. 2: Construction helmet (Photo Courtesy of Milwaukee)

2. **Customized Fit:** Modern helmets are adjustable and come in various sizes to ensure a snug and comfortable fit for each user. This customization minimizes the risk of a helmet falling off during an accident or interfering with the wearer's field of vision.
3. **Versatility:** Helmets are used in a wide range of activities, including sports, motorcycling, mountaineering, and firefighting. Each field has specific helmet designs tailored to the unique demands of the job. The best attributes of these helmets have been incorporated into the construction helmet.
4. **Enhanced Safety Features:** Helmets often incorporate additional safety features such as engineered chin straps, impact sensors, and ventilation systems to provide users with a more comfortable and secure experience. These features help users stay safe while maintaining comfort during extended periods of use.

Fig. 3: Traumatic brain injury (Microsoft Copilot 2024)

TRAUMATIC BRAIN INJURY (TBI) AND ROTATIONAL IMPACT

Traumatic brain injury (Fig. 3) remains a significant concern in various industries, especially those where high-impact accidents are more likely, such as construction. The transition to helmets has brought significant improvements in TBI protection through:

1. **Impact-Absorbing Materials:** Helmets use advanced impact-absorbing materials, such as high-density foam and honeycomb, cellular materials, and liner systems that reduce rotational impact forces, each design incorporating elements that reduce the risk of TBI.
2. **Customization:** A well-fitted helmet minimizes the potential for brain injury by effectively absorbing and dispersing impact forces. The adjustability of helmets ensures a snug and secure fit for each user, optimizing protection.

Rotational impact, often overlooked, is also a critical factor in head injuries (Fig. 4). It occurs when the head is subjected to both linear and rotational forces during an impact, causing strain and damage to the brain. The traditional hard hat design was not effective in addressing these rotational forces, leading to concerns about brain injuries.

REGULATORY REQUIREMENTS

To address the limitations of hard hats and improve head protection, regulatory bodies like the Occupational Safety and Health Administration (OSHA) and the American National Standards Institute (ANSI) established comprehensive standards and regulations for head protection in the workplace.

1. **OSHA Standards:** OSHA, a federal agency in the United States, sets and enforces workplace safety standards. OSHA's standards for head protection are outlined in 29 CFR 1910.135[2]. These standards require employers to ensure that employees wear head protection when working in areas with potential head injuries from falling objects or electrical hazards. OSHA-approved helmets must meet specific design and performance requirements.
2. **ANSI Standards:** ANSI, a non-profit organization, develops consensus-based standards for various industries, including head protection. ANSI/ISEA Z89.1[3] outlines the performance requirements for protective helmets used in industrial and construction settings. This standard categorizes helmets into two classes — Type I and Type II — and specifies requirements for impact and electrical resistance.

Regulatory bodies are currently evaluating how requirements might be changed or augmented to recognize the benefits of a well-designed construction helmet. All helmets must meet the current requirements of ANSI Type I and Type II.

HELMET COMFORT AND FIT

While hard hats were a significant step forward in occupational safety, they often lacked the comfort and adjustability required for extended use. Workers frequently complained of discomfort due to rigid materials and insufficient padding. The transition to helmets has brought a substantial improvement in this aspect. Modern helmets are designed with user comfort in mind, featuring:

1. **Customized Fit:** Helmets come in various sizes and are often equipped with adjustable components such as straps and interior padding. This customization

Fig. 4: Rotational Impact (Microsoft Copilot 2024)

Fig. 5: Thermal gradients of hardhats compared to helmets (Image courtesy of Koroyd)

ensures a secure and comfortable fit for each user, reducing the likelihood of discomfort and fatigue.

2. **Ventilation Systems:** Helmets often incorporate ventilation systems that allow air circulation, preventing heat buildup and discomfort. These systems are especially vital for workers in hot and humid conditions.
3. **Accessories:** Helmets are designed for easy and secure attachment of accessories such as head lamps, earmuffs, and face shields.

ARE HELMETS HOTTER THAN HARD HATS?

The perception that helmets are hotter than hard hats is a common concern among workers. However, the truth depends on several factors:

1. **Ventilation:** As mentioned earlier, many modern helmets feature ventilation systems that help dissipate heat (Fig. 5). While hard hats have solid crowns that can trap heat, helmets are designed to counteract this issue, utilizing vents as well as channels in the foam protection layer, and suspension systems that allow for air flow within the helmet, making them more comfortable in warm environments.
2. **Material:** The type of material used in helmets also plays a role in heat retention. Lightweight materials, helmet color, and advanced design features help reduce heat buildup in helmets.

Manufacturers and testing labs are currently evaluating heat effects with an eye toward better understanding of actual vs. perceived heat retention differences between hard hats and helmets. This information will help dispel myths and misunderstandings and, in some cases, may lead to modifications to the helmet designs, such as a built-in cooling fan as shown in Fig. 6.

Fig. 6: Helmet with a built-in cooling fan. (Photo courtesy: Milwaukee Tool)

NEW TECHNOLOGIES FOR HEAD AND BRAIN PROTECTION

The transition from hard hats to helmets has led to the development of innovative technologies that address rotational impact and offer improved head and brain protection:

1. **Multi-directional Impact Protection System (MIPS):** MIPS is a rotational protection technology incorporated into many modern helmets (Fig. 7). It

Virginia Tech Construction Helmet Ratings

Photo courtesy of Virginia Tech University

Research conducted by the Virginia Tech Helmet Lab is advancing how construction helmets are evaluated for real-world performance. Using its STAR (Summation of Tests for the Analysis of Risk) system, the lab rates helmets based on their ability to reduce concussion risk under multiple impact conditions. (Virginia Tech Helmet Ratings: https://www.helmet.beam.vt.edu)

Unlike traditional standards such as ANSI Z89.1, which rely on pass/fail criteria and primarily address vertical impacts, Virginia Tech testing emphasizes rotational acceleration — a key contributor to traumatic brain injury (TBI).

Helmets are subjected to realistic jobsite scenarios, including slips, trips, and falls, and assigned a 1- to 5-star rating based on measured performance.

WHY IT MATTERS:

- Highlights differences in helmet performance
- Addresses both linear and rotational impacts
- Supports data-driven selection of head protection

As the industry shifts toward preventing serious injuries and fatalities, independent rating systems like this provide a practical framework for selecting higher-performing helmets and advancing worker protection.

consists of a low-friction layer between the outer shell and the inner liner, allowing the helmet to move slightly upon impact. This movement helps reduce rotational forces and the risk of traumatic brain injury.

2. **Improved Materials:** Advanced materials like Koroyd (Fig. 8) and WaveCel (Fig. 9) have been integrated into helmet designs to enhance impact absorption and reduce rotational forces during accidents.

Conclusion

The transition from hard hats to helmets marks a remarkable evolution in head protection. From their origins in the sporting and adventure industries to their growing use in construction, helmets are becoming a symbol of safety, innovation and caring for the health of the workforce. The integration of advanced materials, improved design, and custom-fit options has significantly enhanced the protection offered to workers. As technology continues to advance, we can expect even more innovative solutions to further improve head protection and safety in the workplace and beyond.

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2. OSHA 29 CFR 1910.135, "Head Protection", Occupational Safety and Health Standards, Washington, D.C.
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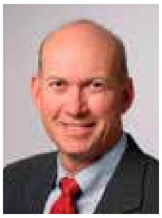

Scott Greenhaus *is a Sr. Advisor with Structural Group and the Principal of SMG Solutions LLC. He graduated with degrees in Civil Engineering and an MBA from the University of Maryland and served as the Executive Vice President and Chief Risk Officer of Structural Group headquartered in Columbia MD. Scott is Chairman of the University of Maryland Engineering School Board of Visitors and is also a member of the CEE Department BOV. He has been on the Board of Directors of the Post-tensioning Institute (PTI), International Concrete repair Institute (ICRI), and American Society of Concrete Contractors (ASCC), and served as the Chairman of the ASCC Safety and Risk Management Council. He is also a member of ASCE, ACI, ANS, and ASSE. Scott served as a past president of PTI, served on the Executive Committee of ICRI, and has chaired many other committees in these trade and technical associations. He has authored and presented publications focusing on concrete repair and preservation technology, post-tensioning system repair and strengthening, safety culture development, and the prevention of head injuries and improvement of mental health challenges in the construction industry.*

Fig. 7 - MIPS

Fig. 8 - Koroyd

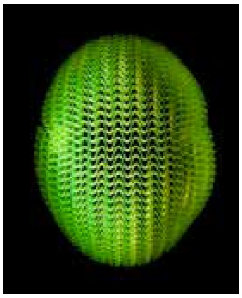

Fig. 9 - WaveCel

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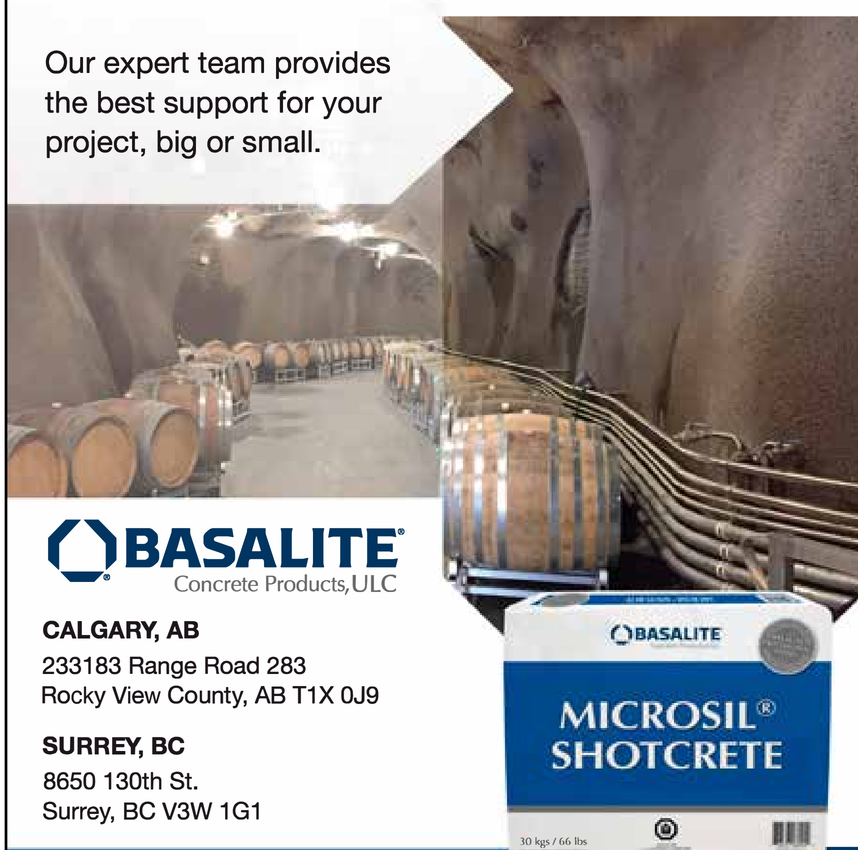

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RAM Construction Services is a nationally recognized specialty contractor delivering comprehensive building envelope, structural rehabilitation, and parking structure solutions for complex and demanding environments. With more than a century of combined industry experience, RAM has built a reputation for technical excellence, innovation, and craftsmanship, earning the trust of owners, engineers, and construction managers across public and private sectors.

OUR MISSION

Our mission is to restore, protect, and extend the life of structures through unmatched expertise in concrete repair, masonry restoration, façade systems, waterproofing, and structural strengthening. We approach every project, large or small, as an opportunity to perform at the highest level and deliver long-term value.

OUR SERVICES

RAM's services are rooted in deep technical knowledge and hands-on execution. Our team specializes in shotcrete applications, conventional and structural concrete repair, and advanced repair techniques that address deterioration caused by age, exposure, and service conditions. These capabilities are critical to our work in parking structures, stadiums, industrial facilities, healthcare campuses, educational buildings, and historic structures. By integrating engineered repair solutions with skilled field installation, we help owners mitigate risk while preserving both function and aesthetics.

OUR PEOPLE

A defining strength of RAM Construction Services is our people. Our workforce includes highly trained tradespeople, experienced project managers, and safety professionals who understand the nuances of restoration and repair work. This expertise allows us to collaborate effectively with engineers and owners during preconstruction and construction, identifying solutions that improve constructability, durability, and cost efficiency. Our teams are well-versed in executing work in occupied and operational facilities, where coordination, safety, and quality control are paramount.

SAFETY, QUALITY, AND INNOVATION

Safety and quality are foundational to our culture. RAM maintains rigorous safety standards and industry certifications, supported by ongoing training and proactive planning. Our commitment to quality extends beyond installation; we focus on proper surface preparation, material selection, and placement techniques that ensure the success of shotcrete and concrete repair systems. Quality assurance procedures are embedded throughout each phase of the project, from initial evaluation through project closeout.

Innovation is another cornerstone of our approach. We continually evaluate new materials, equipment, and application techniques to enhance performance and durability. Membership and participation in industry organizations such as the American Shotcrete Association (ASA) reflect our dedication to staying at the forefront of best practices and advancing the industry as a whole.

VALUES

At RAM Construction Services, we measure success not only by completed projects, but by the lasting relationships we build and the positive impact we leave behind. Our goal is to exceed expectations, deliver resilient repair solutions, and create a legacy of excellence — one structure at a time.

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CONSTANTLY EVOLVING

In 1983, when Robert T. Mazur was named president, the company had 17 employees. Under his leadership, RAM has grown to employ upward of 190 salaried employees and over 600 field personnel, making us the largest Midwestern contractor specializing in the restoration of aging structures and skilled waterproofing.

As we grow, we are guided by our core value "Relationships Are Our Business" to continually forge strong bonds based on trust and mutual respect.

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THE PREMIER TURNKEY SOLUTION FOR CONCRETE WASHOUT, REBOUND MATERIAL, AND ENVIRONMENTAL COMPLIANCE

Eco-Pan stands as a nationwide leader in providing comprehensive, environmentally responsible solutions for concrete washout containment, disposal, and recycling. Established in Seattle (Kent), Washington, in 2000, the company grew from a single-truck operation to a coast-to-coast service provider, specializing in reusable, watertight steel pans and roll-off containers. Our innovative approach helps contractors of all sizes — from residential to industrial — streamline job-site cleanup and maintain strict compliance with federal and municipal environmental regulations like the EPA, NPDES, BMPs, and SWPPP requirements.

ECO-PAN'S CORE VALUES

Eco-Pan's operational success is deeply rooted in its unwavering commitment to three core values: Safety, people, and reliability. Safety is paramount, ensuring that every piece of equipment, from the reusable pans to the service trucks, is operated and maintained to the highest standards, protecting both their employees and the job sites they serve while helping contractors avoid highly alkaline concrete waste spills. This commitment extends to their people, fostering a culture where trained, professional staff provide turnkey, expert service, ensuring the correct washout solution is deployed and managed with professionalism. Finally, the value of reliability guarantees customers receive dependable, cost-effective, on-time delivery and prompt removal of the watertight pans, ensuring job sites remain compliant, clean, and efficient, thus making Eco-Pan the trusted partner for environmentally sound concrete washout solutions.

NATIONWIDE SERVICE AND STRATEGIC LOCATIONS

Eco-Pan's expansive network is a cornerstone of its service model, ensuring fast, reliable delivery and removal across a significant portion of the United States. While the corporate headquarters is in Colorado, their strategic branch placement allows them to efficiently service numerous major metropolitan and surrounding areas. Eco-Pan operates in a wide array of states, demonstrating their national reach.

States where Eco-Pan is available for concrete washout services include, but are not limited to: Arizona, Arkansas, California, Colorado, Delaware, Florida, Georgia, Idaho, Maryland, Nevada, North Carolina, Ohio, Oklahoma, Oregon, South Carolina, Tennessee, Texas, Utah, Virginia, Washington, and Washington D.C. This broad footprint is a testament to the high demand for their compliant and convenient washout services.

ECO-PAN crane truck unloading pump pans at a residential site

10 yd³ (7.6 m³) roll off at Nissan Stadium project in TN

CONCRETE WASHOUT PAN AND ROLL-OFF OFFERINGS

Eco-Pan's core product line consists of reusable steel containers specifically engineered for containing cementitious materials — which can be harmful to the environment if allowed to enter storm drains or soil. The primary offerings are:

1. **Concrete Washout Pans:** Both pans are constructed with integrated fork channels and eye hooks for easy on-site portability via forklift or crane.
   a. **Large Pan:** Measuring approximately 7 ft x 7 ft x 28 in. (2.1 m x 2.1 m x 700 mm) and capable of holding about 475 gal (1800 l) or 5 tons (4.5 tonnes). These pans are versatile, suitable for above or below-grade washouts, and excellent for use with ready-mix trucks and ideal for waste shotcrete rebound.
   b. **Small Pump Pan:** Sized at roughly 7 ft x 7 ft x 12 in. (2.1 m x 2.1 m x 300 mm) with a capacity of about 250 gal (950 l) or 3 tons (2.7 tonnes). Small pans are designed to fit directly underneath the concrete pump truck hopper for easy outlet and transition washout, minimizing spillage.
2. **Roll-Off Washout Service:** For larger pours, extended projects, or sites generating substantial concrete debris, Eco-Pan offers large-capacity roll-off containers. These are typically Large Capacity Roll Off Washouts measuring 20 ft x 7 ft x 28 in. (6 m x 2.1 m x 700 mm), designed to hold concrete washout and rebound. They feature a built-in baffle to safely contain water during pickup and transport, ensuring a watertight solution that is leak-proof and ideal for complying with demanding SWPPP requirements on extensive job sites.

2.35 yd³ (1.8 m³) large ECO-PAN

By offering a full-service, one-call solution — from pan delivery and on-site relocation to haul-away and recycling — Eco-Pan enables construction teams to save time, reduce labor, and avoid costly environmental fines, solidifying its position as the preferred partner for concrete cleanup and disposal.

CONTACT INFORMATION:

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From Experience to Impact:

GET INVOLVED IN ASA COMMITTEES

By LaTosha Meadows

Behind every advancement in the shotcrete industry, a group of professionals volunteer their time and expertise to move the industry forward: Our active committee members. The American Shotcrete Association's (ASA) committee work is the driving factor in shaping standards, influencing best practices, and strengthening the future of shotcrete — and you can be part of that.

The ASA has five active committees representing the diverse needs of our industry, from workforce development and contractor qualifications to specialized markets like pools, skateparks, and underground construction. Each committee tackles meaningful initiatives that benefit contractors, engineers, designers, owners, and the next generation of professionals.

Getting involved is more than volunteering: It's an opportunity to expand your professional network and help define the direction of the shotcrete industry. Check out what each committee is working on — and how you can get involved!

EDUCATION & SAFETY COMMITTEE

Mission: To gather and communicate safe practices and quality placement standards in the shotcrete industry.

Safety and quality are foundational to everything we do in shotcrete placement. The Education & Safety Committee plays a vital role in developing resources that help contractors and crews operate safely, consistently, and confidently in the field.

Current Focus Areas:

- Development and maintenance of shotcrete-specific safety resources, including *ASA's Safety Guidelines for Shotcrete*
- Creation of safety presentations and safety oriented articles published in *Shotcrete* magazine
- New tools in development, including toolbox talks, safety videos, student outreach and an ASA Safety Awards programs

How You Can Get Involved: Members contribute expertise and experience to support the development of resources. Volunteers assist with creating or reviewing materials; participate in presentations, webinars, or conference education efforts; and share data, lessons learned, requested images, video content, or case studies from projects. Education & Safety Committee members also submit articles for *Shotcrete* magazine throughout the year on safety for shotcreters and shotcrete contractors.

MEMBERSHIP & MARKETING COMMITTEE

Mission: To broaden and engage the ASA membership base while supporting ASA committees in their marketing efforts.

The strength of ASA lies in its members. The Membership & Marketing Committee focuses on creating connections and engagement across all career stages. The Committee conducted a member survey last fall and will use the results to refine the Committee's focus.

Current Focus Areas:

- Conducting a membership journey exercise to personalize the ASA member experience and increase retention
- Enhancing the onboarding experience for new members
- Formalizing a structured member recruitment plan
- Developing and launching a mentorship program
- Increasing engagement among young professionals

How You Can Get Involved: This committee ensures that members see real value in their involvement and feel connected to the broader shotcrete community. You can directly impact the efforts of this committee by: Serving on task groups that are working toward the development of the member onboarding and engagement experience, welcoming and engaging with newer members at our conventions or virtual events, and providing suggestions on how ASA should target and attract young shotcrete professionals.

CONTRACTOR QUALIFICATIONS COMMITTEE

Mission: To develop and maintain ASA's Contractor Qualification (CQ) Program.

The Contractor Qualification Committee is responsible for maintaining the integrity and credibility of the ASA Contractor Qualification Program. Their work in the CQ program recognizes shotcrete contractors who have consistently demonstrated high-quality shotcrete placement in the marketplace. This, in turn, helps build trust in shotcrete with project owners and specifiers.

Current Focus Areas:

- Continual refinement of the CQ program and review of applications

- Development of a guide for contractors to use ACI and ASTM standards
- Creating a contractor-focused marketing package to better communicate program value
- Updating FAQs to specifically support ASA Qualified Shotcrete Contractors

How You Can Get Involved: Assist with the development of QC-focused FAQs and documents by sharing your experience in content and attending meetings, in person or online, to provide guidance to help support quality shotcrete placement.

POOL & SKATEPARK COMMITTEE

Mission: To educate and promote the proper use and application of shotcrete in the swimming pool and skatepark markets.

The Pool & Skatepark Committee (previously the Pool & Recreational Shotcrete Committee) addresses the unique technical and quality needs of this specialized market. Their work supports consistency, education, and professionalism across residential and commercial pool construction as well as the under-standardized skatepark industry.

Current Focus Areas:

- Development of future pool and skatepark position statements
- Promotion and awareness of the *ASA Qualified Shotcrete Contractor – Pool* qualification program to the pool industry and self-performing shotcrete pool contractors

How You Can Get Involved: Help build awareness of the new *ASA Qualified Shotcrete Contractor - Pool* program. You could also assist ASA in expanding our network of pool-industry leaders through trade shows, association chapter meetings, and other events. Submit projects to ASA's **Outstanding Shotcrete Projects Awards program** to be recognized and highlight shotcrete's benefits and creativity! Submit articles to *Shotcrete* magazine throughout the year to provide technical guidance or highlight unique projects in the pool and skatepark shotcrete markets. Consider presenting at **ASA's Shotcrete Convention and Technology Conference** to showcase best practices, demonstrate your expertise, and inspire others.

UNDERGROUND COMMITTEE

Mission: To educate and promote the use and proper application of shotcrete in underground construction and mining industries.

Underground applications demand specialized expertise, safety awareness, and evolving technology. The Underground Committee focuses on advancing education, certification, and collaboration within this highly technical sector.

Current Focus Areas:

- Support the development of a mechanized shotcrete certification plan with ACI C660 – Shotcreter Certification Committee
- Presenting underground best practices through seminars, webinars, conferences, and client presentations
- Documenting experience with Type IL (PLC) cement
- Developing underground-specific safety considerations as an Appendix for ASA's *Safety Guidelines for Shotcrete*
- Collaborating with related industry groups

How You Can Get Involved: Assist in developing the *Safety Guidelines for Shotcrete: Underground Appendix*. Submit articles to *Shotcrete* magazine throughout the year on technical issues and case studies for the underground shotcrete industry. Submit projects for **ASA's Outstanding Shotcrete Project Awards program** to show how your work is advancing the industry.

GET INVOLVED

ASA committees are always looking for engaged members who want to make a difference. Participation can be as simple as attending meetings, contributing ideas, helping with projects, or leading initiatives. If you're passionate about advancing safety, education, quality, and growth in shotcrete placement, there's a seat at the table for you.

Take the next step to get involved by joining one of our upcoming online Teams committee meetings this summer. Meeting dates and times will be posted on ASA's online calendar at **www.shotcrete.org/calendar**.

COMMITTEE IMPACT

ASA committees convened March 1-2 during ASA's annual conference to collaborate on key initiatives and establish priorities for the year ahead. Their work continues to advance industry standards, expand member value, and strengthen shotcrete's impact across markets.

EDUCATION & SAFETY COMMITTEE

The committee is advancing two key initiatives: Safety video content development and a student paper competition program.

- Safety Videos: A series of short, practical videos is in development to deliver quick safety tips via social media and for use in toolbox talks. Planned topics include scaffolding, washout, pump safety, hose and pipe safety, line failures, hose inspection, plugs, manlifts/baskets, and concrete burns.
- Student Paper Competition: This new program is being designed to increase student engagement and industry awareness, with a targeted launch in 2027.

MEMBERSHIP & MARKETING COMMITTEE

Under the leadership of its new Chairman, Juanjose Armenta-Aguirre, the committee is developing a comprehensive membership journey. Several task groups are focused on:

- Mentorship programs to strengthen engagement and retention
- Outreach to engineers and State and Province Departments of Transportation (DOTs)
- A targeted outreach strategy for ASA members in the pool industry

american shotcrete association | asa

CONTRACTOR QUALIFICATIONS COMMITTEE

This committee continues to enhance the Contractor Qualifications (CQ) program through several initiatives, including:

- Develop a guide on shotcrete and concrete testing standards
- Developing awareness messaging to support the CQ program
- Creating a mentorship framework for contractors
- Producing FAQs for Qualified Contractors

POOL & SKATEPARK COMMITTEE

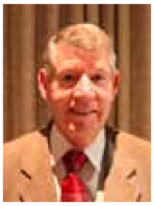
Formerly the Pool & Recreational Shotcrete Committee, this group has been renamed to better reflect these key shotcrete markets. Current efforts include developing a position statement and expanding outreach for the Pool Contractor Certification program.

UNDERGROUND COMMITTEE

The committee is working on an underground-specific appendix to supplement ASA's Safety Guidelines. Additional efforts include developing technical articles and collaborating with industry partners to increase awareness and adoption of shotcrete in underground applications.

JOIN THE CONVERSATION

Each committee hosts online Microsoft Teams meetings that are open to all. Sustaining, Corporate, and Individual members may log in to the American Shotcrete Association **MyASA** to view upcoming meetings and add them to your schedule. Not a member? You are still invited to attend and learn more about ASA's efforts to advance and expand the use of quality shotcrete in concrete construction. We have a great group of members who are passionate about shotcrete, and may just inspire you to join in on these efforts!



LARS BALCK ASA'S NEWEST HONORARY MEMBER

Lars Balck was recognized at our 2026 ASA Convention as an honorary member. He was instrumental in the creation of ASA, serving as our first president in 1998 and again in 2021-2022. Through his individual commitment, Lars has exemplified our Association's common goal of members working together to advance the quality and breadth of shotcrete applications.

He has a long history of giving back to our industry, not only through ASA but also through the American Concrete Institute (ACI). In ACI, he has provided leadership to the ACI 506 Shotcrete Technical Committee (serving as chair of both the main committee and its subcommittees), and has been an active voting member for decades. In his roles with ACI, he has demonstrated a proven ability to get volunteer members to work together and reach consensus as new shotcrete-related technical documents are created or revised.

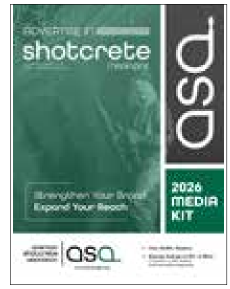
Lars joins the select roster of ASA honorary members, including Merlyn Isaak, Rusty Morgan, and Larry Totten. We are privileged to have had them give so much to ASA and the shotcrete industry for the last 28 years.

JOHN ZHANG NEW CHAIR OF ACI 506

Dr Lihe "John" Zhang has been appointed to his first 3-year term as Committee Chair for ACI 506 – Shotcreting, the main Shotcrete Committee within ACI's Technical subcommittee: Specialized Application & Repair. John replaces Simon Reny (Outgoing Chair) and is supported by James Ragland (Secretary). He also serves as Chair for ACI 506-F – Shotcreting Underground and Past President of ASA.

The mission of the committee is to "develop and report information on the use of shotcrete." ACI 506 is supported by these subcommittees:

506-0A Shotcreting-Evaluation
506-0B Shotcreting-Fiber-Reinforced
506-0C Shotcreting-Guide
506-0E Shotcreting-Specifications
506-0F Shotcreting-Underground
506-0G Shotcreting-Qualifications for Projects
506-0H Shotcreting-Pools



SHOTCRETE MAGAZINE **PREMIER ADVERTISER** PERK

Did you know? **Premier Advertisers** (those who commit to a full-page ad for all four issues of the calendar year by the signup deadline) will now now receive extra recognition in our Q1 Awards issue of *Shotcrete* magazine!

Premier Advertisers also enjoy:

- Quarterly call outs in the Shotcrete eMagazine email announcements
- Individual Social Media posts each quarter
- Inclusion in Premier Advertiser signage in ASA's booth at World of Concrete and ASA's annual convention
- Invitation to post product or service highlights in a special Premier Advertiser section in each Q1 (Awards) issue, our most widely circulated issue each year

Don't miss your chance to strengthen your brand and expand your reach in the shotcrete industry. Keep an eye out for our 2027 Media Kit: Coming soon!

2027 ASA SHOTCRETE CONVENTION & TECHNOLOGY CONFERENCE

Have You Shotcreted Something Worth Celebrating?

We are now accepting submissions for the **2026 Outstanding Shotcrete Project Awards**! Think about the projects your team has completed over the past couple of years. Did shotcrete help you overcome difficult access conditions, reduce construction time, or bring a complex design to life? Did your project demonstrate sustainability, technical advancement, or a unique application of the shotcrete process? These are exactly the kinds of qualities the awards program was designed to highlight. We want to showcase projects that not only succeed, but also elevate what's possible in shotcrete placement.

Submissions are now open, and we encourage you to submit before the deadline, October 1, 2026. Winning projects receive industry-wide recognition through publication in *Shotcrete* magazine's annual Awards Issue, promotion across ASA platforms, and recognition at the 2027 ASA Shotcrete Convention & Technology Conference in Nashville, TN. Don't miss the opportunity to showcase your team's excellence and contributions to advancing the shotcrete industry. Visit **www.shotcrete.org/awards**.

EARLY BIRD INCENTIVE: Submissions received on or before September 22, 2026 will receive preliminary feedback, which may be used to revise your submission by the final deadline for a more favorable review.

SHOTCRETE CONVENTION & TECHNOLOGY CONFERENCE
Hilton Nashville Downtown
Nashville, TN | March 7-9, 2027

TAKE THE STAGE AT THE 2027 ASA CONVENTION IN NASHVILLE

Get ready to bring your expertise to center stage at the ASA Convention's Technical Sessions, taking place March 7–9, 2027, in Nashville, TN. This is your opportunity to spotlight industry topics, share project lessons, and connect with leaders from across the shotcrete community.

Just like Nashville is known for great storytelling, we're looking for presentations that share real-world experiences, innovative solutions, and forward-thinking ideas. We're seeking a broad mix of content covering equipment, materials, case studies, and emerging technologies across key sectors such as pools, skateparks, underground construction, repair and rehabilitation, architecture, and new construction.

Share your knowledge with peers who are ready to learn, collaborate, and grow. **Submit your topic** by August 31, 2026, and join us in Nashville to help drive the next chapter of shotcrete innovation.

JOIN THE ASA HUDDLE: WHERE MEMBERS GET IN THE GAME

The American Shotcrete Association is excited to launch a new quarterly virtual gathering designed specifically for our newest members. The ASA Huddle will be held on the third Wednesday of the second month of each quarter (February, May, August, and November), this interactive Microsoft Teams session is your opportunity to get connected, informed, and engaged with all that ASA has to offer.

Each Huddle will walk through programs and opportunities available through ASA. Topics will include navigating MyASA, leveraging the Buyers Guide, contributing industry knowledge through published articles, and participating in our Outstanding Shotcrete Project Awards Program. We'll also highlight ways to get involved in annual events like the ASA Annual Convention, as well as opportunities to serve as a convention presenter and committee member.

Whether you're new to ASA or simply looking to increase your engagement, the ASA Huddle is your go-to space to learn, ask questions, and build connections within the shotcrete community. If you have recently joined ASA check your inbox for an invite to the next Huddle.We look forward to seeing you there!

ACPA ANNOUNCES 2026 BOARD MEMBERS

LEWIS CENTER, OHIO – (February 13, 2026) The American Concrete Pumping Association (ACPA) is proud to announce the election of its new executive board. The election took place Jan. 21 during the ACPA Annual Meeting and Awards Presentation at World of Concrete 2026 in Las Vegas, Nevada.

Elected to serve a one-year term, the newly elected Executive Board includes:

- President: Nathan Germany—Tri-Way Concrete Pumping, Inc., Flower Mound, Texas
- Vice President: Chris Pernicano—San Diego Concrete Pumping, Inc., Santee, California
- Secretary: Jennifer Lockhart—Florida Concrete Unlimited, Inc., Miami, Florida
- Treasurer: Tyler Wood—McClure Concrete, Inc., Aurora, Colorado
- Past President: Gary Brown—R. L. McCoy, Inc., Indianapolis, Indiana

AMERICAN CONCRETE INSTITUTE

The American Concrete Institute (ACI) announced its 2026-2027 president, vice president, and four board members. As elected by the ACI membership, Scott M. Anderson (General Manager of Keystone Structural Concrete | Houston, TX) will serve as ACI president in 2026-2027, and Anton K. Schindler (Mountain Spirit Professor and Director of the Highway Research Center at Auburn University (AU) | Auburn, AL)has been elected as ACI vice president for a two-year term. Additionally, four members have been elected to serve on the ACI Board of Direction, each for a three-year term: Matthew P. Adams, Tara Cavalline, John J. Myers, and Fouad H. Yazbeck.

INTERNATIONAL CONCRETE REPAIR INSTITUTE

The International Concrete Repair Institute (ICRI) announced its 2026-2027 elected officers and five board members. As elected by the ICRI membership, Dan Wald (National Account Manager, Restoration QXO) will serve as ICRI president, Aamer Syed (Sika Corporation) as Vice-President, Kenny Hopfensperger (Sales Representative, Euclid Chemical) as Secretary, and Sarah H Thaxton (Vice President of Operations, Southern Paint & Waterproofing Company Inc) as Treasurer on the ICRI 2026 Executive Committee . Additionally, five members have been elected to serve on the ICRI Board of Directors, each for a three-year term: Julie Bolding (Salas O'Brien), Joni Jones (Braun Intertec), Joshua Lloyd (J. Lloyd Engineering LLC), Nichole Soto (New Jersey Institute of Technology), and Audrey Wykes (Buildign Forensic Specialist).

KORDSA NAME CHANGED TO ÇIMSA

With Kordsa's strategic decision to focus on its core business areas—tire reinforcement and composite technologies—Kratos Construction Solutions, which we have developed and grown under Kordsa since 2014, will now continue its journey under Çimsa, another strong company within the Sabancı Holding Materials Technologies Group. This step will enrich Çimsa's existing portfolio in construction materials while contributing to Türkiye's value-added export initiative.

We wholeheartedly believe that this new structure, bringing together the innovation-driven strength of Kratos—preferred in next-generation synthetic fiber solutions across 25 countries, with Çimsa's position as Sabancı Holding's global building materials brand will pave the way for a stronger future for both our current business partners and new customers discovering Kratos products.

As a global building materials company with manufacturing operations across three continents, and a strong footprint in key international markets, including the United States where it operates as a local producer of both white and grey cement, Çimsa brings extensive industry expertise and a well-established global sales network. With its international production capabilities and longstanding presence in advanced construction materials, Çimsa is uniquely positioned to further scale Kratos' innovative solutions and integrate them as a strategic component of its broader construction materials portfolio.

The synergy between Kratos' innovative solutions and Çimsa's cement and concrete product groups will allow us to offer a broader and more integrated product range. Through this integration, we will enhance our ability to develop comprehensive and sustainable solutions that meet not only today's needs but also those of the future.

SKATE4CONCRETE CONSTRUCTION SUMMER CAMP

Skate4Concrete, launched in 2023, focuses on education and workforce development in the concrete and construction materials industry. This group seeks to help students find jobs and created Concrete Certification for High School students specifically in the Skatepark industry. Registration for their annual Construction Summer Camp (July 13 – 16, 2026) is now open.

INTEGRATED WATER SERVICES PARTNERS WITH CROM TO LAUNCH NXT|MBR™: THE INDUSTRY'S FIRST "PERMANENT CONCRETE MODULAR" WASTEWATER SYSTEM

AUSTIN, Texas, April 23, 2026 /PRNewswire/ -- Integrated Water Services, Inc. (IWS), a pioneer in modular wastewater treatment and reuse systems, has announced a strategic partnership with CROM, the industry authority in post-tensioned concrete structures, to launch NXT|MBR™. This high-performance water reclamation system introduces a new category of wastewater infrastructure: the Permanent Concrete Modular system.

The structural foundation of NXT|MBR is a post-tensioned structure engineered by CROM utilizing a shotcrete wall with an embedded steel diaphragm and designed specifically for corrosive environments. While traditional modular systems provide unmatched rapid-deployment flexibility for evolving site needs, NXT|MBR's concrete framework offers a fixed, century-class foundation for projects requiring maximum structural permanence.

"By integrating CROM's ACI-350 compliant watertight tensioned shotcrete containment structures directly with IWS's MBR system through design/build delivery, we are able to reduce traditional design and construction durations while delivering a long-lasting treatment solution," said Bobby Oyenarte, PE, CEO of CROM. "NXT|MBR represents the future of resilient wastewater infrastructure—providing developers and municipalities a permanent site-built treatment system customized to meet footprint and process needs." See the full story here: **https://tinyurl.com/3pa6f282**

DOUG ACKER OF EUCLID CHEMICAL RECEIVES PRESTIGIOUS NRMCA SHYDLOWSKI–TURNER MATERIALS LEADERSHIP AWARD

CLEVELAND, Ohio (March 23, 2026) – Euclid Chemical, a leading manufacturer of specialty chemical products for the concrete and masonry construction industry, is proud to recognize its Great Lakes Region Manager Doug Acker for receiving the prestigious Shydlowski–Turner Materials Leadership Award from the National Ready Mixed Concrete Association (NRMCA). The award honors individuals from materials supplier companies who demonstrate exceptional leadership, commitment and support for the ready mixed concrete industry.

WORLD OF CONCRETE 2026 INNOVATIVE PRODUCT AWARDS

Many amazing companies were recognized with World of Concrete 2026 Innovative Product Awards, and we wanted to give a shoutout to ASA member Bekaert Corporation on earning an Industry Choice Award under Concrete Slab Materials for their Dramix® Loop!

Dramix® Loop is the first certified production of second-life steel fibers for concrete reinforcement. It is made from end-of-life tires, combining circularity with near zero carbon emission, reliable mechanical performance, and exceptional environmental value, addressing one of the construction industry's greatest challenges: Drastically reducing CO_2 emissions without compromising performance. Learn more at **https://tinyurl.com/3wneykvs**.

SHOTCRETE CALENDAR

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

JUNE 15-18, 2026	**UCA North American Tunneling Conference** Anaheim, CA
SEPTEMBER 16, 2026	**ACI Shotcrete Inspector Certification: Quality Shotcrete, Know It When You See It** | ACI Mid-Atlantic Resource Center | Columbia, MD
OCTOBER 7-9, 2026	**ACI Shotcreter Certification (Wet- & Dry-Mix)** Minova | Millstadt, IL
OCTOBER 11-14, 2026	**ACI Concrete Convention - Fall** Hilton Atlanta Hotel | Atlanta, GA
OCTOBER 18-21, 2026	**ICRI 2026 Fall Convention** Gila River Resort & Casino Wild Horse Pass | Chandler, AZ
OCTOBER 22, 2026	**ACI Shotcrete Inspector Certification: Quality Shotcrete, Know It When You See It** | Applied Shotcrete | Sebastopol, CA
OCTOBER 23-25, 2026	**ACI Shotcreter Certification (Wet- & Dry-Mix)** Applied Shotcrete | Sebastopol, CA
NOVEMBER 16, 2026	**PSP Pre-Con: Quality Shotcrete - Know It, Demand It** Ernest N. Morial Convention Center | New Orleans, LA
NOVEMBER 17-19, 2026	**International Pool | Spa | Patio Expo 2026** Ernest N. Morial Convention Center | New Orleans, LA
DECEMBER 6-9, 2026	**ASTM Committee Meetings — C09 Concrete & Concrete Aggregates** Hyatt Regency Jacksonville Riverfront | 225 East Coastline Drive | Jacksonville, FL
DECEMBER 18-20, 2026	**ACI Shotcreter Certification (Wet- & Dry-Mix)** Texan Gunite | Cedar Park, TX | *Primarily Spanish Session
JANUARY 18-21, 2027	**2027 World of Concrete** Las Vegas Convention Center | Las Vegas, NV
MARCH 7-9, 2027	**2027 ASA Shotcrete Convention & Technology Conference** Hilton Nashville Downtown | Nashville, TN
MORE INFORMATION	To see a full list, current updates, and active links to each event, visit www.shotcrete.org/calendar.

2026 Open Shotcreter Certification Sessions

October 7-9, 2026 | ACI Shotcreter Certification (Wet- & Dry-Mix) | Minova | Millstadt, IL

October 23-25, 2026 | ACI Shotcreter Certification (Wet- & Dry-Mix) | Applied Shotcrete | Sebastopol, CA

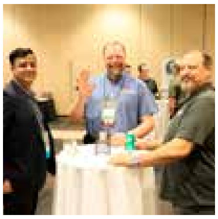
December 18-20, 2026 | ACI Shotcreter Certification (Wet- & Dry-Mix) | Texan Gunite | Cedar Park, TX

For details, visit shotcrete.org/calendar








SHOTCRETE CONVENTION & TECHNOLOGY CONFERENCE

Eldorado Hotel & Spa
Santa Fe, NM | March 1-3, 2026

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SHOTCRETE FAQs

As a service to our readers, Shotcrete magazine includes selected questions and answers by the American Shotcrete Association (ASA). Questions can be submitted to info@shotcrete.org. Selected FAQs can also be found on the ASA website at www.shotcrete.org/FAQs.

QUESTION:

How long should an inspector wait until investigating the bar encasement on a mockup panel? We want to advise our inspector. We would like them to inspect with a trowel. They are using air entrainment, a water reducer, and a water-reducing retarder. We do not want them to fully set. We will not be saw cutting these.

ANSWER:

Usually, mockup panels are allowed to harden and are then cored or sawed to evaluate the concrete section for any voids and the degree of encapsulation of the reinforcing. With typical 4000 psi (28 MPa) or greater 28-day compressive strength, and not too-cold ambient temperatures, you should be able to core or saw the panel for visual defects within 48 hours. In hot summer weather, maybe even quicker.

It is challenging to evaluate voids or encasement with the wet concrete before set. However, an inspector with good shotcrete experience may be able to see poor encasement or voids during placement. Using a trowel when wet would tend to disturb the concrete before final set and make evaluation difficult.

ASA offers a full-day education session for inspectors to teach them about what to look for during placement to ensure quality shotcrete. Two ACI documents may be helpful for you and your inspection team:

- ACI PRC-506.6-17: TechNote: Visual Shotcrete Core Quality Evaluation
- ACI PRC-506.7-23: Shotcrete Preconstruction Mockup—TechNoteQuestion

QUESTION:

I'm an engineer with the Fish and Wildlife Department, and we do a lot of concrete rearing pond construction and repairs. I've included typical drawings for the ponds that are essentially long rectangular shallow tanks with interior dividing walls. Our designs are predominantly cast-in-place concrete with expansion joints that include PVC center-bulb waterstops and an elastomeric sealant, as well as details for a variety of embeds for screens, weir boards, and grating supports. I recently had a contractor ask whether shotcrete could be substituted for cast-in-place construction, and I'm trying to find technical resources on shotcrete for water-retaining structures, specifically the design of expansion joints. If you have any recommendations, I would be grateful for the help.

ANSWER:

The walls of the ponds could undoubtedly benefit from shotcrete placement. Shotcreting the wall will use the same design for the wall thicknesses, strength, and steel layout. Shotcrete placement is included in both ACI 318 and ACI 350. Your structure would fall under the ACI Code requirements. The reinforcing layout is easily shotcreted. We generally request non-contact lap splices, but with #5 bars, a contact lap splice can also be easily encased. Only a simple one-sided form is needed to shoot the wall in place. The 6 in. (150 mm) PVC ribbed center bulb waterstop at the base of the exterior walls can be placed in a bulkhead form for the joint. I recommend tying the waterstop so that the fin is angled toward the surface, pointing away from the form, to allow us to shoot the fin completely. The chamfer can be tooled in if needed. Similarly, the floor-to-wall waterstop can be shotcreted. I didn't see an expansion joint, but it could be treated similarly to the contraction joint, just a wider gap.

The floor should be poured. Shotcrete rebound is problematic for shooting horizontal floors.

On a side note, I see that you are requiring a permeability-reducing admixture (PRA) in the drawing notes. I don't have the corresponding specification to see precisely what you are requiring. Various PRAs have been used in shotcreted concrete without any problems. These do reduce permeability, but high-quality 4000 psi concrete is functionally watertight without them. Your pond walls are only 3.5 to 4 ft (1.1 to 1.2 m) high, so water pressure isn't that high to begin with. The ACI 350 Code does not require the use of PRAs in concrete liquid-containing structures; however, it is an optional consideration. Many suppliers mention that the PRA can seal cracks. This is true of static cracks, but not of moving cracks that open and close in response to seasonal temperature fluctuations of the contents or air temperature, as I expect your ponds will experience. If you are expecting crack sealing attributes of a PRA for this project, be sure to discuss whether they will ensure sealing of moving cracks caused by temperature fluctuations.

As a reference, you can visit our *Shotcrete* magazine article archive at **shotcrete.org/articles** and use the keyword "tank". We have had a variety of articles on shotcrete placement in concrete tanks.

Overall, shotcreting the walls will substantially reduce formwork costs and, in turn, reduce project time. Shotcrete placement of high-quality concrete can meet all the concrete design and material requirements for the project.

QUESTION:

We are preparing plans and specifications for a shotcrete soil nail wall to be put out as a design-build for our north-northeast client, and have concerns with the influence of road salts. The roadway above the wall is already in place, so we won't be able to place a liner beneath the pavement box. The shotcrete is going to be placed over a rusting corrugated bin wall.

Do you have any recommendations for protecting the shotcrete from road salts? We are calling for silane concrete sealant on exposed faces, but are unsure if additional protection is necessary or how additional protection could be provided. Any advice you could share would be greatly appreciated.

ANSWER:

First, shotcrete is a concrete placement method. Thus, we can explore options to maximize the concrete's resistance to chloride penetration and extend the time to corrosion of embedded reinforcing. A silane sealer is effective at sealing the surface and slowing chloride penetration, though it requires periodic recoating.

To reduce concrete permeability, I recommend using supplemental cementitious materials (SCM). Silica fume at 3% to 5% replacement of portland cement has been shown to significantly reduce permeability. Also, consider using fly ash (up to 25% replacement) or slag (up to 50% replacement), as these can help reduce permeability and slow chloride penetration to embedded reinforcing.

Permeability-reducing concrete admixtures, such as Kryton or Xypex, can also help to reduce permeability.

Finally, having the shotcrete contractor (or GC) be proactive in preventing early-age plastic shrinkage cracks and providing proper curing and protection from environmental exposures (cold or hot) can help keep cracking and subsequent chloride penetration to embedded reinforcing steel to a minimum.

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