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shotcrete MAGAZINE

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FEATURES

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American Shotcrete Association
401 Edgewater Place, Suite 600
Wakefield, MA 01880
Phone: 248.963.0210
E-mail: info@shotcrete.org
Website: **www.shotcrete.org**

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).

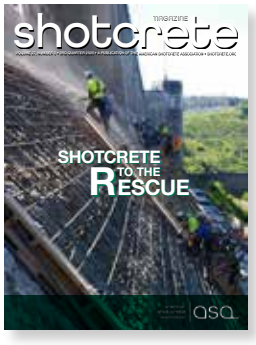
Editor-in-Chief
Charles Hanskat

Senior Editor
Alice McComas

Marketing & Advertising Sales
Tosha Holden
tosha.holden@shotcrete.org

Managing Editor & Graphic Design
Cara Baker
cara.baker@shotcrete.org

DEPARTMENTS



COVER PHOTO: *Surface preparation complete; preparing for shotcrete placement. See full article on Page 20: Lessons Learned on Spillway Shotcrete Overlay*

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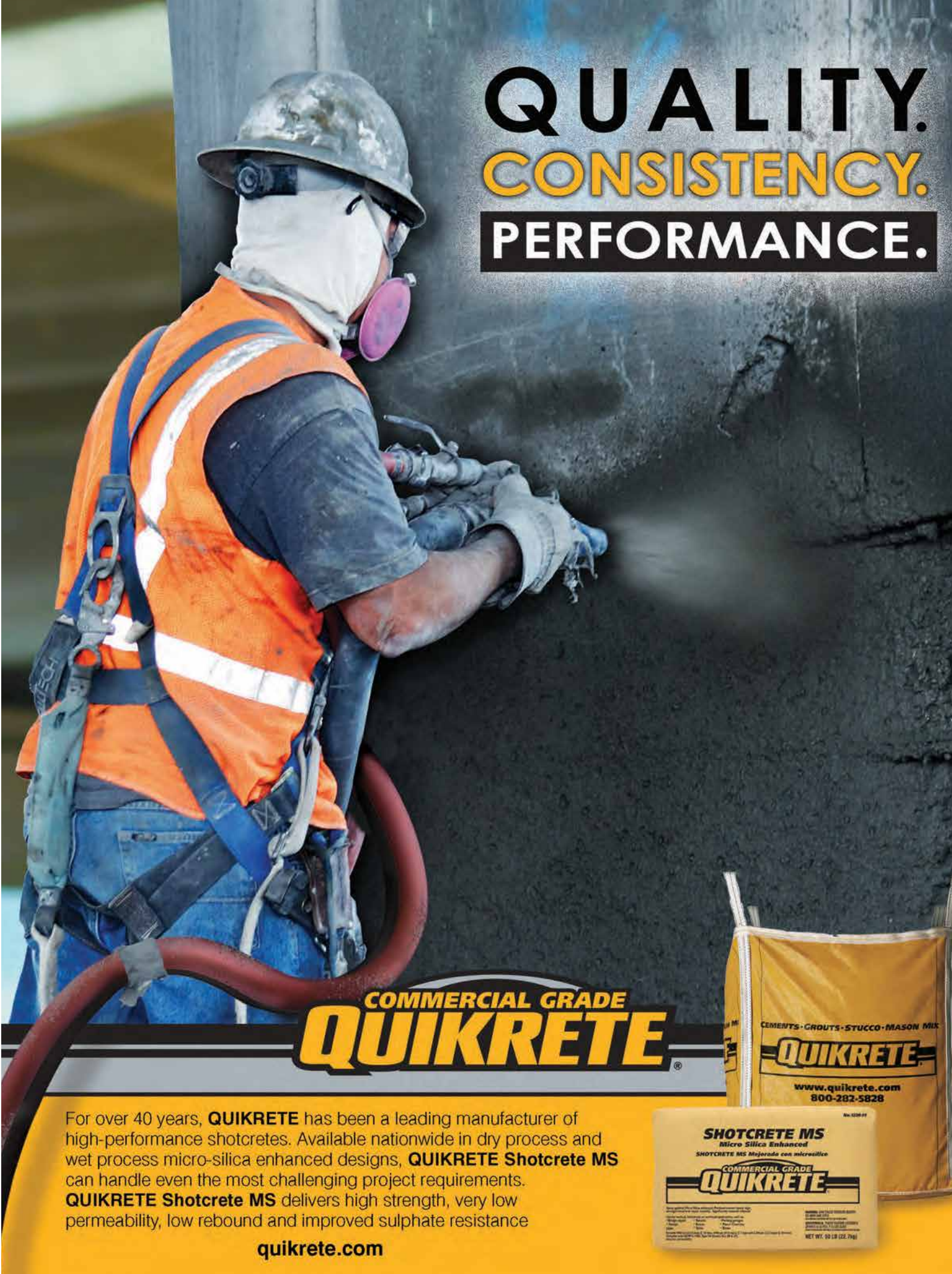

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Shotcrete to the Rescue!

By Bill Geers

Welcome to the 2025 Quarter 3 edition of *Shotcrete* Magazine, with a theme of "Shotcrete to the Rescue!" Shotcrete placement in structural projects (as an alternative to traditional cast-in-place concrete) has experienced significant growth in recent years. This trend can be attributed to the method's economic and environmental advantages, including enhanced cost efficiency, reduced labor demands, accelerated construction timelines, and the potential to lower a project's carbon footprint.

Shotcrete placement can minimize or eliminate the need for cranes, boom pumps, and forms, enabling faster application compared to traditional form-and-pour concrete methods. In challenging terrains and areas requiring complex shapes, it serves as an alternative to conventional form-and-pour construction, resulting in cost savings. Here are several areas where shotcrete placement has now come to the rescue!

CUTTING COSTS IN STRUCTURAL RESTORATION

A city's history is reflected in its old buildings, which often deteriorate with age and exposure to the elements. Today, many historic structures — such as churches, monuments, smokestacks, and schools built from brick or stone — are restored using shotcrete placement.

SLOPE STABILIZATION AND UNDERGROUND CONSTRUCTION

Shotcreting places concrete to stabilize the ground during excavation and differs from traditional timber or steel shoring. The use of shotcrete placement to provide support to the ground, serving as temporary support in mines and more recently as permanent lining in civil tunnels and underground stations, is one of the most significant uses of shotcrete placement in the world today. With its flexibility, shotcreting provides ground stabilization and stress relief in challenging terrain. In urban settings, it's commonly used for tunnels, stations, sewers, and side drifts, as shotcreters can reach difficult underground areas.

APPLICATION OF THE SHOTCRETE METHOD ON DAMS AND BRIDGES

Shotcrete placement is well-suited for sites that are elevated or difficult to access, where accuracy is crucial. It removes the necessity for conventional construction setups, even in environments surrounded by water or dense vegetation. A small, specialized team can efficiently apply, cut, finish, and cure multiple sections of a project. This approach offers significant advantages in congested or remote areas by reducing labor costs and limiting operational downtime.

Advancements in shotcrete technology, combined with improvements in education, training, and certification for shotcrete professionals, have expanded its use to a wider range of applications. ASA members' efforts have resulted in shotcreting being recognized as an approved placement method in the ACI 318 building code. Factors such as safety, adaptability, time efficiency, cost-effectiveness, and quality contribute to durable, economical, and sustainable project outcomes when using shotcrete placement. I hope that you enjoy this issue, and the innovative uses of shotcrete placement.

> "Advancements in shotcrete technology, combined with improvements in education, training, and certification for shotcrete professionals, have expanded its use to a wider range of applications."
>
> **– Bill Geers**

Please consider joining the American Shotcrete Association (ASA) to help us promote quality shotcrete placement in many new project applications like the ones mentioned above. ASA's Outstanding Shotcrete Project Awards program is another easy and rather prominent way to promote! ASA will regularly highlight these projects in our presentations and shows where we exhibit, and the 2025 program is now accepting your company's entries for the great work you've been doing all year. See this issue's insider tips for submission secrets on page 56 as you consider your nomination(s) this year! The deadline is rapidly approaching on October 1st, 2025.

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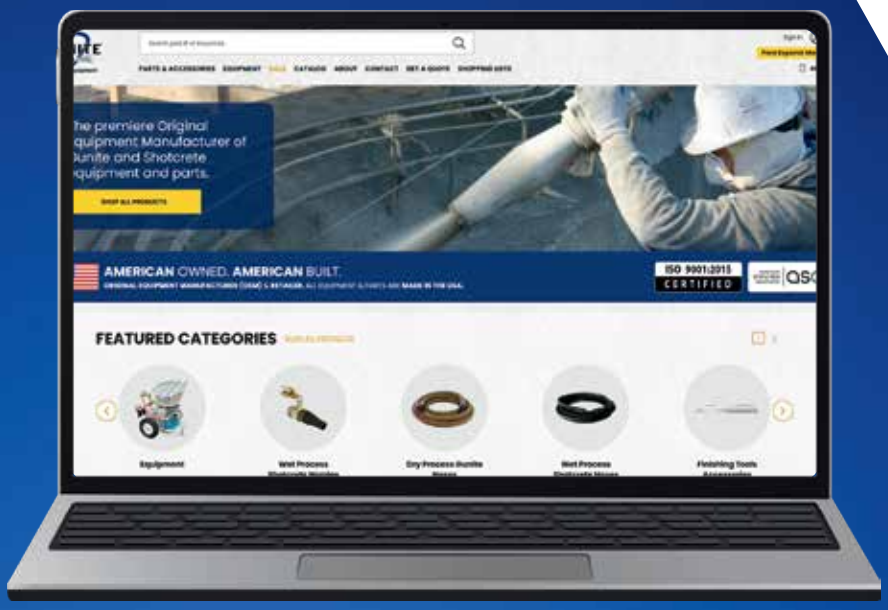

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Complete Your ASA Contractor Qualification

By Marcus von der Hofen

The ASA Contractor Qualification Committee (CQC) was created by the American Shotcrete Association (ASA) to focus on establishing and maintaining standards for shotcrete contractors. Our committee plays a crucial role in ensuring that contractors meet specific qualifications, thereby enhancing the quality and reliability of shotcrete work in various construction projects. The CQ committee is also working towards compiling resources for ASA-qualified contractors to assist them in their shotcrete businesses.

CONTRACTOR QUALIFICATION PROGRAM

The Contractor Qualification Program (CQP) is designed to evaluate and certify shotcrete contractors based on their experience and successful project completions. The committee reviews applications and assesses contractors' qualifications, ensuring they have a proven track record in quality shotcrete work.

We previously focused on two levels of qualification, and have now added a pool-specific category as well. The qualification also recognizes the shotcrete process the contractor uses, specifically dry-mix or wet-mix. Contractors can be qualified in a single process or both, depending on their experience. Self-performing shotcrete contractors may pursue the following ASA Qualified Shotcrete Contractor (QSC) qualifications:

- **Structural Level I (QSC – SI):** This level is for contractors who handle thin, lightly-reinforced shotcrete sections that are easily accessible.
- **Structural Level II (QSC – SII):** This level is for contractors dealing with thick, heavily-reinforced sections or those in difficult-to-access locations.
- **Pool Qualification (QSC – Pool):** Tailored specifically for contractors in the pool industry

PROMOTION AND VISIBILITY

ASA-qualified contractors are listed on the ASA website and promoted through various channels, including *Shotcrete* magazine and events where the ASA is represented. This visibility helps specifiers identify qualified contractors for their projects, ensuring they select professionals who meet the necessary standards.

Shotcrete contractors often work closely with other construction professionals, such as engineers, testing labs, inspectors, project managers, and general contractors, to ensure that projects are completed efficiently and to specifications. Thus, the shotcrete contractor must oversee quality control of the concrete placement, ensure the project layout is safe and efficient, and ensure that the crew has training for both safety and quality shotcrete placement. An ACI-certified shotcreter is an essential part of the shotcrete crew, but the entire field team needs to work together for quality and safety.

The American Shotcrete Association (ASA) provides a contractor qualification program to ensure that shotcrete contractors meet high standards of quality, safety, and expertise. Read on for some key aspects of the ASA's contractor qualification program.

WHY IS ASA SHOTCRETE CONTRACTOR QUALIFICATION ESSENTIAL?

The comprehensive program requirements and detailed application ensure that shotcrete contractors qualified by ASA have the necessary experience, skills, crew, and equipment to apply shotcrete correctly. Thus, when a shotcrete contractor achieves the ASA qualification the owner and specifier on a shotcrete placement project can be assured of a potential for a high quality concrete structure that has the serviceability and durability equal or better than a form-and-pour job.

WHAT ARE THE BROAD REQUIREMENTS FOR ASA CONTRACTOR QUALIFICATION?

- **Experience and Expertise:** Depending on the level of qualification, contractors must have a minimum of 3 to 5 years of experience in shotcrete application, with a proven track record of successful projects.
- **Certified Shotcreters and Shotcrete Team:** They must have ACI-certified shotcreters on their field crews. The experience of their field supervisor(s) and foremen is also evaluated.
- **Equipment and Quality Control:** Contractors must have the necessary equipment and quality

control procedures in place to ensure correct shotcrete placement.

- **Education:** Contractors must have completed a full-day ASA education program that provides information on the key aspects of running a shotcrete contracting business. Contractors are also evaluated on the continuing education of their staff.

Full details of the ASA QSC program and applications could be found at **Shotcrete.org/Certification-Qualification**.

By becoming qualified through the ASA's program, shotcrete contractors demonstrate their expertise and commitment to quality, safety, and customer satisfaction through a close review by an experienced group of their peers. All ASA QSC must also adhere to this ASA Code of Conduct:

> *"As an ASA Qualified Shotcrete Contractor, we agree to ongoing compliance with the requirements and standards set forth in the ASA Shotcrete Contractor Qualification Program description. We will not knowingly or purposefully violate any project specifications or requirements. We agree to maintain required insurance coverage, staff our projects with trained and certified personnel, and strive to produce a high-quality product in a safe and professional manner."*

By selecting an ASA QSC, owners and specifiers can be assured that the company has demonstrated by their company longevity, structure, field team, and equipment that they have the potential for quality shotcrete placement on their projects. Our ASA CQ Committee is continually working to increase the visibility of the program, refine the overall program, and ensure it meets the needs of the concrete construction industry. The ASA CQC serves as a cornerstone for maintaining high standards in the shotcrete industry, ensuring that contractors are well-equipped to deliver quality work. Take advantage of this valuable ASA resource both as a contractor (to receive a review and nod from experienced industry peers – apply for your ASA QSC qualification) and project owners (to lean in on the expert review of industry leaders – look for ASA QSC for your projects). If you have any specific questions or need further details about the committee or its processes, feel free to ask! (**info@shotcrete.org**)

Finding a Qualified Shotcrete Contractor

QUESTIONS TO ASK A POTENTIAL SHOTCRETE CONTRACTOR:

- **Experience:** What experience do you have with shotcrete applications of a similar size and scope?
- **References:** Can you provide references from previous clients?
- **Qualifications:** Are you an ASA Qualified Shotcrete Contractor? Is the qualification in the application and process for your project?
- **Certifications:** Do you have ACI-certified shotcreters on your field crews?
- **Insurance and Bonds:** Do you have liability insurance and workers' compensation insurance? What is your bonding capacity, and who is your bonding agent?
- **Warranty:** Do you offer a warranty for your work?

RED FLAGS TO WATCH OUT FOR:

- **Lack of Certification:** Be wary of shotcrete contractors who are not qualified by the ASA. Other qualifications or certifications for non-shotcrete work have limited impact on quality shotcrete placement.
- **Poor Reviews:** Be sure to check the references provided. Check online reviews and ratings but be aware some "positive reviews" may be fabricated.
- **Unclear Pricing:** Be cautious of contractors who are unclear about their pricing or try to rush you into a decision.

Back-to-School – ASA Style

By Charles S. Hanskat, Executive Director

As summer winds down in the Northern Hemisphere, many are sending their children back to school. This prompted me to reflect on our version of "back-to-school" in our careers and businesses, like how my professional engineering license requires periodic continuing education (CE) for renewal. Some states also require CE for contractors to renew their licenses.

ASA's Vision is "To expand and advance global utilization of the shotcrete process for concrete placement," which we do by "providing shotcrete leadership, knowledge, resources, qualification, certification, and education for the concrete industry." (ASA Mission Statement)

Can ASA be your "back-to-school" for shotcrete knowledge through education opportunities? Definitely! Since our inception in 1998, we have developed a diverse range of educational programs designed for a broad audience, including engineers, owners, DOTs, shotcreters, inspectors, pool builders, general contractors, and shotcrete contractors. The program delivery ranges from online webinars to lunch or dinner onsite presentations and full-day in-person classes.

SO, WHO CAN BENEFIT FROM OUR EDUCATION?

ENGINEERS, OWNERS, AND DOTS

These are generally specifiers who first need to know what shotcrete is and then how it can be used for quality shotcrete placement on their projects. For this group, we offer our 1-hour *Introduction to Shotcrete* seminar (A market-specific version for the Underground market is also available). This is often presented during a lunch-and-learn on-site or sometimes as a webinar — for firms with remote offices, our staff have broadcast on-site seminars to the remote attendees. Presenting our webinars through Teams or Zoom makes it easy for your team members to join. The Q&A segment of the presentation seems to be livelier with the on-site seminars, but a webinar with chat or audio links works too.

ENGINEERING STUDENTS

ASA presents an *Introduction to Shotcrete* at a variety of schools across the country, with a target group of civil engineering or construction management programs. Most are in-person presentations with the occasional webinar. This allows us to expose students to the unique benefits of shotcrete placement in concrete construction, often for the first and only time. Usually, showing the students (and professors) the flexibility and creativity of shotcreting is an eye-opener for what can be achieved in such a wide variety of concrete structures. We coordinate with professors (to come in as a guest lecturer) or with students (as a speaker at a chapter meeting).

GOVERNMENT AGENCIES

This group includes the US Army Corps of Engineers, various State DOTs (main or district offices), and the Canadian Ministries of Transportation. These groups are often involved not only in specifying but also in inspecting the field construction. We've presented our full-day Shotcrete Inspector seminar, *Quality Shotcrete, Know It When You See It*, to many of these groups. We've also presented our one-hour *Introduction to Shotcrete* or *Shotcrete for Underground Applications*, depending on the needs of the group. If you have a project where the overseeing agency needs a bit more shotcrete knowledge, feel free to recommend our ASA seminars.

CONCRETE-RELATED ASSOCIATIONS

We have made many presentations to the American Concrete Institute (ACI), the International Concrete Repair Institute (ICRI), and the Pool & Hot Tub Association (PHTA), both with local chapters and at their national conferences. This provides us with an opportunity to educate a large number of people simultaneously. Also, many who attend local chapter meetings don't attend the national conventions, so we are reaching different groups.

The local chapter meetings also tend to have a more diverse cross-section of the concrete industry, with individuals from testing labs, concrete and material suppliers, engineers, and contractors. In contrast, the large national conferences seem to attract more engineers and educators. If you are part of a local chapter looking for speakers, be sure to mention to the officers or staff that ASA can provide a speaker on a great topic — shotcrete!

POOL BUILDERS

Pool and other watershapes are a big market for shotcrete, and most pool builders use subcontractors for shotcrete placement. Though the pool builder has overall responsibility for the pool construction, they may not have the necessary knowledge to identify quality shotcrete

placement. We've developed a full-day seminar for the pool industry, *Quality Shotcrete for Pools – Know It, Demand It*. Attendees learn the basics of shotcrete placement and, most importantly, the visual cues to identify good or bad concrete as it is being placed.

So, who should attend? Owners, project managers, superintendents, and foremen have benefited highly from this seminar. Shotcrete contractors who routinely shoot pools can also benefit from this pool-specific course. Watershape University (WU), a pool educational organization, recognized the value of ASA's shotcrete seminar for the pool industry and requires this seminar as a prerequisite for two of their shotcrete-related certifications. You can find out more about WU certifications at **Watershape.org/Certification**. We offer the course at select pool trade shows nationwide as well, plus on-site upon request. We have also provided it at ASA's annual convention held in late February or early March.

SHOTCRETE INSPECTORS

Our *Quality Shotcrete, Know It When You See It* full-day seminar is geared toward inspectors who need to know the specifics of quality shotcrete placement. The education gives a broad knowledge of shotcrete that can't be covered in our one-hour *Introduction to Shotcrete*. Those who can benefit from the seminar include inspectors from testing labs, engineering firms, or oversight agencies (such as DOTs).

It's also an excellent course for engineers, owners, and contractors who want to have a more in-depth understanding of quality shotcrete placement for their projects. It's a great educational session for shotcrete contractor staff as well, who may not be hands-on shotcreters but need to know more about quality placement.

Finally, the seminar can benefit attendees pursuing ACI Shotcrete Inspector certification, as not only do they gain a more thorough knowledge of shotcrete, but the course counts as the equivalent of one year of work experience. We offer the course at the annual World of Concrete, ACI's Resource Centers, and ACI local chapters. Companies have also requested the seminar for their staff, and others for specific projects.

SHOTCRETE CONTRACTORS

ASA has a full-day shotcrete contractor education seminar. This course focuses on the specifics of developing and running a shotcrete contracting firm. As in our shotcrete inspector class, it addresses the many aspects of shotcrete placement necessary for quality concrete, but also covers additional planning, safety, and business-related items. The course is a prerequisite for pursuing the ASA Qualified Shotcrete Contractor or ASA Qualified Pool Shotcrete Contractor qualifications. Details on the ASA Qualified Contractor program can be found at **shotcrete.org**. Attendees who could benefit from this are shotcrete company owners, operations managers, project managers, and superintendents.

SHOTCRETERS

For 25 years, ASA has provided a full day of education for shotcreters pursuing ACI certification. The course focuses on the concrete and shotcrete-specific knowledge required for the shotcreter operating the nozzle. Shotcrete contracting companies host most of our ASA education and ACI Shotcreter certifications. Though geared towards the shotcreter, the full-day seminar may also be beneficial for others in the company, like project, operations, or safety managers. We also offer the ASA Shotcreter education at the annual World of Concrete tradeshow.

CONCLUSION

So, who can benefit from ASA shotcrete knowledge and education? The answer — most everyone involved with concrete placement! Even those not directly involved on a shotcrete project may benefit from learning about the creativity, flexibility, efficiency, durability, and quality of shotcrete placement. Investing an hour or a day to learn more about shotcrete placement can make shotcrete projects better, and even perhaps reveal how shotcrete can be an option for a future project where you've only seen form-and-pour. For more details on our ASA educational offerings, visit **Shotcrete.org/Events-Education**.

Learning is a lifelong endeavor. As Henry Ford once said, "Anyone who stops learning is old, whether at twenty or eighty. Anyone who keeps learning stays young." Let's all stay young!

Shotcrete as Final Liner — Design Considerations

By Andy Thompson

SUMMARY

The use of shotcrete placement (often called sprayed concrete) for the final permanent structural lining of underground structures and facilities continues to increase around the world. Where non-uniform shapes are required, shotcreting provides great flexibility, eliminating the need for complex and time-consuming formwork installation. This can improve the logistics and reduce the cost of the final lining work. As a placement method for concrete, there are certain elements of the design process where shotcreting can be beneficial.

INITIAL CONSIDERATIONS

Some key factors in determining whether and how shotcrete may be used for the installation of the permanent lining are the governing codes and standards where the work is being undertaken. There may be restrictions on where such methods can be used or local design codes and standards that have a direct impact on the design, quality control, and other factors that need to be considered by both the designer (when preparing the project drawings and specifications) and the contractor (when developing their placement plans). For this article, the author has primarily drawn on U.S. practice for examples of design impacts.

SHOTCRETE LININGS

Where shotcrete is used for the permanent lining, it is also commonly used for the initial or primary ground support that is installed immediately after the excavation of the ground. Depending on the ground conditions, the shotcreted concrete may form part of a support system comprising rock bolts/dowels, lattice girders, etc., and welded wire mesh or steel fibers may be used to enhance the tensile capacity of the concrete and ensure ductile behavior. The thickness of the concrete to be shotcrete-applied will depend on the span to be supported, the specific ground conditions, and the use of other support elements. Typically, the initial lining is designed to resist external forces due to short-term ground loads as well as the effects of other transient loads such as compensation grouting and any surcharge loads applied at the surface level during construction works. It may also be designed to resist a certain percentage of the long-term ground loading, while hydrostatic loading from groundwater is more typically designed to be carried by the permanent lining.

This initial lining will usually be installed in layers to achieve the required thickness and — depending on whether steel fibers are used and the type of waterproofing system to be installed between the primary lining and the permanent lining — may require that a plain unreinforced layer of concrete be shotcreted to provide a suitable substrate for the waterproofing system. One critical item that requires specification in any use of shotcrete placement for primary lining is a "smoothness" criterion, to be achieved prior to the installation of a sheet membrane system to reduce the potential for pillowing and potential damage to the sheet waterproofing membrane during installation of the permanent lining. This is relevant both in the use of shotcrete or form-and-pour concrete as the placement method for the permanent concrete lining. Typically, the membrane manufacturer will provide details of what the membrane can tolerate as part of the membrane material data sheets. These should be reflected in the project contract documents along with a clear process that outlines who is responsible for determining whether these tolerances have been met prior to permitting membrane installation to proceed. Similarly, if spray-applied membranes are being used, the surface preparation and sign-off needs to be established and reflected in the project specifications and drawings based on the manufacturer's requirements.

Routinely, the initial lining design uses two-dimensional (2D) and three-dimensional (3D) numerical modeling techniques utilizing software packages such as Fast Lagrangian Analysis of Continua (FLAC), which can represent the non-linear behavior of the ground and provide a reliable representation of the ground-structure interaction. 2D numerical models of selected critical sections, highest cover, lowest cover, etc. are used to confirm the stability of the excavation and to determine the tunnel lining internal forces both in the long term and the intermediate construction stages. 3D analyses may be needed in more complex excavations, such as junctions or caverns, where the presence of a headwall has an influence on the final output of the internal lining forces. These models will include the effects of all the adjoining structures — including the appropriate surcharge loading — and make allowances for tolerances at each construction stage. The time-dependent development of shotcreted concrete strength and stiffness can also be included in these models using the strength gain curves. If there is historical data from previously excavated tunnels in the same ground, the lining design models can be calibrated against any historical data.

The permanent lining design must consider the following:

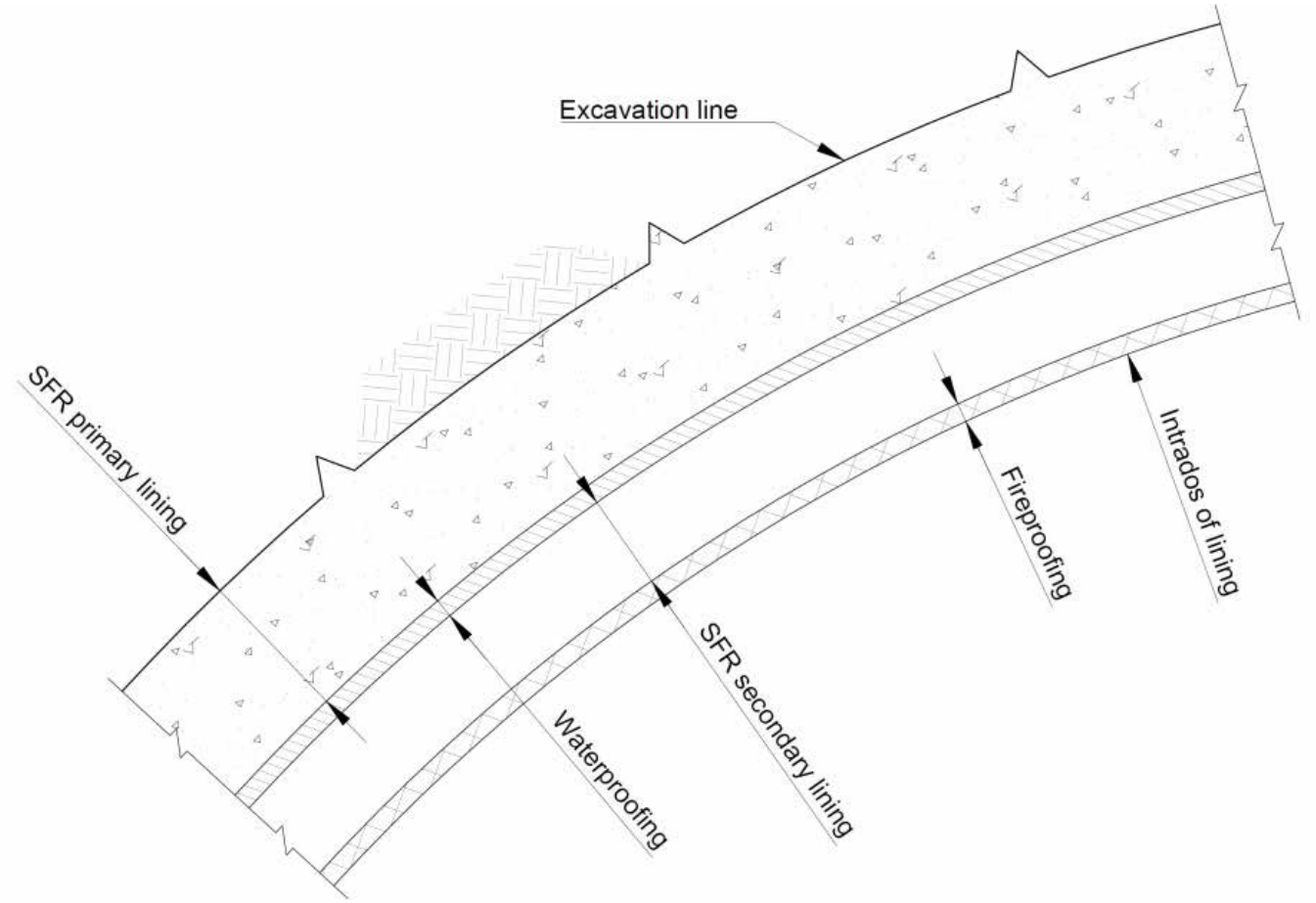

Fig. 1: Example of a shotcreted lining used on Crossrail, UK, using steel fibers

- The internal forces generated by its self weight
- Long-term ground loadings
- Hydrostatic loading
- Temperature
- Concrete shrinkage effects

Depending on the use of the tunnel, there may also be a need to consider fixing loads for the support of tunnel systems, like jet fans, as well as the effects of a fire on the lining. For fire resistance, it may be necessary to provide a final layer of shotcreted concrete containing polypropylene fibers as a 'sacrificial' layer to protect the remainder of the permanent lining. For example, on the Crossrail Project in London, the shotcreted linings were designed to provide sufficient residual capacity to resist ground and hydrostatic loads after a tunnel fire, as represented by the RABT-ZTV (Eureka) (EC 1196, 2008) time-temperature fire curve. Fire testing of shotcreted panels was undertaken with various combinations of lining layers to demonstrate the lining's ability to resist the RABT-ZTV fire curve. The end use of the underground facility is a major factor in determining whether such requirements and testing need to be accommodated in the project drawings and specifications. It is incumbent upon the designer to identify these and design for them.

When a waterproofing membrane is required for the long-term durability of the linings or to ensure a dry facility, the choice of membrane type will affect how the shotcrete is placed and the lining's long-term performance. Although some composite action between the initial support and the permanent lining can be considered, there are some limitations that need to be recognized based on the performance of spray-applied membranes. Where sheet membrane is used, a fully composite action cannot be assumed, and local codes should be consulted to determine how much capacity of the initial lining can be considered in the long-term performance of the lining. For spray-applied membrane, the material needs to be tested to determine its bond strength with the concrete and whether it can be relied upon in the long term to allow full composite action to be assumed in the design.

FINAL LINING VARIATIONS

As noted previously, shotcrete (or sprayed concrete) is a method of concrete placement; in and of itself, the final lining structural design is not dependent on the placement method. However, if a decision is made to utilize shotcrete placement, there are elements of the design that should be considered to allow for the use of this method that meets the performance requirements.

In determining the detail of the permanent lining, the codes, standards, and local practices also need to be considered. For example, in the U.S., hand-sprayed

shotcreting is used alongside remotely manipulated nozzling (robotic) applications, whereas in many locations, shotcrete applications are almost entirely remotely manipulated. This will, to some extent, dictate the designs that can be constructed using shotcrete as a placement method. To further illustrate this, some examples will be presented to show how these factors can influence the design.

Shotcrete final lining designs typically use lattice girders to support the lightweight steel reinforcement and assist in controlling the profile/geometry of the tunnel cross-section. Concrete is shotcreted in layers to build up the thickness of the final lining. Reinforcement in such applications is typically small-diameter, well-spaced bars, as recommended by ACI 506, to minimize the potential for shadowing that may create voids in concrete around the lattice girders and reinforcing bars. An increasingly common alternative is the use of steel fiber-reinforced (SFR) concrete, which removes the need for the lattice girders and steel wire or bar reinforcement. In both cases, high levels of application skill and workmanship, as well as rigorous quality control processes, are needed to ensure the concrete is correctly placed and that the required profile is being met. Depth control and profile bars are routinely used to provide a visual guide for the shotcreter. Depending on the finish required and the final use of the underground space, a smoothing layer may need to be placed over the final lining to provide the necessary finish.

For example, a generic sequence for the shotcreted final lining (SFL) may include:

1. Installation of lattice girders at 5 ft (1.5 m) centers with a steel reinforcing bar mat placed against the waterproofing membrane at the extrados side of the girders, and partial encasement of the lattice girders;
2. Shotcreting of an infill first layer between the lattice girders;
3. Shotcreting of a second layer;
4. Installation of reinforcing bars on the intrados side of the lining; and
5. Installing a final shotcreted layer to provide minimum cover over the reinforcement.

The number of shotcreted layer installations would depend on the total design thickness of the final lining. The designer should prepare the design drawings and specifications to provide this level of detail and any quality control requirements.

Fig. 2: Installation of SFL

Fig. 3: Preconstruction mockup panel

Fig. 4: Production Spraying

SHOTCRETE LINING ALTERNATIVES

On the East Side Access project in New York, an alternative shotcrete lining was used extensively to replace the use of form-and-pour concrete, as well as in some cases, the previously designed SFL . In this application, concrete was shotcreted around the reinforcement using hand-spraying methods and the final lining was designed with no consideration for the method of placement. As expected, this presented significant challenges and required a very different approach to the testing and approval of shotcreters as well as the quality control processes that needed to be followed. What did not change was the structural design, which performed in the same way as if these linings were to be placed by form-and-pour methods. However, when shotcrete was specified, accommodations in the reinforcement design could have optimized this approach — by considering shotcrete's proclivity towards layered placement and potentially adjusting the reinforcing layout.

Given that this was a commuter railroad project, the underground structures were considered to be occupied structures, and as such, the New York State Building Code (NYSBC) applied to the designs. NYSBC Section 1914 contains specific requirements for the use and testing of shotcrete. The steps taken to allow shotcrete to be used in this particular application provide a good example of how local codes and standards can influence the design and specifications.

Section 1914.4 of the NYSBC states: "The maximum size of reinforcement shall be No. 5 bars unless it is demonstrated by preconstruction tests that adequate encasement of larger bars will be achieved," and that "When No. 5 or smaller bars are used, there shall be a minimum clearance between parallel reinforcement bars of [2.5 in.]. When bars larger than No. 5 are permitted, there shall be a minimum clearance between parallel bars equal to six diameters of the bars used. When two curtains of steel are provided, the curtain nearer the nozzle shall have a minimum spacing equal to 12 bar diameters and the remaining curtain shall have a minimum spacing of six bar diameters." This is similar to the requirements of ACI 506, and on the face of it, rules out the use of shotcreting in applications where the structural reinforcement needed is heavier than this. But, the NYSBC also provides an exception: "Subject to the approval of the code enforcement official, required clearances shall be reduced where it is demonstrated by preconstruction tests that adequate encasement of the bars used in the design will be achieved."

NYSBC also restricts the use of lap splices. "Lap splices of reinforcing bars shall utilize the noncontact lap splice method with a minimum clearance of [2 in.] between bars. The use of contact lap splices necessary for support of the reinforcing is permitted when approved by the code enforcement official, based on satisfactory preconstruction tests that show that adequate encasement of the bars will be achieved, and provided that the splice is oriented so that a plane through the center of the spliced bars is perpendicular to the surface of the shotcreted concrete."

Regarding testing, the NYSBC states the following: "When required by the code enforcement official, a test panel shall be shot, cured, cored or sawn, examined, and tested prior to commencement of the project. The sample panel shall be representative of the project and simulate job conditions as closely as possible. The panel thickness and reinforcing shall reproduce the thickest and most congested area specified in the structural design. It shall be shot at the same angle, using the same [shotcreter] and with the same concrete mix design that will be used on the project. The equipment used in preconstruction testing shall be the same equipment used in the work requiring such testing, unless substitute equipment is approved by the code enforcement official."

To advance the use of shotcrete placement for the permanent linings that had been designed with the use of form-and-pour concrete placement, the project team — including the NYSBC Code Enforcement official — developed the following strategy, which was reflected in the specifications and required no changes to the design drawings.

1. Requiring a full-scale mockup for each separate contract
2. The mockup to represent the most congested rebar layouts horizontally and vertically
3. Demonstration by *each* shotcreter that encapsulation of rebar was satisfactory to the engineer-of-record

Shotcreters qualified through these measures would be allowed to place shotcrete in the same reinforcement designs previously intended for form-and-pour placement.

OTHER DESIGN CONSIDERATIONS

Where shotcrete placement is to be used, the entity responsible for producing the project specifications — be it the designer or owner — needs to address issues such as:

- Applicability of local codes and standards (as discussed above)
- Quality control (QC) for both pre-construction and production testing, which includes:
  - Concrete mixture design testing and approvals
  - Shotcreter project qualification and ACI certification
  - Placement quality through the use of mockups and destructive testing
  - Production QC for thickness, shape, concrete quality, proper placement, surface finish, etc.
- Need for detailed Construction Work Plans from the contractor that include realistic quality control processes, especially where hand spraying is to be performed
- Readiness reviews before production operations start, to ensure that all necessary preparation work has been performed and everyone involved understands the process as well as the safety and quality considerations required
- Surface preparation
- Layering control and bond strength
- Exclusion zones for entry after overhead placement
- Early strength testing
- Interaction with waterproofing supplier and installer and the approvals process to create hold points that demonstrate compliance with the project requirements before work is covered up
- Construction tolerances
- Surface finish, including acoustic considerations as well as operation and maintenance issues for the finished facility
- Ventilation, lighting, and working at heights during concreting operations

WORKING UNDER NEW PLACEMENT

In underground overhead shotcrete applications, gravity has a constant impact on shotcrete placement. According to the project records for the Crossrail project in the UK, the majority of shotcrete fallouts occurred within 15 minutes of overhead shotcrete placement. Following a fatality on that project from

falling shotcreted concrete, the project introduced a rigorous exclusion zone approach. A similar approach was developed on the East Side Access Project in New York, also after a fatality. In both cases, the approach was to eliminate the need for workers to work under freshly shotcreted concrete and restrict access to these areas after placement was completed. As a result of these actions, no further serious injuries occurred. The use of such exclusion zones, as well as the concept of painting yourself out of the room, is one that should be considered for implementation on any underground project where overhead shotcrete placement is being used, but especially where the permanent lining is being placed by this method. Such a process should be written into the project specifications if appropriate.

The use of early age strength testing may also be appropriate to permit work to resume once the shotcreted concrete has reached a certain strength. That strength requirement is dependent on what the concrete is required to do. For example, in a Sequential Excavated Tunnel the initial lining will be required to resist the relaxation of the ground. As such, the designer should determine what the strength requirement is and the time in which the strength needs to be achieved to ensure that the lined excavation is safe to enter. This requirement may be different in a rock tunnel, a rehab project, or in a mining environment. There are a variety of different methods to determine the early strength gain — including the beam test, needle guns, etc. — and the designer needs to specify an appropriate method for the specific application. The ASA Underground Committee has written an article concerning the use of these different methods (**shotcrete.org/wp-content/uploads/2024/12/SCM4Q2024_Early-Age-Strength-Testing.pdf**).

CONCLUSION

Shotcreting for permanent final lining applications is a well-established placement method. When specifying shotcrete as a placement method, the project designer must consider a significant number of factors to ensure the required quality of the product can be delivered safely. The method of shotcrete placement — whether remotely manipulated or hand sprayed — together with the local codes must be taken into account in developing the design. Still, the final product is ultimately a reinforced concrete lining that has been placed using shotcrete rather than the form-and-pour method. As such, the structural design is not impacted by the selected method.

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

Shotcrete Placement for Initial Support: CLIMATE PLEDGE ARENA TUNNEL PROJECT

By Mark Pinske, Elizabeth Lenker, and Paul Mockus

The Washington State Coliseum was an arena built for the 1962 Seattle World's Fair. More than half a century later, in 2019, a $1B construction program began to redevelop and expand the arena. The redeveloped building, with a new name — Climate Pledge Arena — retains the historical roof, but below the surface is another story. Underground, the arena continues 30 ft (9 m) below the original floor to expand the arena's capacity. As part of the project, a tunnel was constructed under Thomas Street and the Bressi Garage, a 100-year-old unreinforced masonry landmarked building, so trucks could directly access the arena without disrupting traffic in the surrounding area (Fig. 1). This tunnel is approximately 180 ft (55 m) long, with a finished width of 25 ft (7.6 m) and a vaulted roof 20 ft (6 m) high. The project design was led by the architectural firm Populous. Construction was awarded to Mortenson Construction, who selected Delve Underground and J.W. Fowler in a design-build subcontract for the tunnel construction.

The design phase was performed under an accelerated schedule to meet the arena's fixed opening date. The tunnel excavation was completed within 2 months, and the tunnel and portal construction were completed in 14 months. Given the limited cover and proximity to the Bressi Garage, a pipe arch canopy was installed as a pre-support system to enhance ground stability and safety during excavation. The canopy consisted of 24 in. (600 mm) diameter pipe canopy tubes, which were set around the tunnel perimeter, as shown in Fig. 2. The tunnel was constructed using the sequential excavation method (SEM), with each advance stabilized with 14 in. (350 mm) deep steel sets and steel fiber-reinforced shotcrete (SFRS) lagging. Note that the south tunnel headwall is within 6 ft (1.8 m) of the Bressi Garage, and the tunnel passes within 3 ft (0.9 m) of the building's foundations. The ground between the pipe canopy and the existing footings was improved using permeation grouting prior to the excavation.

Soil conditions along the tunnel alignment consisted of less than 15 ft (4.6 m) of fill over very dense, glacially overridden granular soils, with interbedded layers of over-consolidated fine-grained soils. Static groundwater was approximately 20 ft below the ground's surface. A system of eductor wells and wellpoints was installed to lower the groundwater below the tunnel, allowing successful shotcrete placement without the

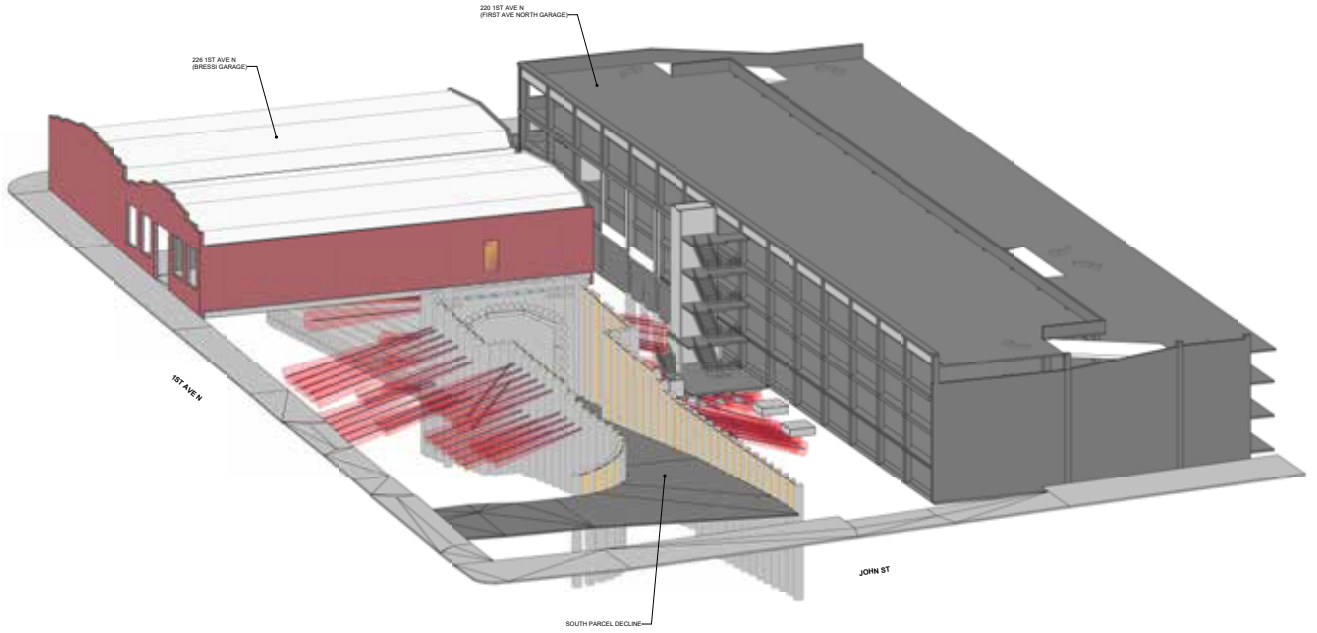

Fig. 1: Partial site plan showing decline, tunnel, and proximity to adjacent structures

Fig. 2: Pipe arch canopy being installed prior to tunnel excavation; note the proximity of the future tunnel and existing Bressi Garage

presence of groundwater.

The initial structural support for the tunnel consisted of steel sets every 4 ft (1.2 m) on center, with steel-fiber reinforced concrete utilized as lagging by shotcrete placement. The steel sets were chosen as the temporary tunnel support because of how quickly they could be assembled and erected. This also minimized the amount of field corrections to fit each steel set. This temporary tunnel lining was designed for full overburden pressures, as it was assumed that soil arching could not be considered because of the shallow cover over the tunnel. This assumption resulted in larger steel sets, and thus a thicker shotcreted layer to bring the concrete lagging flush with the steel sets.

Concrete was shotcreted robotically and by hand. The robotically applied concrete was a wet-mix concrete, delivered to the site by concrete trucks that backed into the tunnel and end-dumped into the hopper for the shotcrete robot. The easy access for concrete trucks to reach the shotcrete robot meant that no pump truck was needed, minimizing the congestion in the tunnel during shotcreting operations with the robot. The shotcrete robot used was a Normet Spraymec 8100 VC (Fig. 3), which was able to reach between the steel sets and apply the concrete. The wet-mix concrete was applied once a day and was in tandem with the excavation sequence of one 4 ft round of excavation per day. The concrete was placed in multiple lifts to reach the design thickness. One placement concern was that the shotcreted concrete might not adhere properly to the steel pipe canopy tubes that made up the roof of the tunnel as the tunnel was being excavated. Wire mesh was on site and ready to be placed on the canopy tubes to help the concrete adhere to them. However, this ultimately was not needed as the shotcreted concrete adhered to the canopy tubes without issue, and no fallout was observed during or after shotcrete placement.

During excavation of the tunnel, dry-mix concrete was hand nozzled and used as flashcrete. Flashcrete was applied as a 2 to 3 in. (50 to 75 mm) layer of unreinforced or fiber-reinforced shotcrete to the face and sidewalls of the excavation as a way to retain soil moisture and limit premature ground relaxation in advance of the temporary shotcreted steel set support installation. Face maps were completed at the end of each shift or round of excavation to detail the ground conditions at that time. The face maps included details of the type and location of soils encountered, groundwater seepage, and any other notes relevant to the excavation. An example of the face map used during construction is shown in Fig. 4.

Shotcrete placement was completed by ACI-certified shotcreters who were certified for both dry-and wet-mix vertical and overhead positions. Preconstruction trials were used to prequalify the shotcreters for the project and allowed the design team to evaluate overall quality, such as workmanship, uniformity, and strength of the concrete mixture. Test panels were shot in both vertical and overhead positions for both dry- and wet-mixes. Early preconstruction test panels did not meet the performance requirements, therefore alternative mixtures and trials were performed to meet the design requirements.

During construction, shotcrete placement testing included shooting daily test panels. These were a combination of dry-mix shotcreted test panels shot by hand and wet-mix shotcreted test panels shot by the robot. A penetrometer was used to test the 1-hour early strength. These panels were then cored and tested for compressive strength at 1-day, 7-day, and 28-day intervals. The purpose of early concrete strength testing was to inform the contractor and design team that the shotcreted concrete had gained enough strength to provide sufficient ground stability under the excavated face prior to the next advance. Flexural concrete panel testing per ASTM C1550 was originally specified to calculate the residual flexural strength of the steel-fiber reinforced concrete. Due to challenges with obtaining reliable test data and additional correlation testing required to verify the residual flexural strength values using round panels, the ASTM 1609 test was ultimately used to directly evaluate the flexural performance of fiber-reinforced concrete.

Monitoring of the Bressi Garage was performed continuously with approximately 60 optical prisms monitored by an automated motorized total station (AMTS), supplemented with manual survey monitoring of convergence points inside the tunnel. Delve Underground's structural engineers performed pre- and mid-construction walkthroughs to assess the structural condition of the nearly 100-year-old building, including its original wood beams and concrete foundation. An independent third-party building condition

Fig. 3: Shotcrete robot (Normet Spraymec 8100 VC) applying flashcrete to the advanced top heading

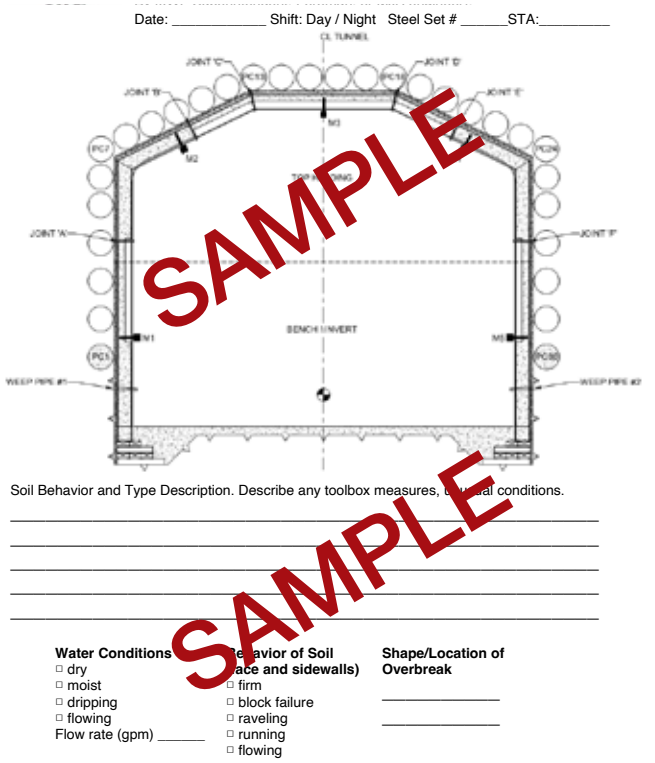

Fig. 4: Example of a face map data sheet

survey was also performed. Twenty-three crack gauges were installed on existing cracks in the concrete and masonry walls and were monitored weekly during tunnel excavation. Manual surveys were performed within the tunnel to measure convergence on survey points installed on the steel sets and within the concrete lagging. Up to about 0.3 in. (8 mm) of vertical displacement in the tunnel crown was observed, as shown in Fig. 5, with minimal horizontal inward movements measured on the vertical sidewalls. Similar magnitudes of movement were observed in the steel sets as observed on survey points installed on the concrete lagging between the steel sets. These movements were generally below the 0.3 in. trigger level criteria and stabilized within about 2 weeks or less after the steel set was installed. Even with such little cover between the top of the tunnel and the bottom of the historic building foundations, total recorded settlement of the building monitoring points was less than 0.75 in. (29 mm), and no significant widening or cracks were observed.

In conclusion, shotcrete placement played a crucial role in the successful completion of the Climate Pledge Arena access tunnel. It was utilized as lagging, foundation support, and a means of initial ground stabilization, while additionally providing the necessary structural support and allowing for safe and efficient excavation. The project used both wet-mix and dry-mix concrete and included shotcrete placement both robotically and by hand, demonstrating its versatility. The success of the tunnel construction validates shotcrete placement as an indispensable tool in modern underground construction, particularly in projects with sensitive surroundings.

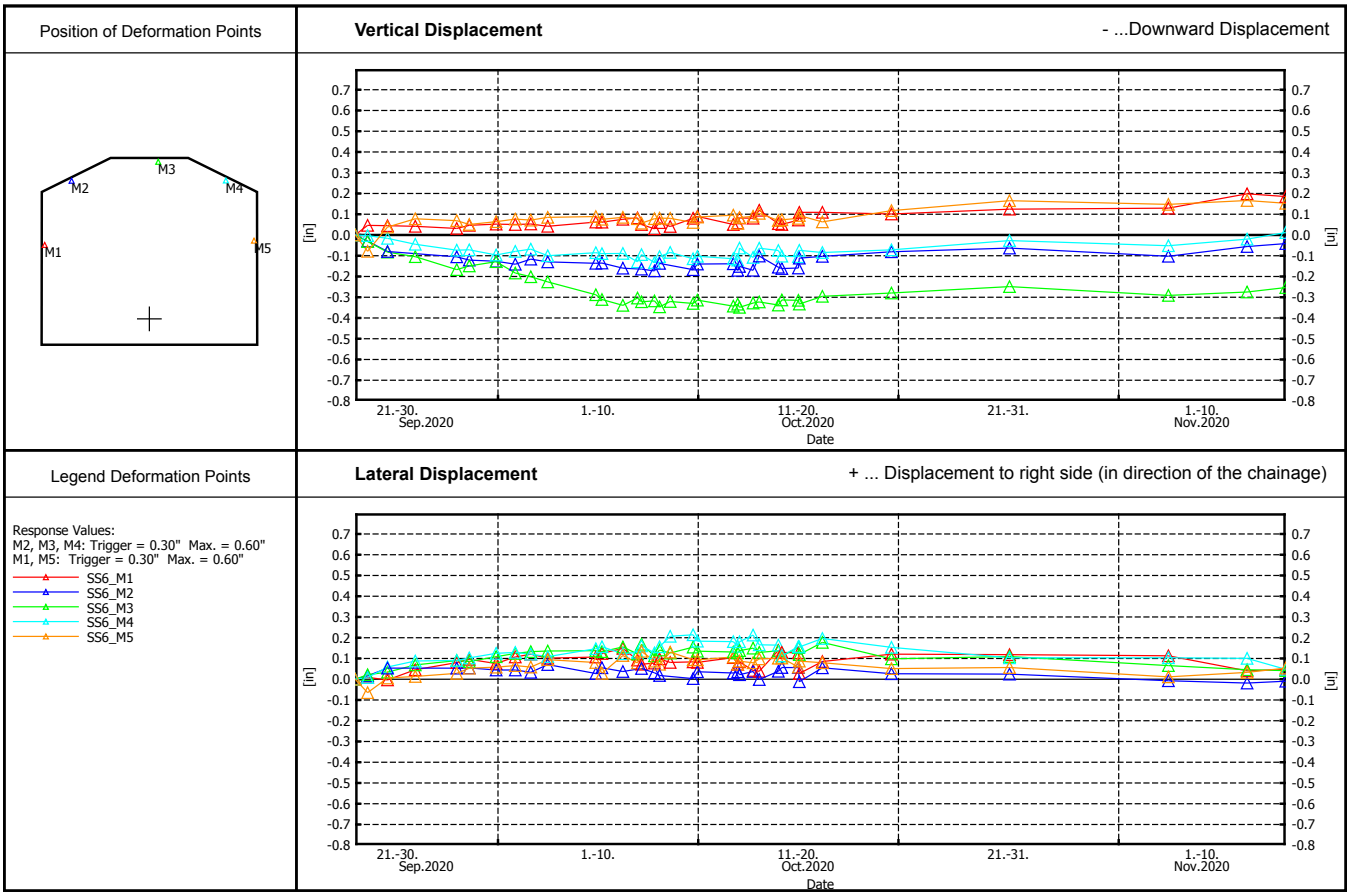

Fig. 5: Displacement observed during tunnel excavation

Elizabeth Lenker *is a Senior Project Engineer at Delve Underground. She has over 13 years of experience with a focus in geotechnical engineering, tunnel lining design, SEM tunneling, and construction management. Elizabeth earned her B.S. in Civil Engineering from Seattle University, and she is a licensed Professional Engineer in Washington State.*

Mark Pinske *is an Associate Engineer at Delve Underground. He received his B.S. and M.S. in Civil Engineering from the University of California, Davis. Mark has over 14 years of geotechnical engineering experience on a variety of underground construction projects including tunnels, shafts, and excavation support. He is a licensed Professional Engineer in Washington State, California, and Idaho.*

Paul Mockus *is a Lead Associate Engineer at Delve Underground. He has over 14 years of structural design experience for underground structures and works primarily on projects associated with rail and highway transit and water/wastewater storage/ conveyance. Paul has a B.S. in Civil Engineering and a M.S. in structural engineering, both from Purdue University. He is a licensed Professional Engineer in Washington State, California, and the District of Columbia.*

Fig. 1: Surface preparation complete; preparing for shotcrete placement

Lessons Learned on Spillway Shotcrete Overlay

By Billy Roy, P.E.

In early 2017, Knowles Industrial Services Corporation (KISC) was issued a contract by Great River Hydro, LLC (GRH) to perform a reinforced shotcrete overlay on an overflow spillway at Comerford Dam in Monroe, NH. The original Request for Bids specified that cast-in-place concrete be used, with no substitutions provided. After multiple site visits to better understand staging and access, debris removals, and placement logistics, KISC began to develop a value-engineered approach involving the use of air-entrained wet-process shotcrete to replace the cast-in-place specification.

The 58,000 ft^2 (5400 m^2) spillway surface is ogee-shaped at the crest. This curvature made design and construction of concrete formwork difficult. Additionally, the crest was located directly beneath the access bridge, making placement of forms with hoisting equipment nearly impossible without disassembling the bridge deck. Shotcrete placement was presented as a small-footprint option requiring little to no crane work throughout the duration of the project. This also made it easy to accommodate the existing surface curvatures.

The toe of the dam is a combination of ledge and wetland growth, making the construction of an access road difficult

and environmentally invasive. The owner was receptive to methods involving a smaller footprint. KISC proposed using cable climber scaffolding systems for elevated access and line pumps for conveying concrete. Shotcrete placement allowed elimination of heavy formwork, which in turn eliminated the need for cranes and fixed scaffolding. During the bid review process, several different repair methods and logistics plans were presented. KISC provided a unique, low-cost, reinforced shotcrete approach — and while shotcrete placement has proven to be the best option, we've learned some lessons along the way in ensuring a safe and strong spillway.

LESSONS LEARNED

PUMPING / NOZZLING SAFETY IS #1

No job is important enough to ever sacrifice the safety of the crew members and others around them. The shotcrete industry is often the underdog when compared to conventional form-and-pour methods. As such, greater visibility and scrutiny are placed on the safety measures employed in the shotcrete process. PPE is a necessary baseline, but more importantly, shotcreters must consider pumping and nozzling safety. Scaffolding systems must be built to provide firm and stable footing, free from the risk of falls. A comfortable and safe shotcrete crew shoots and finishes more effectively and is more aware of their surroundings. Pump operators must be experienced with various concrete mixtures and comfortable with anticipating plugs before they happen. Understanding pump pressures, hose accessibility, safe hose de-coupling techniques, replacement of excessively worn delivery lines and proper pump cleaning procedures can help ensure injuries are avoided.

A WELL-DESIGNED AND EXECUTED CONCRETE MIXTURE IS EVERYTHING

For all shotcrete projects, and specifically projects in remote locations such as this one, concrete mixture designs must be carefully considered and executed by a trusted vendor partner. With access on dams and spillways being so complicated,

Fig. 2: Typical steel reinforcing: #5 (#16M) L-dowels at 2 ft (0.6 m) spacing with a #5 rebar at 1 ft (0.3 m) on center each way

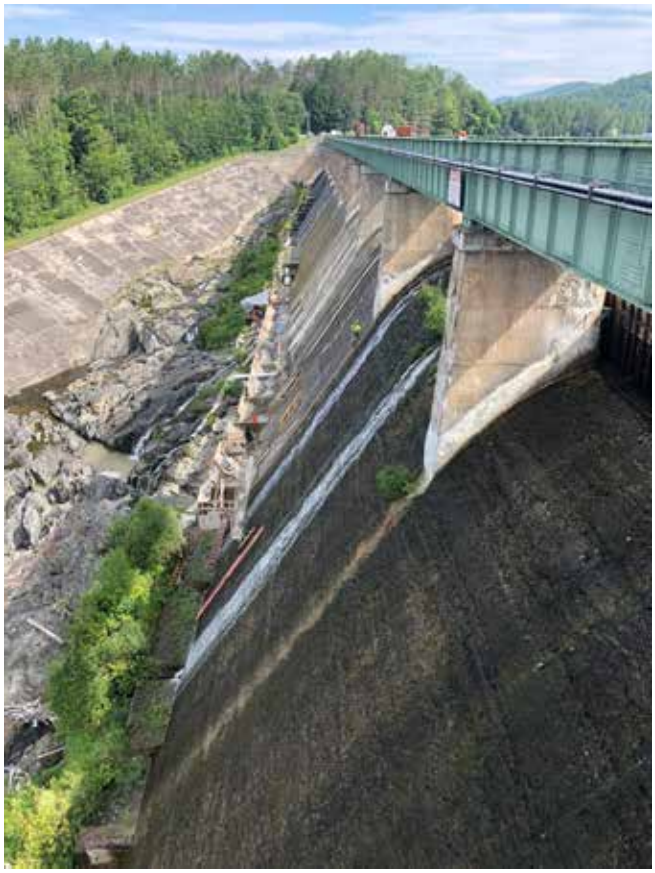

Fig. 3: View of the entire 850 ft (260 m) long overflow spillway

hose plugs and premature initial set can be catastrophic. It's imperative to develop a strong relationship with the local concrete supplier, founded on patience, good communication, and collaboration.

USE ADMIXTURES THOUGHTFULLY

Wet-mix shotcrete has come a long way from 1 to 2 in. (25 to 50 mm) slump mixture with uncontrollable initial set times. Mid-summer concrete placements are especially susceptible to quicker and potentially unexpected set times. Complex staging and access arrangements make rapid placement difficult, requiring additional time to place 10 yd^3 (8 m^3) loads effectively and safely. A hydration stabilizer was used to delay the initial set and to provide additional working time. A high-range water-reducing admixture was added to enhance workability and pumpability without compromising strength through excessive addition of water. A rheology modifier was added when the concrete arrived at the site to allow for deeper placements and more effective bench shooting. Microsynthetic fibers were dosed at a rate of 2.5 lbs/yd^3 (1.5 kg/m^3) for plastic shrinkage crack control. Site conditions must be carefully considered when designing the various ingredients to be put into a prospective mixture.

BE CONSISTENT BUT FLEXIBLE WITH THE MIXTURE

Not all concrete mixes are created equal, and the same mixture is not always optimal in different environments. It's easy to become complacent and go with what's simple from

Fig. 4: Completion of Bays 5, 6, 7, and 8 in 2019

a pumping and placement perspective. However, seasons change; including temperatures (highs and lows), humidity, wind, length of daylight, etc. It's important to remember that shotcrete mixes are not one-size-fits-all. They must be carefully considered and designed to meet the performance needs of the job as well as the environment in which it's being placed and cured.

USE ENGINEERING CONTROLS

Dams are especially susceptible to excessive surface evaporation due to wind and sun. As such, achieving Saturated Surface Dry (SSD) is imperative to combat drying and plastic shrinkage cracking. After shotcrete placement, we found it helpful to use a combination of finishing agent and evaporation control product to protect the concrete during the curing process. These products assisted with workability while finishing the concrete, while also providing significantly more protection against evaporation from wind and sun exposure.

NEVER UNDERESTIMATE THE NEED FOR PROPER EDUCATION AND TRAINING

As with many shotcrete projects, the repair method is site- and job-specific. Having crew members who fully understand the work is imperative to delivering a good project. To assist with this, KISC employed the services of RCS Consulting. Ray Schallom assisted with pre-job planning, concrete mixture designs, equipment selection, pumping logistics, and supplemental crew training. Investing in training and education for the crew was time and money well spent.

THE IMPORTANCE OF BENCH SHOOTING

Much of the shotcrete application exceeded 12 in. (300 mm) in depth. Our process involved bench shooting while mobilizing the scaffolding up the spillway to fill the section and prevent sloughing. The final 2 to 3 in. (50 to 75 mm) of shotcrete placement was achieved while mobilizing the scaffolding down the spillway. This allowed for proper cutting and finishing techniques to not damage the finished surface.

UNDERSTANDING YOUR FOOTPRINT AND SITE GEOMETRY

When specifying shotcrete placement as a substitute for conventional form-and-pour concrete, it's essential to highlight the laydown area and equipment footprint required for each construction approach. Shotcrete placement offers an incredible advantage for sites with limited access or small staging and laydown areas. The elimination of heavy formwork, in turn, reduces the amount of hoisting and heavy lifting required from cranes or other equipment. In the shotcrete industry, we continually strive to be safer, more economical, and more sustainable than conventional concrete and provide clear value for owners.

SUMMARY

KISC mobilized Phase 1 in 2017. Fast forward to 2025 and approximately 70% of the spillway has been successfully restored with a reinforced overlay using shotcrete placement. The project is scheduled to be completed in 2027 as the owner has elected to complete the work on a multi-year, phased approach. At completion of the project, KISC will have demolished and replaced approximately 1700 yd^3 (1300 m^3) of concrete. This collaborative, value-engineered approach demonstrates how shotcrete placement can effectively and efficiently meet the unique needs of complex projects. With licensed professional engineers and several ACI-certified shotcreters on staff, we developed a repair method and specification that met the intent and performance expectations of the original form-and-pour specification.

Several lessons were learned, but the most important was the concept of continuous learning. We found that success often requires thinking of new placement and finishing techniques, exploring new concrete mixture designs with appropriate admixtures, upgrading with better equipment and tool technology, and staying connected with other members of the industry. Adaptability and lifelong learning are key components to staying successful and guaranteeing future success in the shotcrete industry.

ABOVE: *Fig. 5: Typical shotcrete placement from a suspended scaffolding system*
BELOW: *Fig. 6: Shotcrete pumping and chemical dosing operation from the bridge overhead*

Billy Roy *is the Vice President for Knowles Industrial Services Corporation based in Gorham, ME. He received his B.S. in Construction Engineering Technology and M.B.A. in Engineering Management, both at the University of Maine. He is a licensed Professional Engineer in the State of Maine, and specializes in design and management for shotcrete placement, concrete repair, and pressure grouting projects throughout New England, with a focus on the Power Generation and Utilities sectors. Billy is an ACI Certified Concrete Testing Technician, ACI Certified Shotcreter (Dry-Mix and Wet-Mix), NACE CIP Level 2 Coatings Inspector, and holds a Lead Abatement Supervisor certification with the State of Maine.*

Blue Plains DC Water – World's Largest Advanced WWTP

SewperCoat® Rehabilitation with Dry-Mix Shotcrete Placement

By Sam Zakeri

Maintaining wastewater infrastructure is essential for public and environmental health in our communities. Treatment plants collect effluent from nearby areas and treat the water before discharging it into local waterways. DC Water operates Blue Plains, the largest Advanced Wastewater Treatment Plant servicing Washington D.C., northern Virginia, and southern Maryland. The plant opened in 1937 and treats an average of 300 million gallons of wastewater from over 2 million people daily. The processed water is discharged into the Potomac River and meets strict permit limits.

The grit chambers at this site experience aggressive biogenic corrosion conditions from bacteria that naturally exist in wastewater systems. These concrete grit chambers frequently needed repairs and protective linings installed, but nothing lasted long-term. In 2012, a pilot project was conducted with shotcrete installation of Imerys's SewperCoat® in a single grit chamber. After 5 years of service, they were impressed with the results and Coastal Gunite Construction Company lined the remaining grit chambers, totaling 54,000 ft^2 (5000 m^2) from April 2017 to June 2018.

Biogenic corrosion is commonly misunderstood as a direct chemical acid attack, but this does not account for the biological cause. The biogenic corrosion occurs above the water line where bacteria colonize on the surface and lower the pH by generating acid during their metabolic activity. Biogenic corrosion can rapidly deteriorate ordinary portland cement (OPC) concrete at rates up to 1 in. (25 mm) per year if not protected. This is visibly seen as yellow sulfur deposits, exposed aggregates, and a biofilm on the surface. This process directly attacks concrete and steel and indirectly delaminates inert liners by attacking the substrate from behind if any imperfections exist (Fig. 1).

The mechanism of biogenic corrosion is important to understand. The process begins with sulfate-reducing bacteria in the effluent that convert sulfur-containing compounds into hydrogen sulfide (H_2S). This H_2S is released into the vapor space as concentration rises in the effluent and with turbulent flow. Bacteria on the surfaces above the flow line convert this H_2S into elemental sulfur and then sulfuric acid. This acid reacts with calcium hydroxide and calcium

Fig. 1: Biogenic corrosion attacks concrete and steel

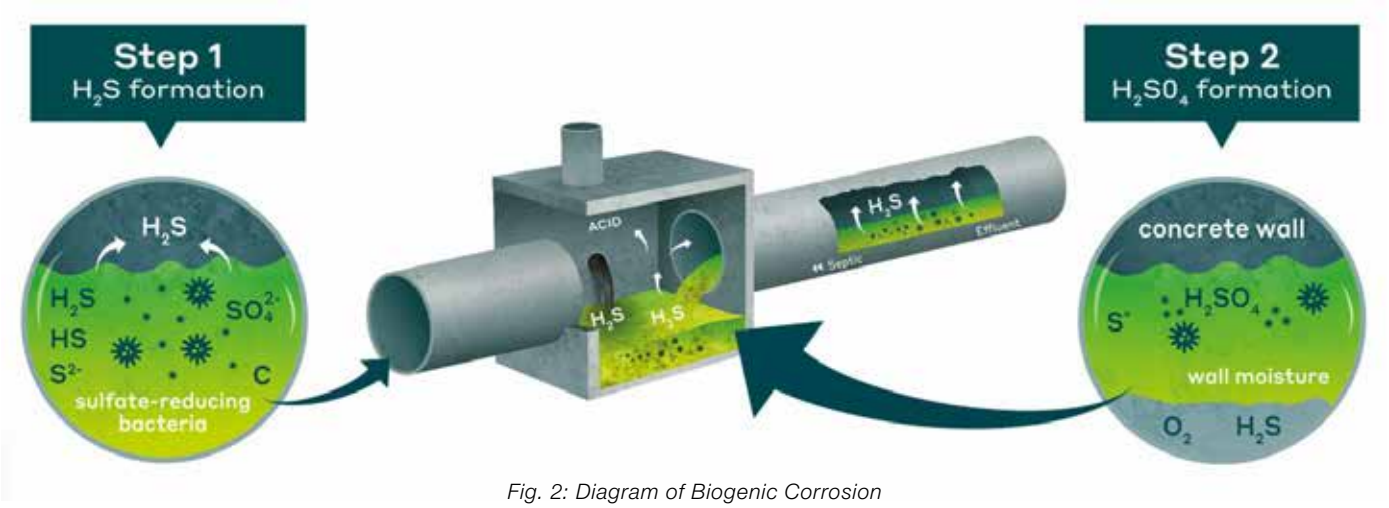

Fig. 2: Diagram of Biogenic Corrosion

silicate hydrates found in the portland cement matrix. The calcium hydroxide reacts with sulfuric acid to create gypsum. This total process converts hard concrete into a soft, water-soluble gypsum powder (Fig. 2).

The SewperCoat® spray-applied cementitious protective lining has unique material properties that make it resistant to corrosion in aggressive wastewater environments. The binder and aggregate system is 100% calcium aluminate cement (CAC) and calcium aluminate fused synthetic aggregate. The grit chamber rehabilitation used a dry-mix shotcrete repair mortar formulation. The material readily adheres to a rough concrete surface profile (CSP) greater than 4 and damp concrete surfaces. The CAC mortar is designed as a lining but is still tough, having 8000 psi (55 MPa) compressive strength at 24 hours. This allowed for rapid return to service and structural enhancement by replacing the corroded portland cement elements. The unique chemistry of calcium aluminates results in the formation of alumina hydroxide during hydration, which dramatically inhibits bacterial activity and maintains a higher surface pH. The minimum protective lining thickness recommended is 0.5 in. (13 mm), however, a 2 in. (50 mm) application was used here to repair the damaged structure as well as provide robust protection.

Surface preparation is critical to a successful installation. Hydrodemolition was used to remove damaged concrete and the failing epoxy liner. A substrate that is clean, free of loose materials, structurally sound and with a saturated surface dry (SSD) surface condition is required for good bond with the shotcreted materials (Fig. 3).

Dry-mix shotcrete placement allowed staging equipment and raw materials in a single location, using a rotary dry-mix gun to convey the dry material a long distance to the installation location, where water was introduced at the nozzle. The grit chambers at Blue Plains were in difficult locations to access and shotcrete placement was the only practical way to install cementitious mortar efficiently. The SewperCoat® mix

Fig. 3: Surface preparation via hydrodemolition

Fig. 4: Dry-mix application on wall

Fig. 5: Dry-mix application on column and beam

can be shotcreted on any surface shape, including overhead (Figs. 4 and 5).

After the material is sprayed, workers commonly use a trowel to cut back the surface for a consistent thickness throughout. The surface has a rough gunned finish.

Satisfied with the results, Blue Plains has continued to use SewperCoat® in current and future rehabilitation projects. This year, work is being conducted on the headwork influent and effluent structures that require rehabilitation. This is a 3-year-long project that will be conducted in phases, mostly involving repairs of large underground pipes. So far, about 750 ft^3 (21 m^3) of material has been applied. The ongoing project installation volume will largely depend on the condition of the structures after hydro-demolition. Many of these structures have not been repaired in 100 years and require extensive work. Shotcrete placement and CAC technology create an easy-to-apply and long-term solution for asset owners in the wastewater industry.

Sam Zakeri *is a Technical Support Manager for the Imerys infrastructure Americas segment. He specializes in calcium aluminate technologies and is a member of ACI Committee 201-K Biogenic Attack.*

THE CONCRETE BOOKSHOP

The Concrete Society

The Concrete Bookshop supplies a range of publications, digital downloads and webinars on concrete.

Technical Report 18:

A guide to the selection of admixtures for concrete

This is a non-technical guide to admixture selection for those who are not materials specialists. It recognises the many applications of admixtures and their effects on the properties of concrete. The guide is in two parts: The first provides a general overview of admixtures and usage trends. The second consists of a series of Information Sheets showing the main admixture types.

2002, 60 pages

Non-members: £50 **Members: £30**

Technical Report 70

Historical approaches to the design of concrete buildings and structures

Approaches to the design of concrete structures have changed considerably since the first national Code of Practice for reinforced concrete was published in 1934. This report summarises the contents of all the relevant Codes and Standards, from the earliest guidance up to about 1990.

2020, 56 pages Format: PDF

Non-members: £40 **Members: £24**

Technical Report 44

The relevance of cracking in concrete to corrosion of reinforcement

This report examines the relevance of cracking in concrete on the corrosion of reinforcement. The first edition in 1995 was a response to BRE publications, which suggested that cracks in concrete structures can give rise to reinforcement corrosion. In this new edition, the discussion has been reassessed to bring it in line with current thinking.

2015, 38 pages

Non-members: £33.75 **Members: £20.25**

Concrete Advice Sheet No 19

Historic reinforcing bars and steel fabric

In assessing an existing structure, there is often a need to determine the load capacity of reinforced concrete elements. Original drawings would have been prepared in accordance with the then current Standards. This sheet provides information on how Standards have changed.

2016, 3 pages Format: PDF

Non-members: £8.00 **Members: £4.80**

Concrete Advice Sheet No 23

Large area pours for suspended slabs

Large area pours for suspended slabs improve both productivity and quality. This document provides background information to help designers and contractors avoid unnecessary restrictions on pour size and gives sources of information on the provision of reinforcement to control cracking due to restrained early thermal movements.

2020, 3 pages Format: PDF

Non-members: £10 **Members: £6**

Concrete Advice Sheet No 33

Axial shortening of concrete columns in high-rise buildings

Reinforced concrete is the chosen material for many medium- and high-rise buildings of 8–20 storeys and beyond. For such structures, the prediction and control of axial shortening are becoming increasingly important.

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Practical Benefits of Shotcrete on Geotechnical Projects

By Michael Klemp

This article covers the advantages of using shotcrete placement for soil nail projects. In permanent soil nail structures, shotcrete offers a wide variety of architectural finishes that can be produced economically and efficiently. This is in stark contrast to the limited options offered by using traditional form-and-pour or precast concrete panels.

DISADVANTAGES OF FORM-AND-POUR AND PRECAST PANELS

Let's look at the disadvantages of the alternatives to shotcrete placement:

PRECAST CONCRETE PANELS

When using precast panels, the lead time and scheduling requirements can add significant time and coordination to a project. The panels must be designed not only for the in-place loads but also for loads from transportation and erection. Additionally, the precast must be transported from the plant to the job sites. This incurs trucking costs, as well as costs for staging or on-site storage. Many soil nail job sites are in relatively remote areas and may have limited or difficult access that complicates the transportation.

Areas under bridges can be hard to access with lifting equipment. This results in making the setting of precast concrete panels under bridges very difficult and time-consuming. When setting the precast panels, you typically need a leveling pad to support them or backfilling behind the panels. This requires a low-strength concrete to either be delivered or mixed on-site.

Finally, using precast entails using more heavy equipment. This includes cranes and off-road forklifts that would not be needed for a shotcrete placement project.

FORM-AND-POUR PANELS

Form-and-pour methods of constructing concrete panels require double-sided forms. These forms need to be shipped to the site or fabricated on-site. The forms need to withstand the liquid pressure of wet concrete when pouring the concrete into the form, which requires the formwork to be heavy to carry the internal pressures. The time just erecting or building the forms on-site can be time consuming and expensive. Additionally, after pouring the panel, the forms need to be stripped and then disposed of or transported to storage. Soil nail walls are built to tight tolerances and form-and-pour doesn't provide the flexibility or bond of shotcrete placement against the surface.

Figs. 1 and 2: Soil nail wall in progress

Another consideration after stripping the form-and-pour forms is that there are bug holes and sometimes voids from improper vibration. Preparing the surface and patching these areas are time-consuming tasks that require close attention to surface preparation, materials used, and application to get a good bond of the repair materials.

As in the precast panels, the form-and-pour option requires a leveling pad of low-strength concrete. This essentially acts as a firm base to set the forms (and subsequent placement of concrete) upon. Anchoring the panels to the soil nail wall is also time-consuming, and there is always patching required.

THE MANY ADVANTAGES OF USING SHOTCRETE PLACEMENT

Shotcrete placement significantly reduces the time on the job, and on construction jobs, time is money. It reduces time on-site and exposure to changing weather conditions.

SO WHY IS SHOTCRETE PLACEMENT SO ADVANTAGEOUS?

- There is little or no formwork to erect, strip, and transport. Not only does this save time and cost, but it also means that using shotcrete is more sustainable, using less lumber and transportation.

Figs. 3 and 4: Soil nail wall in progress

- Shotcrete placement can easily adapt to varying soil surface profiles.
- Smaller equipment is needed on-site and can reduce mobilization to a minimum.
- Shotcrete placement requires less of a footprint during the installation. Wherever we can run the delivery hose, we can place quality concrete.
- A leveling pad is not required, which reduces both cost and schedule. With no leveling pad, the wait time needed for curing and strength gain is totally eliminated.
- There are no anchoring requirements besides the Nelson studs on the bearing plate that is attached to the soil nail. You simply install the required reinforcing steel onto the Nelson studs, install piano wire for thickness control, then shotcrete and sculpt the fresh concrete surface of the panels.
- The tolerance on the soil-nail section of the wall is less critical to the overall construction, as there is room for slight imperfections of the wall face.

Overall, shotcrete placement is more than twice as fast for soil nail panel construction when compared to traditional panel installation, regardless of whether this is form-and-pour or precast. Thus, using shotcrete placement is more efficient, saves money, and provides more flexibility in scheduling field operations.

Michael E. Klemp *is the CEO and Business Development Officer of Thorcon Shotcrete and Shoring, LLC, a geotechnical construction firm based in Littleton, Colorado. With a strong background in construction management, Klemp has led Thorcon in delivering complex design-build solutions involving micro-piles, soil nails, tie-backs, rock anchors, and sculpted shotcrete. The company is responsible for a project at West Point Military Academy involving 80,000 ft² (7400 m³) of reinforced sculpted shotcreted facing, as well as a significant shoring wall in El Paso TX, including a grouted slurry wall, soil nails, tie-backs, and alignment shotcrete, summing up to $21M in work. Beyond Thorcon, Klemp is involved in several other ventures, including GeoCraft Builders, BDM Capital Time Investments, Sentry Siren, TSS Equipment Leasing, and MK Ranch.*

Traffic Repairs Using Low-Dust Shotcrete Material

MONITOR-MERRIMAC TUNNEL PROJECT

By Thomas Brennan

Flexibility, efficiency, and cost effectiveness drive dry-mix shotcreting as a popular application method for concrete repair, especially in tunnel and bridge applications. In high-pressure situations with a short turnaround, shotcrete contractors can mobilize with minimal equipment to complete structural repairs, both vertical and overhead, rapidly. Historically, the dust associated with dry-mix shotcreting caused hesitation in projects in urban or live traffic environments; however, recent innovations in low-dust materials have significantly changed planning considerations. The Monitor-Merrimac Tunnel project combined careful construction planning with new material technology to execute emergency repairs using shotcrete placement, without closing the tunnel for more than a few minutes at a time.

WHAT CAUSES DUST IN SHOTCRETE?

Due to the nature of cementitious materials, dust prevention can be highly challenging. The small particles associated with cement, sand, and other cementitious powders are key contributors to dusty environments, especially in confined installation areas with shotcreting. In the case of dry-mix shotcreting, there are two clear avenues for dust to occur: At the dry-mix gun hopper and at the nozzle. As shown in Fig. 1, between the concrete material being dumped into the hopper and the agitation of the dry material once inside, the dry-mix hopper area traditionally emits quite a bit of dust. Predampening of the dry-mix materials can help to reduce the level of dust at the gun.

The second and more commonly identifiable source of dust

Fig. 1: Dry-mix gun hopper

Fig. 2: Dry-mix shotcrete application

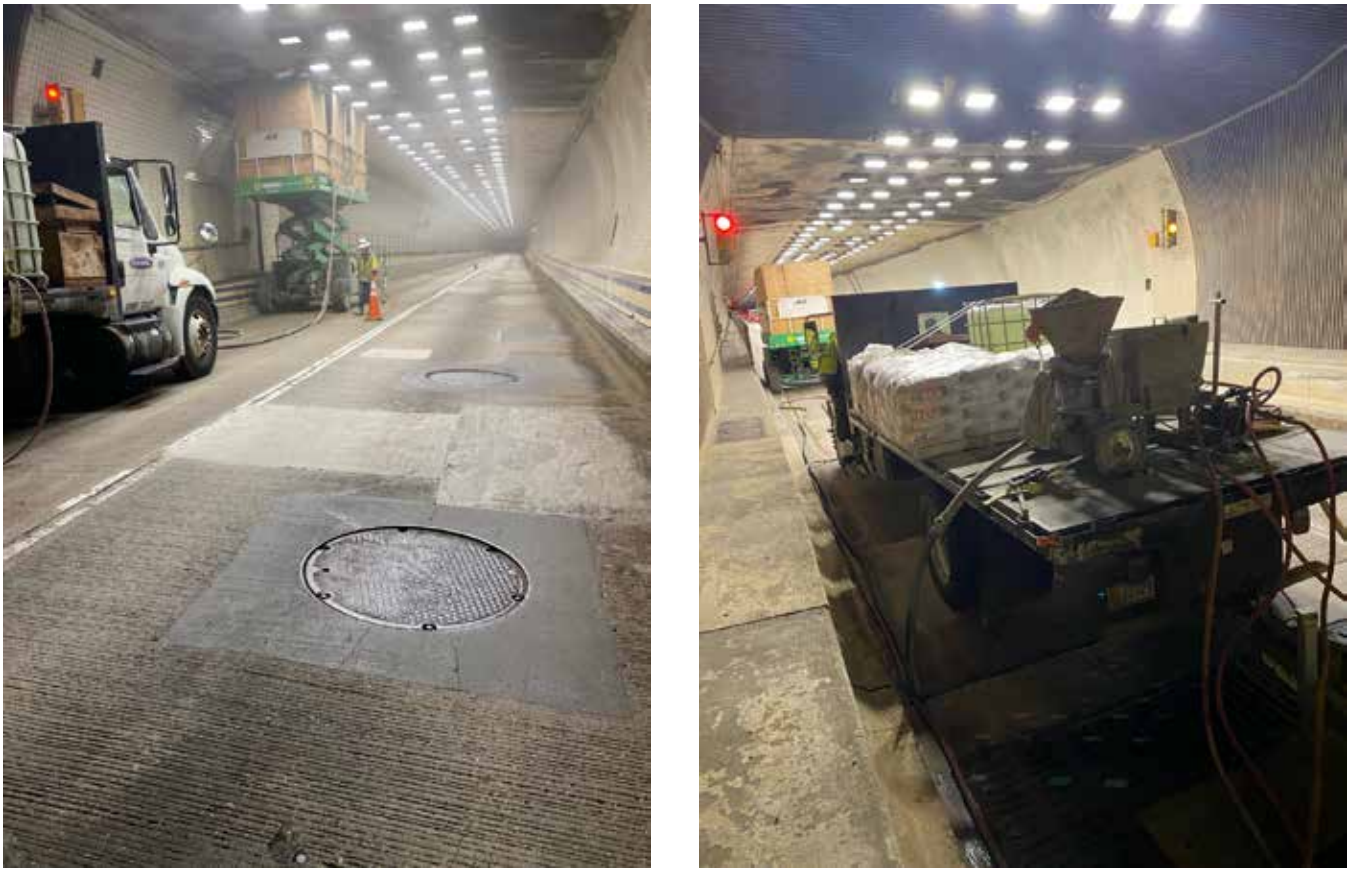

Fig. 3: Shotcrete placement in the tunnel

in shotcreting is the placement process, as illustrated in Fig. 2. The amount of dust generated at the nozzle and point of placement may necessitate additional oversight, specialized nozzles, and protective equipment. Proper use of a hydromix nozzle can significantly reduce dust produced at the nozzle.

When significant dust and high rebound occur, a lower quantity of concrete is retained in the repair area. Thus, in addition to the dust exposure, the concrete materials are not used as efficiently as possible. As ACI 506 details, coarse aggregate selection in a shotcrete mixture design plays a significant role in rebound (ACI PRC 506-22). Aggregate gradation, as well as the use of supplementary cementitious materials like silica fume, are key when discussing shotcrete mixture performance, as approved gradations have been designed to ensure proper compaction and account for the rebound of larger particles.

STRIDES IN DUST REDUCTION TECHNOLOGY

The additional equipment and concrete delivery logistics often associated with wet-mix shotcrete placement can lead to selecting a lower-dust dry-mix material. The American Shotcrete Association (ASA) has published articles (**shotcrete.org/articles**) showcasing significant research aimed at reducing dust in dry-mix shotcrete. Historical tests have consistently shown that success in dust reduction is often accompanied by durability challenges, lower later-age strengths, or reduced early strengths (Clements & Fournier, 2020).

Over the last few years, however, there have been breakthroughs in the technology associated with dry-mix shotcreting additives that do not compromise other material properties. For example, proprietary admixtures recently became available that have been shown to reduce dust by up to 95% compared to traditional dry-mix shotcrete materials. When combined with properly graded aggregate, these admixtures function to reduce both dust and rebound.

The admixture has been included in the single component mix, which can be installed like any other dry-mix material for shotcreting, but results in significantly less dust and, consequently, rebound. As expected, less rebound equates to more material in place, reducing waste. By reducing dust without compromising other material properties, the resulting product is not only safer but also a more efficient for completing dry-mix repairs with shotcrete placement.

SUCCESS AT THE MONITOR-MERRIMAC TUNNEL

Emergency repair needs were identified at the Monitor-Merrimac Tunnel when delamination was discovered during an inspection in July 2022. As inspections were completed, worry grew that the delaminated concrete, which was located on the ceiling of the tunnel, would endanger motorists driving through the tunnel. As a result, emergency priority was quickly given to closing lanes of traffic at night to complete the repairs and remove the threat to traffic.

Coastal Gunite Construction's recent track record of completing similar work with VDOT on a nearby tunnel made

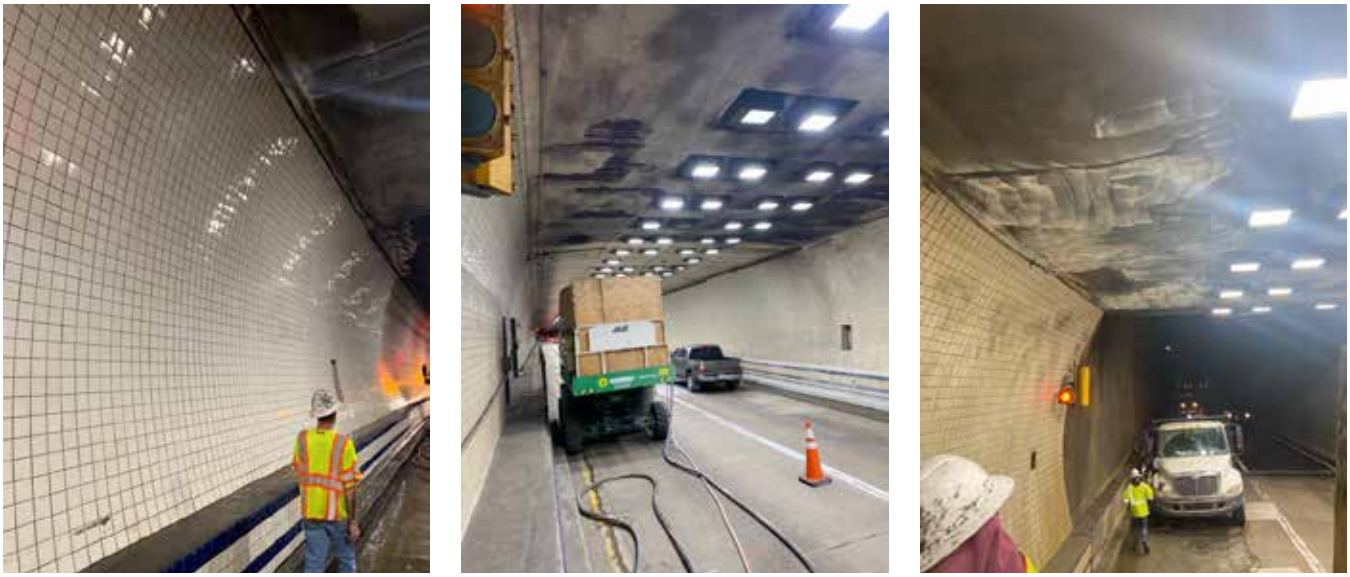

Fig.4: Mobile staging allowed quick move in and move out

them an outstanding candidate to complete the job. Once the project characteristics were established, shotcrete placement using the novel dustless admixture technology was identified as a perfect fit, given the traffic stoppages would only be 15-20 minutes in lieu of a total closure.

To ensure safe removal and shotcrete placement next to traffic, a scissor lift was boxed in with plywood. A demolition hammer was used to remove all the loose and delaminated concrete, embedded corroded utilities were replaced, and deteriorated steel was repaired or replaced. After the repair locations were cleaned and the existing concrete surfaces were properly prepared, a Piccola rotary gun was used for shotcrete placement of a low-dust dry-mix, as shown in Fig. 3. Emergency preparedness in the tunnel required a procedure for rapid tunnel evacuation. With the compact nature of the dry-mix shotcrete process, all equipment and materials can be quickly loaded onto a truck for evacuation (also shown in Fig. 3).

The use of low-dust shotcrete material provided several benefits to the team throughout the project's duration. Given the short window of time to pause traffic, it was vital that as much concrete be placed in as short a window as possible, cleanup of rebound be minimized, and the shotcrete placement have minimal impact on visibility. The low-dust shotcrete material ensured that all three of these key execution items were possible.

The increase in productivity and decrease in cleanup ensured the repairs were complete when the outage time had expired. Similarly, motorists were never impacted by unsafe road conditions associated with lowered visibility. The use of low-dust dry-mix shotcrete material ensured that the Monitor-Merrimac Tunnel project was an efficient and effective repair, minimizing regional traffic impacts.

CONCLUSION

Understanding what causes dust on a concrete repair site allows for the proper mitigation measures to be put in place, minimizing crew exposure. In dry-mix shotcrete placement, understanding the relationship between the manufacturer's mixture design and rebound can significantly impact dust exposure, enabling optimal material selection. Every project is different, but reducing dust in confined spaces, such as the Monitor-Merrimac Tunnel, offers an advantage from both safety and construction planning perspectives. On projects with higher complexity, collaboration between the material supplier and the contractor can make a difference, in the success or failure of the job.

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2. Clements, W., & Fournier, C. (2020). Developing Dust Reduced and Low Cracking Potential Dry-Mix Shotcrete Mixes. *American Shotcrete Association*.

***Thomas Brennan**, USCP Technical Manager holds a Bachelor of Science in Mechanical Engineering from UMass Amherst and has spent his entire career in construction. After five years as a project engineer with ExxonMobil in Houston, Mr. Brennan joined USCP in October 2021. Thomas currently oversees the QC program and leads the development of new products in addition to supporting sales efforts nationwide. Thomas is a member of the board of directors for the Baltimore-Washington ICRI Chapter. He is a certified ACI Field Testing Technician Level I, a published author in both the ICRI Concrete Repair Bulletin and the American Shotcrete Association's "Shotcrete" magazine, and a previous ICRI National convention speaker.*

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Managing Groundwater Using Shotcrete

By Michael Klemp

Managing groundwater using shotcrete placement involves integrating structural reinforcement with effective waterproofing strategies to ensure durability and prevent water ingress in underground or below-grade structures.

KEY TECHNIQUES FOR GROUNDWATER MANAGEMENT WITH SHOTCRETE

DRAINAGE SYSTEMS

In areas with active groundwater flow, it's essential to install drainage mechanisms before applying shotcrete. This typically involves drilling weep holes and inserting short pipes filled with quick-set mortar to redirect water away from the receiving surface. Drainage mat systems can also be used to control groundwater at the receiving surface. These drainage mats are placed on the wall before shotcrete placement, and depending on the groundwater flow rate, 20 to 100% of the wall may be covered.

WATERPROOFING MEMBRANES

- Spray-Applied Membranes: These are essentially coatings applied directly onto the substrate to create a seamless barrier that prevents water from flowing through and withstands the high-velocity shotcrete application of concrete.
- HDPE Dimple Sheets: High-density polyethylene sheets with a dimpled surface to provide a somewhat roughened surface to enhance the bond of the shotcrete placement and provide drainage channels for groundwater behind the sheet.
- Bentonite-Based Sheets: Comprised of sodium bentonite between geotextiles, these membranes swell upon contact with water, sealing potential leaks and accommodating minor movements in the structure.

SHOTCRETE APPLICATION

After installing the waterproofing system, shotcreted concrete is applied in layers. The initial layer may be thinner to lessen the impact and provide support of the system, while subsequent layers provide the structural strength of the concrete section. The final layer can be finished as required, from a gun finish to a floated or even a carved finish. Proper sequencing of the shotcrete placement with careful attention to maintaining the integrity of the waterproofing membrane is key to a successful project.

Fig. 1: Shooting soil nail wall with drainage behind

ADDITIONAL SEALING OF THE CONCRETE

Some specifiers also like to decrease the effective natural permeability of the placed concrete. Though quality concrete with 28-day compressive strengths over 4000 psi (28 MPa) and proper placement is functionally watertight, there are concrete admixtures that can further reduce permeability. Though these permeability-reducing admixtures (PRA) are often called "waterproofers", as they help fill the natural pores in the concrete matrix and thus reduce permeability, they do not, however, make concrete entirely impermeable against water. Most of these admixtures are crystalline-based, but supplementary cementitious materials, such as silica fume, fly ash, and slag, will also help reduce the permeability of concrete. ACI PRC 212.3-16 *Report on Chemical Admixtures for Concrete* is a good reference for PRAs.

CRYSTALLINE PERMEABILITY REDUCING ADMIXTURES

Some of the most common PRA in concrete are crystalline materials. The crystalline materials are hydrophilic (attract water), and exposure to water causes them to increase the density of the cement hydration products and generate

Fig. 2: Tall soil nail wall shot from top to bottom

additional deposits to help fill the pores in the concrete. The result of the materials "growing" in the concrete matrix can also help to fill existing microcracks and capillaries.

Although crystalline PRA can potentially seal static, non-moving cracks in concrete, it is less effective against moving cracks. Cracks in concrete sections exposed to temperature swings are not static, non-moving cracks and will open and close due to the thermal volume change in the concrete.

There are two primary methods for using crystalline PRA in shotcrete placement: admixture or surface applied. Proper mixing and curing are essential to activate crystalline growth, and shotcrete application must ensure complete coverage and compaction.

ADMIXTURE METHOD

The PRA is blended directly into the concrete mixture during batching. This is desirable for wet-mix shotcrete, as it is part of the concrete matrix, reducing permeability from within. Depending on the manufacturer, the dosage typically ranges from 0.8% to 2% by weight of cementitious material.

SURFACE TREATMENT METHOD

For existing or exposed shotcreted surfaces, a slurry with a high concentration of the PRA is applied as a brush-on or dry-pack. It is suitable for dry-mix or where integral PRA was not used, and helps to seal static cracks and surface pores post-application.

SUMMARY

Shotcrete placement with quality concrete materials and proper application creates concrete sections with high strength and inherently low permeability. Many designers specify the use of membrane systems (spray-applied, sheet, or bentonite) to provide a primary barrier to groundwater contact or to relieve pressure against the shotcreted concrete. Crystalline PRAs may be used with the concrete shotcreted against the membrane systems. The PRAs can also be used in applications where a membrane system is not needed, but a lower permeability or ability to seal small, static cracks and voids is desired.

Fig. 3: Soil nail wall with drainage panels to be shot in next

Fig. 4: Final carved soil nail wall

All these groundwater control techniques benefit from shotcrete placement's ability to eliminate formwork and easily adapt to irregular surfaces, while providing structural integrity, and longevity in challenging environments.

Michael E. Klemp *is the CEO and Business Development Officer of Thorcon Shotcrete and Shoring, LLC, a geotechnical construction firm based in Littleton, Colorado. With a strong background in construction management, Klemp has led Thorcon in delivering complex design-build solutions involving micro-piles, soil nails, tie-backs, rock anchors, and sculpted shotcrete. The company is responsible for a project at West Point Military Academy involving 80,000 ft^2 (7400 m^3) of reinforced sculpted shotcreted facing, as well as a significant shoring wall in El Paso TX, including a grouted slurry wall, soil nails, tie-backs, and alignment shotcrete, summing up to $21M in work. Beyond Thorcon, Klemp is involved in several other ventures, including GeoCraft Builders, BDM Capital Time Investments, Sentry Siren, TSS Equipment Leasing, and MK Ranch.*

Shotcrete Resources

Shotcrete is used for new structural concrete construction and a variety of pool, repair, and repurposing applications. ACI offers numerous industry-leading shotcrete products and programs. Some highlights include the newly released, ACI PRC-506.8-24, “Shotcrete Use in Pool Construction - Guide”; On-Demand Course: “Shotcrete—Guide and Specification”; and more. For a complete list of all shotcrete products and programs, visit **www.concrete.org** or **www.shotcrete.org**.

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Care & Feeding of Your Engineer on Shotcrete Projects

By Christoph Goss

Most readers of this article have probably had some terrific — and some less than terrific — experiences on shotcrete construction projects. While some projects just sailed along smoothly with everyone wanting to work together again, others were a miserable slog that might have ended up in lawsuits. Often the project experience is driven by the relationship between the engineer and the contractor. As an engineer working at an engineering company and spending a lot of time on job sites, I would like to share some thoughts aimed at contractors who would like to have more effective communication with their engineers.

STARTING OFF WELL

One of the defining characteristics of engineers is that they dislike risk. As Scott Adams's *Dilbert* once stated, "It is the goal of every engineer to retire without getting blamed for a major catastrophe." This attitude likely came from engineering design, where you come up with every possible way something can fail and design to avoid that. Concrete can fail in a variety of ways; including shear, compression, diagonal tension, bending, and debonding.

Designing to avoid these failure modes requires assumptions for the calculations of concrete strength, thickness, and bond. Once the calculations are complete, the engineer prepares drawings and specifications for bidding and construction. These specifications then typically require submittals and testing, both before and during construction, to show that what is being built matches the assumptions in the calculations.

"I love submittals" is a phrase that no one has ever said. Submittals are tedious to prepare and review, but they are also vital to effective construction communication between the contractor and engineer. In submittal packages, contractors describe how they will build the designed project, who will build it, the materials that they will use, and how it will be tested. By describing how and with what the project will be built, the engineer can verify assumptions, and the contractor can propose value engineering options. It is much cheaper and more effective for all parties to do this before mobilization than in the middle of construction.

THOUGHTS ON CONCRETE MIXTURE DESIGN

Concrete mixture designs are one of the key submittals on a shotcrete placement project. While the engineer is most concerned with the final in-place specifications (strength, sometimes permeability or shrinkage), the mixture must be effective for shotcrete placement. That means it must:

Fig. 1: If a dozer runs over your panel, throw it out

- Be pumpable for the project delivery line setup;
- Give enough working time, and;
- Be shootable for the specific project needs

For example, some mixtures are optimized for overhead placement, others for pools, others for thick highly congested reinforced walls, and others for small repair patches. There is no single perfect concrete mixture. During the preconstruction submittal phase, it is best to get several mixtures approved for flexibility and fewer delays — ideally from different suppliers in case a plant is unavailable. Another good idea is to have prepackaged bags of an approved mixture on site that can be mixed and used when no off-site supply is available.

Fig. 2: Shooting test panels

Specifications typically require the mixture design to include information on the various components because small details can have a major impact. For aggregate, this includes sizing and mineral properties for potential alkali-silica reaction problems. For cement, the type (C-150 I-V or C-595 1L) along with supplementary cementitious materials like fly ash, slag, and silica fume are critical. For chemical admixtures, the focus should be on compatibly between both the chemical admixtures and the cementitious materials. For underground projects, dosage and rapid-set accelerator compatibility with the rest of the mix is critical. The intent is to avoid unpleasant surprises in the field. If you are on a state DOT or some federal projects, find out if they require special testing or pre-approval by their labs.

WHAT IF THE SPECIFICATIONS ARE BAD?

As an engineer, I find bad specifications appalling; fortunately, there is an effective solution. The American Concrete Institute (ACI) publishes the following guides, tech notes, and specifications for shotcrete placement:

- ACI PRC 506-22: Shotcrete - Guide
- ACI PRC 506.1-21: Fiber Reinforced Shotcrete - Guide
- ACI SPEC 506.2-13 (18): Specification for Shotcrete
- ACI PRC 506.4-19: Guide for the Evaluation of Shotcrete
- ACI PRC 506.5-22: Specifying Underground Shotcrete - Guide
- ACI PRC 506.6-17: Visual Shotcrete Core Quality Evaluation - Tech Note
- ACI PRC 506.7-23: Shotcrete Preconstruction Mockup - TechNote

If you find a section of the project specification unpalatable, look up that section in the ACI documents and politely point out the discrepancy to the engineer. In most cases, the engineer will agree that following these recommendations is acceptable. For bonus points, check out ASA's searchable *Shotcrete* magazine archive (**shotcrete.org/articles**) and share with the engineer some similar projects where shotcrete placement and your approach were successful.

TESTING IS PROGRESSING

During or upon completion of the submittal process, other pre-construction qualifications are carried out. This typically involves the shotcreters demonstrating that they can shoot what is required for the project with preconstruction panels. In some cases, it is just a material test panel to confirm the concrete's hardened properties, while for projects with complex geometry or congested reinforcement, a mockup panel representing the most challenging configuration is required. The material or mockup panel should be shot using the proposed concrete mixture and shotcreting equipment. Material test panels are normally shot vertically. Mockup panels are generally shot in the same orientation as needed on the project. Get the number and type of panels required sorted prior to construction.

Once construction begins, the field quality control (QC) program is used to demonstrate that the shotcrete placement meets the design requirements. The QC plan should be a submittal describing what kind of panels will be shot at what intervals, as well as how and by whom they will be tested. Check the plan against both the project specifications and the ACI recommendations or requirements. Keep an eye out

for specific requirements — for example, instead of using standard shotcrete material test panels, is it acceptable to take concrete material cylinders at the truck, or is coring of in-place material required? Testing requirements must be clear before the project starts construction.

EDUCATE EVERYONE

The next suggestion is a hard one: Consider educating the inspector to be a growth opportunity for all, instead of a shouting match that makes your ready-mix trucks time out. If you have regular inspectors on site, take the time to teach them about shotcrete placement and the ACI recommendations. Even better, let them know about the ACI Shotcrete Inspector Certification. ASA's "Quality Shotcrete – Know It When You See It" seminar is more than just the education that supports ACI's Shotcrete Inspector program; it also provides knowledge about industry standard shotcrete practice you can use in your efforts to educate. Having an ACI-Certified Shotcrete Inspector on your team also makes sense: It ensures your crew delivers high-quality shotcrete placement on every project while also giving you the credibility to show your project owner or less experienced inspector what quality shotcrete placement should look like. If you already have the required work experience, add this credential to your company's offerings as well, starting at **shotcrete.org/inspector**.

MATCH TO KEEP MOMENTUM

During construction, ensure that the shotcrete placement matches what you documented in the submittals and QC plan: Engineers hate discrepancies and will call you out. Use the right material and equipment, and make sure that the crew has the lighting, ventilation, access, and safety equipment to let them do a good job safely and efficiently. Empower your crew, particularly the shotcreter, to stop work if the material is not right or the equipment is malfunctioning. It is much less expensive to send away a truck or have the crew on standby than to spend several shifts removing defective concrete.

Invite the engineer and inspector to watch the placement and show them how the shotcreter controls the placement sequence, distance, and angle. If you see the crew doing something incorrectly or unsafely, stop the shotcreting in front of the engineer and correct it. Proper placement the first time is in the best interest of all.

During placement, have an effective method of measuring shotcrete thickness and share that with the engineer. It can be a grade line, internal template, monitoring nails, pattern rock bolts with constant hardware stick-out, or pre- and post-placement Lidar scans.

Compare the theoretical volume to the actual volume and see if they make sense. If you are using a rapid-set accelerator, check the actual volume used for each truck and compare that to the mixture design and preconstruction testing: Too little accelerator will make the shotcreted concrete more likely to fall or have low early strength, whereas too much accelerator will weaken it.

For materials testing, make sure that test panels are protected for at least 24 hours and then carefully taken to the lab: In colder weather, significantly more than 24 hours may be required to have adequate strength to tolerate moving to the testing lab. You want to make sure that they reflect what you are doing in the field. Also, confirm that the lab knows

Fig. 3: Shooting underground on a platform with good light and ventilation

Fig. 4: Use guides for alignment and thickness

how to sample panels and test shotcrete. Get the results to the engineer promptly, but check the results before you pass them on. If a tested sample does not meet the specification requirements, figure out why, point it out, and have some corrective measures ready — do not wait for the engineer to tell you that a test failed, because it suggests that you are hiding something.

YOU'RE ON THE SAME TEAM

If you have a better or different way of doing the work, explain well in advance why your way is better, and with lots of detail.

- Get technical and document your assertions; provide data (the more the better), testing (standardized), and experience.
- Reference ACI shotcrete documents or ASA's *Shotcrete* magazine articles to prove your recommendations have been used successfully.
- Present facts, not vague thoughts — certainly not sales pitches — and be transparent about what you know and do not know.
- Be realistic about the pros and cons.
- Give the engineer time to digest the data and do independent research.

If you are not sure what the engineer is looking for, read the specifications and plans. Get the engineer onboard with your approach, and the project will go more smoothly.

Throughout the project, keep in mind that the contractor, owner, suppliers, and engineer all want the same thing: A project built correctly and within budget.

Disclaimer: These are my thoughts and do not necessarily reflect those of Schnabel Engineering.

Christoph Goss *is a Principal Engineer, Tunnels & Underground at Schnabel Engineering in Longmont, CO with a PhD in Mining Engineering and BS in Civil Engineering, both from Colorado School of Mines. His work has been mostly in tunnels, underground mine rehabilitation, ground support design, site investigations, and as resident engineer during construction. He has been an ACI Shotcreter Certification Examiner since 2007, is an ACI Certified Shotcrete Inspector, and currently serves as chair for the Underground Committee and on the Board of Directors of the American Shotcrete Association.*

Fig. 1: Fabric reinforcement exposed, inner wear liner missing

Shotcrete Hoses

SELECTION, INSPECTION, AND SAFE INSTALLATION

By Michael Cetnar

Hoses play a crucial role in efficient shotcrete placement for any job site. The operator and jobsite personnel are either near or in direct contact with many hoses, and as it is difficult to track hose wear using yardage figures, it's very important to inspect every hose every time it is used.

Three key considerations should be kept in mind when working with shotcrete hoses: Select the proper hose for the application, conduct a thorough inspection before use, and adhere to safe jobsite practices while using them.

SELECTING THE RIGHT HOSE

Using the wrong hose for the job can have significant safety implications and negative consequences.

- Certified Product: The Concrete Pump Manufacturers Association (CPMA) performs independent audits of products and manufacturers to confirm that all certified hoses and pipes meet safety standards. Start with a CPMA-certified product that is designed specifically for the severe wear and rugged usage of shotcrete placement.
- Length: Flexible hose can be up to four times harder to pump concrete through than steel pipe due to differences in friction, which means the pump must work four times harder and consume significantly more fuel. The pressure required to pump will drastically increase, taxing every component in the system and

creating the potential for a blowout if any component is unfit to withstand the load. The higher internal friction can also increase the risk of having the concrete mixture plug in the line. In all laydown applications, use the minimum length of hose necessary to reach the point of placement.

- Site Requirements: The need for hose flexibility and radius of curvature varies depending on the application. Laydown lines may need to avoid obstacles along the path or be easily positioned when relocating on top of rebar sleds. All premium hoses are manufactured with an internal liner, layers of reinforcement (typically fabric or steel cord), and a tough weather- and wear-resistant outer wrap. Your manufacturer should be able to match the hose design, materials, and fabrication to meet your application requirements.
- Working Pressures: The compatibility of the hose with the pump and concrete mixture design is essential. The smaller the hose diameter, the higher the pumping pressure required to pump a given mixture at the same volume output rate. The aggregate in the concrete must also not be larger than 1/3 of the hose's inside diameter. For the best results, size the system to the largest diameter that is practical for the application. Always use a hose rated for working pressures that exceed the pump's rated output.

Fig. 2: Hose body worn through, exposing the hose beneath it; can be seen and felt as a bumpy wear pattern by using your fingers

INSPECTION OF HOSES

Shotcrete hoses are constantly subjected to wear, both internally from the concrete being pumped and externally from the punishing construction environment. Because they are made from rubber (which is more easily damaged than steel pipes), it is essential to regularly inspect them for damage that could result in decreased efficiency, costly downtime, and unsafe conditions leading to potential accidents.

A thorough pre-pumping inspection is the first step in guaranteeing that everything runs smoothly. The following guidelines outline the steps for conducting an effective inspection.

OUTSIDE COVER

Examine the outside cover for bulges, folds or kinks, and soft spots. These defects may indicate that the inside reinforcement layer could be broken or displaced due to overinflation, deterioration, or side-loading trauma (such as using a heavy sledgehammer to clear a plug). The result is a weak point that will not perform as expected during operations. These hoses should be replaced.

Check for cracks, tears, abrasions, missing material, or exposure of the inner reinforcement layer. Over time, this may cause deterioration of the reinforcement layers, resulting in full-blown ruptures under pumping pressures, and should be monitored for near-term replacement.

INNER LINER

Examine the inner liner for localized wear areas that indicate wall thinning, paying special attention to the first twelve inches adjacent to the metal hose body.

Use a flashlight to examine the entire length for signs of exposed reinforcement (sometimes referred to as bird nesting or spider webbing), loose plies, or cuts and gouges. When working with a steel-reinforced hose, avoid reaching into a damaged hose to prevent cuts. Exposed materials indicate a worn patch that is weakened and cannot withstand full pumping pressures. This can also interfere with the smooth flow of concrete.

Excessive, dried concrete residue inside the hose can restrict flow and increase pumping pressures. Also be aware of any discoloration or corrosion, particularly at the hose ends, which can point to chemical degradation or exposure to harsh environments.

METAL ENDS (HOSE BODY)

Examine the inlet face of the metal hose body for the wear known as bell-mouthing. Excessive material loss is detrimental to its functionality. Periodically measure the inside opening diameter with a bore gauge and verify with the manufacturer to determine what level of wear is acceptable.

Examine the inside of the hose body, particularly under the barb area, for signs of wear. This can be seen and felt as a bumpy wear pattern using your fingers. This indicates the hose body has worn completely out, and the hose assembly

must be retired immediately.

Verify that the hose is visible through the ferrule inspection hole. If it is not, the hose may have started to slip out of the hose body assembly.

ADDITIONAL SAFETY CONSIDERATIONS

- Hoses can get soft and flimsy over time. A flimsy hose can kink more easily, and more care must be taken to prevent a kickback.
- Repetitive pressure pulses can cause a hose to lose its pressure-handling capability over time. Even though a hose passes visual inspection, its age or usage may hurt its ability to handle pressure (especially fabric-reinforced hoses).
- Hoses that have experienced heavy sun damage can dry out, causing the hose to lose flexibility and increasing the effort required by crew members in the field.
- It's good practice to document a complete inventory of your hoses every six months. Thorough inspections should be completed and manufactured dates documented; remove any damaged or old hoses from service. Consult your manufacturer for information on production dates and the expected shelf life of your specific hose model.

INSPECTION OF COUPLINGS & GASKETS

The metal ends of the rubber hose and the connecting components are crucial to its safe and effective operation. Proper inspection of all connections is necessary.

- Examine the surface of the hose body assembly (where the rubber gasket attaches) for damage such as nicks, dents, and abrasions. Ensure the area is free of concrete buildup, which may indicate prior gasket leakage or inadequate sealing action by the coupling.
- Ensure that the mating parts are correctly aligned. Poorly connected hose ends or misaligned couplings can cause serious accidents or leaks.
- Ensure that couplings are securely fastened and free from damage or wear. The coupling must make a tight and flush fit to avoid leaks or detachment during pumping. Remember to use safety pins in all snap couplings.
- Before making every connection, inspect the gasket, clean out the grout, and ensure the gasket can seal the joint.

HOSE JOBSITE SAFETY

The best shotcrete hoses in the world should be matched with the best job-site operational practices.

- Never kink the hose to stop the flow of concrete. Kinks cause blockages and pressure spikes that can violently and uncontrollably straighten out under pressure. Kinking also damages the reinforcement elements of the hose.

Fig. 3: Bulge in outer hose jacket exposing a 'soft spot' in the hose

- Do not attempt to resolve a hose kink by crushing the sides; this will damage the reinforcing materials and lead to a faster failure.
- Only use hoses with a working pressure rating that meets or exceeds the maximum pressure rating of the concrete pump with which it is being used.
- Extreme care must be taken before opening any coupling when dealing with a plugged system.
- Never look into a hose that is plugged.
- Never sit on or stand on a hose while it is in operation.
- Never use a hose with frays, breaks, or exposed braiding/reinforcement on either the inside liner or outside shell.
- Only use compressed air to clean out a hose, exercising extreme care and confirming the ends of the hose are firmly tied down. Water cleanout is much preferred.
- Never drag a hose by pulling on the attached coupling.
- Never beat on a hose with a hammer or other blunt object. The impact risks damaging the built-in reinforcing material, potentially leading to premature failure.
- Always perform the internal and external visual inspections before every shoot, even if this is the second shoot of the day.

CONCLUSION

By following the above steps, proper care and regular inspection of your shotcrete hoses will provide a safer job site for you and your customers.

Michael Cetnar *has been in the pumping industry for over 30 years, operating, maintaining, and managing concrete and shotcrete pumps on many different projects. He is also a safety trainer for the ACPA as well as a member of the ASA Safety and Education Committee. Michael is currently working at Con Forms, selling concrete and shotcrete delivery systems for the past 10 years.*

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ACI Resource Centers have teamed up with ASA to present ASA's Shotcrete Inspector Education, which supports the ACI Shotcrete Inspector Certification program.

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Answering the Call

A CONSTRUCTION INDUSTRY RESPONSE TO THE OPIOID OVERDOSE CRISIS

By Joseph Whiteman, CSP, CHST

> Between 2011 and 2020, nearly 30% of all overdose deaths in construction involved opioids. Construction workers remain nearly seven times more likely to die from an opioid overdose than the average American worker. **That's not just a public health crisis — it's a jobsite crisis.**

You don't always see it coming. Opioid overdoses aren't always tied to illicit use or addiction in the traditional sense; many begin with a prescription after a jobsite injury or surgery. But just as often, they stem from an unspoken yet common reality in our industry, with workers quietly self-medicating to power through the day. Years of hard labor leave lasting pain, and in an environment that values toughness, consistent production, and showing up no matter what, masking that pain can feel like the only option. Add in long hours, economic pressures, uncertainty about future work, and a constant push to 'make the cut,' and you have a high-risk environment where stigma and silence often stand in the way of life-saving intervention.

That's where the Alliance for Naloxone Safety in the Workplace (ANSW) comes in.

WHAT ANSW IS, AND WHY IT MATTERS

ANSW.org is the product of a unique industry-wide collaboration, a volunteer effort formed by a small but dedicated group of safety professionals, trade association representatives, general contractors, specialty contractors, and industry-aligned professionals. The goal was simple but urgent: Create a free, credible, and easy-to-use resource that would help employers and workers respond to the growing overdose crisis in construction.

This resource wasn't built by outsiders or consultants: It was built by people in the field, for people in the field.

WHAT YOU'LL FIND AT ANSW.ORG

The ANSW website houses a wide range of tools and training resources to raise awareness, reduce stigma, and equip workers to act in the event of an opioid overdose. These include:

- **Free online naloxone awareness training**, hosted by an industry-trusted Learning Management System (LMS)
- **Downloadable SCORM files** for companies with their own LMS, completely free to import for their use internally
- **A model naloxone policy** for employers to adopt or adapt internal protocols
- **Educational tools** for overdose recognition and emergency response
- **Industry-specific insights** into pain management, recovery, and support

Most importantly, ANSW is a nonprofit volunteer initiative — not a commercial enterprise. It's still managed by the same core group of volunteers who built it, and it remains relevant, up-to-date, and grounded in the needs of the industry. It's even featured on the White House's official list of workplace opioid safety resources.

A JOBSITE TOOL — NOT JUST A HEALTH TOOL

We focus daily on delivery line bursts, hose whipping, fall protection, and scaffold safety. But opioid overdoses — often quiet, stigmatized, and overlooked, remain one of the deadliest and least discussed threats on our jobsites.

This isn't just about 'drug use'. It's about the long-term toll of a physically demanding profession, where workers often push through pain until something breaks. Naloxone is a jobsite tool, just like CPR training or AED access — and one that can make the difference between life and death.

ASA'S ACTIVE SUPPORT

The American Shotcrete Association (ASA) is already helping to bring this conversation to the forefront. On its website, **shotcrete.org**, ASA has added ANSW to its Safety Resources section, giving members direct access to free training, sample policies, and overdose response tools.

Even more, ASA has now formally joined ANSW as a Proud Supporting Organization, committing to share this vital information and resource with its membership and stakeholders. ASA's support underscores what we all know to be true: Addressing the opioid crisis is not optional — it's essential.

The construction industry has always looked out for its own. ANSW — now supported by ASA — is one more way to do just that, visibly, practically, and without stigma. Visit **ANSW.org** to explore the free training, download your own naloxone policy, and access tools to help protect your workforce. Because safety isn't just about safety glasses, helmets, and harnesses anymore.

Opioid Overdose: What to Look For & How Narcan Helps

COMMON SIGNS OF OVERDOSE:

- Slow or stopped breathing
- Unconscious or unresponsive
- Pale, clammy, or bluish skin
- Gurgling, choking, or snoring sounds
- Very small (pinpoint) pupils

ABOUT NARCAN (NALOXONE):

- A fast-acting medication that quickly reverses the effects of an opioid overdose
- Available over the counter in most states
- Most commonly available as a nasal spray, it's easy to use with minimal training
- Restores breathing within 2–3 minutes
- Safe to use — it won't harm someone who is not experiencing an overdose

WHY IT MATTERS:

- Quick action can save a life
- Legal to carry and administer in nearly all states
- Simple enough to be kept in jobsite first aid kits or with foremen, designated responders, or trained personnel

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***Joseph Whiteman**, CSP, CHST, is the Director of Safety Services for the American Society of Concrete Contractors (ASCC), bringing over 20 years of construction safety experience. His background includes leadership roles with Turner Construction and Morley Construction, both with a strong focus on structural concrete. Since joining ASCC in 2018, Joseph has supported the organization's mission to help contractors build safer jobsites and stronger safety cultures. A U.S. Marine Corps combat veteran and Purple Heart recipient, he is also a committed 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.*

AMERICAN SOCIETY OF CONCRETE CONTRACTORS
Enhancing the Capabilities of Those Who Build with Concrete

Respondiendo al Llamado

LA RESPUESTA DE LA INDUSTRIA DE LA CONSTRUCCIÓN A LA CRISIS DE SOBREDOSIS POR OPIOIDES

Por Joseph Whiteman, CSP, CHST

> Entre 2011 y 2020, casi el 30 % de todas las muertes por sobredosis en la construcción involucraron opioides. Los trabajadores de la construcción siguen teniendo casi siete veces más probabilidades de morir por sobredosis de opioides que el trabajador estadounidense promedio. **Esto no es solo una crisis de salud pública: es una crisis en el lugar de trabajo.**

No siempre se ve venir. Las sobredosis por opioides no siempre están vinculadas al uso ilícito o a la adicción en el sentido tradicional; muchas comienzan con una receta después de una lesión en el trabajo o una cirugía. Pero, con la misma frecuencia, se originan en una realidad no dicha pero común en nuestra industria: trabajadores que, en silencio, se automedican para poder continuar su jornada.

Años de trabajo físico intenso dejan un dolor persistente y, en un entorno que valora la dureza, la producción constante y la presencia sin importar qué, ocultar ese dolor puede parecer la única opción.

Si a esto sumamos largas horas, presiones económicas, incertidumbre sobre el trabajo futuro y una presión constante por “cumplir con la meta”, tenemos un entorno de alto riesgo donde el estigma y el silencio a menudo bloquean intervenciones que salvan vidas.

Ahí es donde entra la Alliance for Naloxone Safety in the Workplace (ANSW), Alianza para la Seguridad con Naloxona en el Lugar de Trabajo.

QUÉ ES ANSW Y POR QUÉ IMPORTA

ANSW.org es el resultado de una colaboración única en toda la industria, un esfuerzo voluntario formado por un pequeño pero dedicado grupo de profesionales de seguridad, representantes de asociaciones comerciales, contratistas generales, contratistas especializados y profesionales vinculados al sector.

El objetivo era simple pero urgente: crear un recurso gratuito, confiable y fácil de usar que ayude a empleadores y trabajadores a responder a la creciente crisis de sobredosis en la construcción.

Este recurso no fue creado por consultores externos: fue creado por gente de la construcción, para gente de la construcción.

LO QUE ENCONTRARÁS EN ANSW.ORG

El sitio web de ANSW alberga una amplia gama de herramientas y recursos de capacitación para aumentar la conciencia, reducir el estigma y capacitar a los trabajadores para actuar en caso de una sobredosis por opioides. Entre ellas:

- Capacitación gratuita en línea sobre naloxona, alojada por un proveedor de LMS de confianza en la industria.
- Archivos SCORM descargables para empresas que cuenten con su propio sistema de gestión de aprendizaje (LMS), completamente gratis para su uso interno.
- Un modelo de política sobre naloxona para que los empleadores la adopten o adapten a sus protocolos internos.
- Herramientas educativas para reconocer una sobredosis y responder en emergencias.
- Información específica del sector sobre manejo del dolor, recuperación y apoyo.

Lo más importante: ANSW es una iniciativa voluntaria sin fines de lucro, no un negocio comercial. Aún es gestionada por el mismo grupo central de voluntarios que la creó y se mantiene relevante, actualizada y enfocada en las necesidades de la industria. Incluso está incluida en la lista oficial de recursos de seguridad laboral de la Casa Blanca sobre opioides.

UNA HERRAMIENTA PARA EL LUGAR DE TRABAJO — NO SOLO DE SALUD

Nos enfocamos a diario en peligros como estallidos de mangueras, latigazos de líneas, protección contra caídas y seguridad en andamios. Pero las sobredosis por opioides — a menudo silenciosas, estigmatizadas y pasadas por

alto — siguen siendo una de las amenazas más mortales y menos discutidas en nuestros lugares de trabajo.

Esto no se trata solo de "consumo de drogas". Sino del impacto a largo plazo de una profesión físicamente exigente, donde los trabajadores a menudo suelen seguir trabajando a pesar del dolor hasta que algo se quiebra. La naloxona es una herramienta del lugar de trabajo, al igual que la capacitación en RCP o el acceso a desfibriladores (AED), y puede marcar la diferencia entre la vida y la muerte.

APOYO ACTIVO DE ASA

La American Shotcrete Association (ASA) ya está ayudando a poner esta conversación en primer plano. En su sitio web, **shotcrete.org**, ASA ha añadido ANSW en la sección Recursos → Recursos de Seguridad, brindando a los miembros acceso directo a capacitación gratuita, modelos de políticas y herramientas para responder a sobredosis.

Además, ASA se ha unido formalmente a ANSW como una Proud Supporting Organization (Organización Patrocinadora Orgullosa), comprometiéndose a compartir esta información vital y este recurso con sus miembros y partes interesadas. El apoyo de ASA subraya lo que todos sabemos que es cierto: Enfrentar la crisis de opioides no es opcional; es esencial.

La industria de la construcción siempre ha cuidado a los suyos. ANSW — ahora con el apoyo de ASA — es una forma más de hacerlo, de manera visible, práctica y sin estigmas. Visita **ANSW.org** para explorar la capacitación gratuita, descargar tu propia política de naloxona y acceder a herramientas para ayudar a proteger a tu fuerza laboral. Porque la seguridad ya no se trata solo de gafas de seguridad, cascos y arneses.

Sobredosis por Opioides: Qué Buscar y Cómo Ayuda Narcan

SIGNOS COMUNES DE SOBREDOSIS:

- Respiración lenta o detenida
- Inconsciente o no responde
- Piel pálida, fría o tono azulado
- Sonidos de gorgoteo, asfixia o ronquidos
- Pupilas muy pequeñas (puntiformes)

SOBRE NARCAN (NALOXONA):

- Medicamento de acción rápida que revierte rápidamente los efectos de una sobredosis por opioides
- Disponible sin receta en la mayoría de los estados
- Generalmente disponible como aerosol nasal, fácil de usar con capacitación mínimo
- Restablece la respiración en 2–3 minutos
- Es seguro — no dañará a alguien que no esté sufriendo una sobredosis

POR QUÉ IMPORTA:

- Actuar rápidamente puede salvar una vida
- Es legal llevarlo y administrarlo en casi todos los estados
- Lo suficientemente simple como para mantenerse en botiquines de primeros auxilios en el lugar de trabajo o con capataces, respondedores designados o personal capacitado

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***Joseph Whiteman**, CSP, CHST, es el Director de Servicios de Seguridad de la American Society of Concrete Contractors (ASCC), con más de 20 años de experiencia en seguridad en construcción. Su trayectoria incluye roles de liderazgo en Turner Construction y Morley Construction, ambos con fuerte enfoque en concreto estructural. Desde que se unió a ASCC en 2018, Joseph ha apoyado la misión de la organización para ayudar a los contratistas a construir lugares de trabajo más seguros y fortalecer las culturas de seguridad. Veterano de combate del Cuerpo de Marines de EE.UU. y receptor del Corazón Púrpura, también es un defensor comprometido de la salud mental y la prevención del suicidio en la industria de la construcción. Joseph mantiene certificaciones CSP y CHST y posee un título en seguridad y salud ocupacional.*

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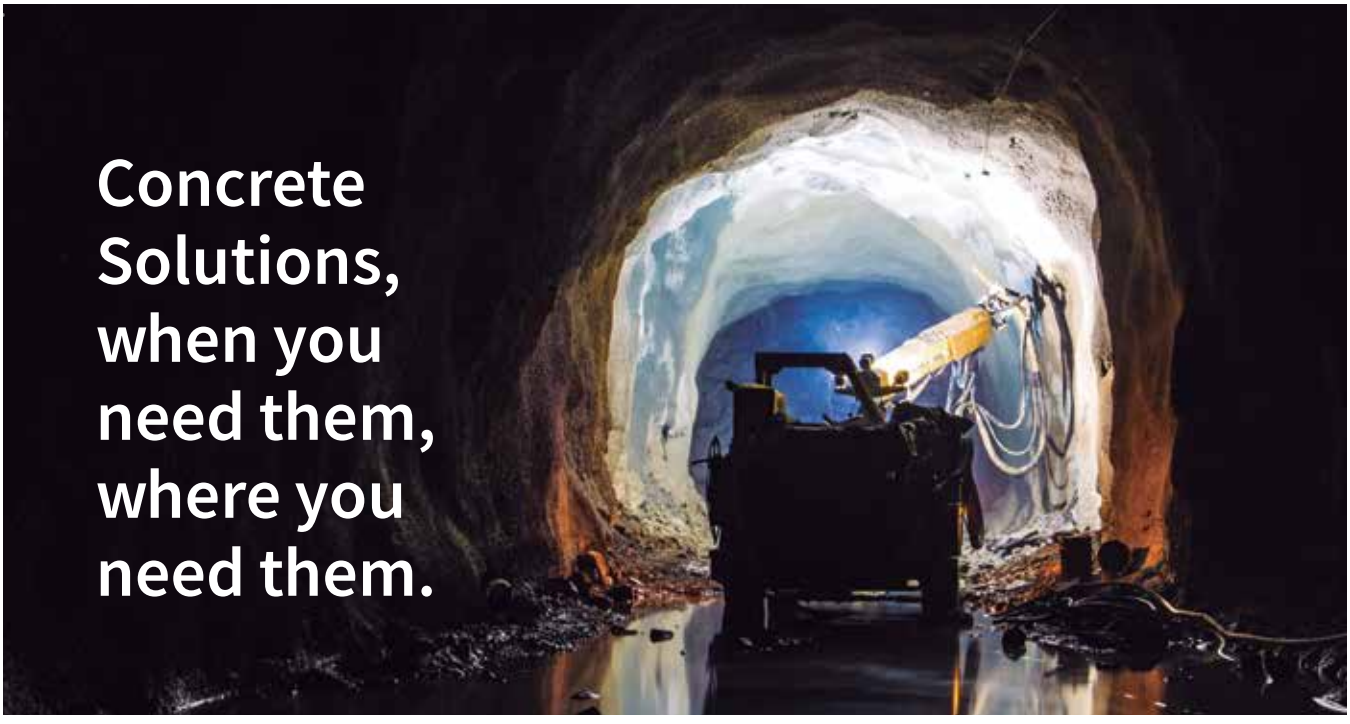

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- Available in diesel OR electric power

SCAN ME

TK 1005

- A compact pump that handles harsh mixes
- CAT 3.6 diesel engine
- Used for a variety of civil applications

SCAN ME

TK 1005H

- Pushes low slump shotcrete mixes long distances with little loss of volume
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SPM 500 WETKRET

- Vertical spraying reach of 17 m
- Ideal for medium and large tunnels, caverns and slopes

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WETKRET 3

- 7 m horizontal spraying reach
- Designed for shotcreting in small tunnel sections with difficult access

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WETKRET 4

- 8.5 m spraying reach
- Robust and compact chassis
- homogeneous shotcrete application
- Ideal for underground mining

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WETKRET 5

- 17 m spraying reach
- Shotcreting for demanding underground projects with medium to large cross-sections

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KORDSA

THE REINFORCER

INNOVATING SYNTHETIC FIBER REINFORCEMENT SOLUTIONS FOR SHOTCRETE APPLICATIONS

Kordsa, a global supplier of tire and construction reinforcement, and composites, operates in 11 facilities throughout 7 countries, including the USA, Türkiye, Brazil, Indonesia, Thailand, Italy, and Germany with over 4500 employees. Through its mission to "Reinforce Life", Kordsa aims to create sustainable value to all its stakeholders and society, by combining high value-added reinforcement technologies with innovation for over 50 years.

Initially recognized for its expertise in tire reinforcement and composite industries, Kordsa has expanded its scope to deliver innovative synthetic fiber reinforcement solutions and structural reinforcement systems for construction reinforcement. With a focus on cutting-edge technology, Kordsa's construction reinforcement brand, Kratos™, offers products that provide solutions that address the demands of shotcrete applications worldwide.

Shotcrete placement has become indispensable in modern concrete construction, particularly for underground and mining projects where speed, strength, and safety are paramount. Kordsa's synthetic fibers, such as CE-certified Kratos Macro PP 54+ (Fig. 1) and Kratos Macro PP 60+, offer reinforcement solutions for shotcrete placement. Engineered to replace traditional steel mesh, these fibers ensure enhanced crack control, improved toughness, and long-lasting durability.

Made from high-performance polypropylene, Kratos macro fibers provide a 3-dimensional reinforcement structure within the concrete mixture, allowing for better load distribution and crack resistance. This makes them particularly suited for high-stress environments such as tunnels, slopes, and underground mining spaces. Additionally, the corrosion-free nature of these fibers makes them ideal for applications in challenging environments, as exposure to moisture, aggressive soils or

Fig. 1: Kratos Macro PP 54+ Synthetic Fibers

chemicals could corrode traditional steel reinforcement.

Kratos fibers also significantly streamline the shotcrete process, reducing labor and equipment costs while accelerating the application timeline by up to 25%. Their ease of handling and rapid integration into concrete mixtures ensures faster project completion, making them the go-to choice for time-constrained projects globally.

Moreover, Kratos structural carbon fiber polymer (CFRP) reinforcement systems are a second product group in the Kratos concrete reinforcement portfolio. These CFRP products are primarily used to strengthen structures. It can be used to repair a structure that has been damaged by earthquake or accident, to extend the life of a structure, or to increase the capacity of a structure to support additional loads.

In shotcrete applications, material loss due to rebound during spraying can be significant, especially in mining and underground constructions. Kratos RM (Fig. 2) is a synthetic fiber designed to address this issue head-on. This micro synthetic fiber reduces rebound by ensuring that more shotcreted concrete adheres to the surface. Kratos RM is particularly suited for challenging underground environments where efficient material use and fast strengthening of tunnel excavations are critical to operational success.

A COMMITMENT TO INNOVATION IN SHOTCRETE APPLICATIONS

Kordsa's dedication to advancing synthetic fiber technologies is evident in its Research and Development Center. The R&D team continually works to optimize fiber solutions that meet the specific challenges of shotcrete applications in the underground and mining industries.

This commitment was recently recognized with the 1st Place Award for the Macro Innovative Fiber Project of the Year by the Fiber Reinforced Concrete Association (FRCA), for the TCDD Yerkoy-Sivas Safety Tunnels Project in Türkiye (Fig. 3) — a major infrastructure initiative utilizing advanced macro synthetic fiber technologies.

With a dedicated focus on quality, safety, and sustainability, Kordsa remains a global leader in delivering reinforcement technologies that are essential to the construction industry.

CONTACT INFORMATION:

Kordsa
kratos@kordsa.com
www.kordsa.com
www.kratosreinforcement.com

Fig. 2: Kratos Rebound Minimizer Synthetic Fibers

Fig. 3: TCDD Yerkoy-Sivas Safety Tunnels Project / Türkiye

Show Off Your Company

SUBMIT A STANDOUT ASA MEMBER PROFILE

By Cara Baker, Managing Editor

Is your company a Sustaining or Corporate Member of the American Shotcrete Association (ASA)? Then you have a unique opportunity to be featured in *Shotcrete* magazine. Each issue highlights one Sustaining Member and one Corporate Member with up to two dedicated pages per profile. This is a fantastic way to introduce your team, share what you do best, and show off some of the work you're most proud of. But this chance doesn't come around often — Sustaining Members are eligible to feature once every five years, and Corporate Members every ten. So, let's make it count!

WHAT MAKES A GREAT PROFILE?

Start by thinking of your profile as a story, not a sales pitch. What makes your company tick? How did you get started? What kind of work do you love doing? Your profile is a chance to talk about your history, your values, the projects you're proud of, and the people behind it all. You don't need to cover everything — just paint a clear picture of who you are. Aim for around 500 words, and keep it conversational and real.

Alongside your story, include your contact information — your company name, address, phone number, website, and the name of a contact person. That way, anyone who reads your profile and wants to reach out can easily do so.

Photos help bring your story to life. Send in a few high-quality images — 300 dpi (around 1MB or greater per image) in PNG or JPG format — that show off your work or your team in action. Whether it's a striking shot of a completed project or a behind-the-scenes moment on-site, choose images that reflect the spirit of your company. Add a simple caption to each one to explain what it is.

And of course, don't forget your logo! A vector file (EPS) is best, but if that's not available, a high-resolution PNG, JPG, or PDF will do just fine.

KEEP IT SIMPLE — AND GENUINE

Your profile doesn't need to be flashy. It just needs to reflect your company in an honest, engaging way. Focus on the things that set you apart, use a few strong visuals, and make sure your contact details are accurate.

This is your company's moment to shine in front of the ASA community and beyond. Each profile is also called out on the current magazine tab on our website for the duration of that issue, before it's replaced by the next issue. Sustaining and Corporate Member profiles are printed in the order they are received.

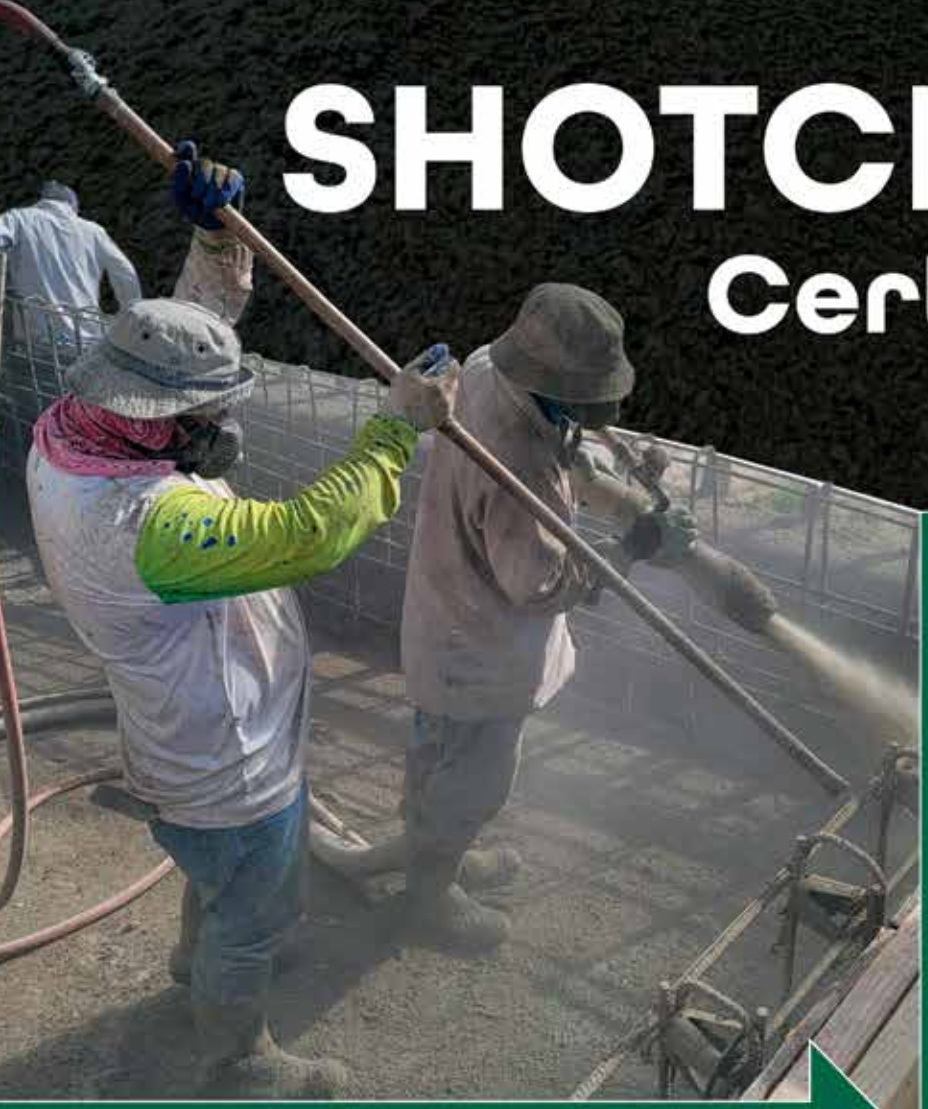
QUESTIONS? READY TO GET STARTED?

Reach out to me at **cara.baker@shotcrete.org**. We're here to make sure your profile looks great and captures exactly what makes your company special. So go ahead — take advantage of this distinct member benefit and show off your company! We're excited to help share your story!

What to Submit with Your Sustaining or Corporate Member Profile

- **Article text in Microsoft Word (suggested average length is 500 words)**
- **Up to two pages of content (includes text and imagery)**
- **Company contact info: Full name, contact person(s), address, phone, fax, and website information**
- **Accompanying photo(s): 300 dpi, PNG or JPG format and corresponding caption(s)**
- **Company logo: Vector file (EPS) preferred; 300 dpi PNG or JPG format otherwise**

SHOTCRETER Certification



QUALITY SHOTCRETE | PROJECT CHECKLIST

Project-Appropriate Specifications

Qualified Contractors with Relevant Project Experience

Verified ACI-Certified Shotcreter

Verification:
www.concrete.org/verify

Certification:
info@shotcrete.org

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The Secret's Out:

YOUR PROJECT COULD BE THE NEXT OUTSTANDING SHOTCRETE PROJECT WINNER!

By LaTosha Holden

Every year, the American Shotcrete Association (ASA) Outstanding Shotcrete Project Awards shine a spotlight on the most innovative construction projects in the shotcrete industry. But if you've ever wondered what really catches the judges' attention — what takes a good project and turns it into an award-winning one — we're letting the cat out the bag and sharing insider secrets to how you can submit a winning award submission.

Here are the secrets to creating a submission that stands out from the rest.

SHOW US WHAT YOU'RE WORKING WITH!

Shotcrete placement allows contractors to tackle projects we haven't seen before, so uniqueness is at the top of our list. Judges are drawn to projects that tell a story, specifically one where shotcrete placement is the hero. Did your team overcome a tough logistical challenge? Did shotcrete placement allow you to work faster, safer, or in a way that traditional concrete couldn't? We want to see how your project pushed boundaries, solved problems, or broke the mold.

Projects that stand out are those where shotcrete placement wasn't just an option, it was the only viable solution. If your submission answers the question, "Why shotcrete?", you're on the right track.

PAINT THE PICTURE

Here's a secret that many miss: Judges appreciate complete submissions. That doesn't just mean filling out every field on the form; it means clearly communicating the story behind your project. Explain the challenges, the approach, and the execution — not just in general terms, but with specifics!

> **Secret Tip:** Involve key people from your project team, such as contractors, engineers, or owners, to help tell the whole story behind your project. BUT, don't include names in the narrative (you should list them under the project team section). Use terms like "contractor," "engineer," "owner," etc. to keep the judging portion unbaised.

PHOTOS CAN MAKE OR BREAK YOUR ENTRY

Think of your photos as your visual pitch. The best submissions include clear, high-quality images that document the process from start to finish. Judges want to see shotcrete placement in action — not just the pretty pictures of the final result. Note: more is not necessarily better. Don't do an image dump of your entire project! Judges will not have the time to look through everything. So, would you rather pick out the 6 to 7 images that best represent your work, or have the judges base their decisions on a random selection? Take the time; pick out your best.

> **Secret Tip:** Include photos that highlight how shotcrete placement outperformed form-and-pour concrete in your project. Show us the tight spaces, the complex or the extreme conditions where shotcreting excels. Supplement them with captions that help draw out what you want the judges to see from your chosen images. Want to kick it up a notch? Share a video!

A picture really is worth a thousand words: In this case, it might earn an award.

FOCUS ON THE "WHY," NOT JUST THE "WHAT"

Yes, we want to know what you did, but why you did it with shotcrete placement is even more important. Don't just list the specs or features. Tell us the story behind the project. Why was shotcrete the option of choice? What unique benefits to shotcrete placement contributed to the success of this project? How did shotcreting make the impossible possible?

THE BOTTOM LINE

If your project highlights shotcrete placement as the clear solution, especially where other methods fall short, and you take the time to tell a complete story with visuals to match, you're already ahead of the game.

The ASA Outstanding Shotcrete Project Awards are more than recognition; they're a chance to showcase the very best our industry has to offer.

Visit **shotcrete.org/awards** for full details and submission guidelines. Submission deadline is October 1, 2025.

EARLY BIRD BONUS

Projects submitted by September 15 will receive ***an initial review and suggestions for improvement which can be resubmitted by October 1st*** for your best chance of success. Take advantage of this service, especially if this is your first submission: We want to partner with you in sharing your amazing work with the industry! Submit early, then plan to join us in Santa Fe, NM next March to celebrate the winners! (**shotcrete.org/convention**)

CALL FOR ENTRIES!

Submission Deadline:
October 1, 2025

RECOGNIZING EXCELLENCE IN SHOTCRETE PROJECTS!
Submit your shotcrete project for a chance to be celebrated at the 2026 ASA Shotcrete Convention & Technology Conference. Projects completed between January 1, 2023 and September 1, 2025 are eligible.

Categories:
Architecture | New Construction
Infrastructure
International Projects
Pool & Recreational
Rehabilitation & Repair
Underground

Learn more and apply online:
www.shotcrete.org/projectawards

asa OUTSTANDING SHOTCRETE PROJECT Awards

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:

We are a pool company and are a little uncertain about how to adjust our dry-mix using the new Type 1L cement. We have had several calls with local ready-mix companies, and they do not have any experience with dry-mix proportioning. The ready-mix supplier states that the Type 1L cement weighs less than the old Type I or I/II products. Does that change our dry-mix proportions? Old school, we always referenced 4:1 sand to portland by weight. Could you provide some guidance on proportions by weight using Type 1L cement?

ANSWER:

Type 1L (Portland Limestone Cement) is a new 'blended' cement with up to 15% replacement of portland cement with ground limestone. The specific gravity changes depending on the percentage of replacement. The percentage of replacement depends on the cement manufacturer. However, the specific gravity doesn't make any difference in dry-mix designs since all ingredients are by weight, even if just using the 'old school' 4:1.

Type 1L introduces issues by replacing portland cement with limestone. We observe extended set times, slower strength gains, and occasionally a higher risk of a flash set. Thus, we recommend watching the set times closely, especially if you are shooting more than one lift in a wall or shooting overhead. A slower strength gain may be an issue if filling the pool for early curing or in cold weather. You may need to consult with your design engineer to determine the required timing for strength gain.

QUESTION:

Our new pool and spa were shotcreted in February 2025 and remained empty as of July 2025. We are in a desert environment in AZ. The pool builder says there is no problem with plastering now, even with some cracks. Do you agree?

ANSWER:

Cracks that have formed in the pool shell over the past 5 months are most likely due to drying shrinkage of the concrete. These shrinkage cracks penetrate through the entire thickness of the shell. If the crack width is greater than 0.005 in. (0.13 mm) they will leak. The plaster is a thin, cementitious coating that provides a uniform color and texture to the pool surface. Unfortunately, unless the pool is located in a controlled indoor environment, the concrete shell will expand and contract in response to daily and seasonal temperature fluctuations. This means the cracks in the pool shell are moving cracks, as they open and close with the concrete contracting and expanding. Though the plaster may temporarily span over the cracks, they will likely mirror through the plaster at some point. Typically, issues with cracks become apparent in colder weather after the pool has undergone a hot summer of exposure.

You should consult with your builder to discuss their proposed solution for covering moving cracks with plaster. If the builder is not concerned about the cracks, you may want to consult with an engineer experienced in concrete pools.

QUESTION:

Have evaporation reducers been used successfully with shotcrete? We had an inquiry about using one on pier repairs. Possible conditions include high winds, temp, and sun exposure. The department does not have a specification for these products.

There have been past issues with the use of surface retarders/evaporation reducers (contractors overworking these products into the surface), resulting in surface/scaling defects.

In this situation, the contractor proposes using an evaporation reducer and will then apply a curing compound. The group here commented that the stringent curing application requirements for most of the department's concrete applications (i.e. 30 mins) would preclude the use of surface retarders/ evaporation reducers.

ANSWER:

Evaporation reducers are suitable for use on shotcreted concrete surfaces. Please note that they should be applied after the finishing process, not during it. As they are generally very high in water content, spraying on and working into the surface is like adding water to the surface. This increases the w/cm, reducing the strength and durability of the surface. They are not a substitute for curing, but rather a mechanism to slow evaporation and potentially reduce early-age plastic shrinkage cracking.

QUESTION:

In non-reinforced shotcrete, is cracking expected? If so, what is the nature of expected cracking? In our application, we are placing a 2.25 in. (64 mm) concrete layer on top of a sloped HDPE liner. Will cracks penetrate to the full depth of the shotcrete? What is the difference between an acceptable and an unacceptable crack in most circumstances?

Should expansion joints be used in shotcrete, similar to concrete?

ANSWER:

Unless you take care to reduce drying shrinkage, all concrete will crack unless you space contraction joints close together. You will see many unreinforced concrete sidewalks with 6 ft (1.8 m) joint spacing. Drying shrinkage cracks extend through the concrete section thickness. Early-age plastic shrinkage cracks in concrete are only at the exposed surface, relatively shallow, and do not extend through the section.

Expansion joints are only necessary for very long sections that are exposed to significant expansion due to hot weather. Contraction joints provide a location for the concrete to crack and are typically used in reinforced sections that span over approximately 20 to 40 ft (6 to 12 m). In unreinforced or very lightly reinforced sections, you may want contraction joints spaced closer together (like the sidewalks). Shotcreted concrete can have both contraction and expansion joints as needed.

Acceptable crack size depends on the application. In a water storage tank, cracks should be less than 0.005 in. (0.13 mm). In most structural concrete, 0.010 to 0.015 in. (0.25 to 0.38 mm) cracks are not unusual. In some cases the aesthetics of the section may control what is acceptable visually. Below is a table from ACI 224R-19 with a guide to reasonable crack widths.

Overall, shotcrete is just a placement method for concrete, so typical concrete design and performance requirements are the same as cast concrete. Shotcrete has the advantage of needing much less or no formwork, and generally less mobilization and equipment overhead than typical formed concrete work.

Table 4.1—Guide to reasonable* crack widths, reinforced concrete under service loads

Exposure condition	Crack width	
	in.	mm
Dry air or protective membrane	0.016	0.41
Humidity, moist air, soil	0.012	0.30
Deicing chemicals	0.007	0.18
Seawater and seawater spray, wetting and drying	0.006	0.15
Water-retaining structures†	0.004	0.10

*It should be expected that a portion of the cracks in the structure will exceed these values. With time, a significant portion can exceed these values. These are general guidelines for design to be used in conjunction with sound engineering judgement.
†Excluding nonpressure pipes.

DISCLAIMER: *The technical information provided by ASA's technical team is a free service. The information is based on the personal knowledge and experience of the ASA technical team and does not represent the official position of ASA. We assume that the requester has the skills and experience necessary to determine whether the information provided by ASA is appropriate for the requester's purposes. The information provided by ASA is used or implemented by the requester at their OWN RISK.*

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CALLING ALL ASA MEMBERS TO THE ASA FALL 2025 VIRTUAL COMMITTEE MEETINGS

We are excited to announce our upcoming Teams Committee Meetings Week, scheduled for November 5–7 and November 10, 2025. These virtual meetings offer all ASA members the opportunity to provide updates and collaborate on initiatives that support the shotcrete industry. You do not need to be on the Committee Roster to attend! Come see what your Association is doing and how you can participate!

Throughout the week, we'll be hosting scheduled 1 to 2-hour long Teams meetings for these ASA committees:

- Education and Safety Committee
- Membership and Marketing Committee
- Underground Committee
- Contractor Qualifications Committee
- Pool and Recreational Committee
- Board of Directors

Be sure to mark your calendars and come prepared to share your insights and expertise. Visit www.shotcrete.org/calendar for the specific meeting date and time of each committee!

SURVEY

WOMEN IN SHOTCRETE:

Call to all women working in the shotcrete industry: LAST CHANCE! The 4th Quarter 2025 issue of *Shotcrete* magazine wants to recognize you! Scan or click this QR code and share your journey to encourage and celebrate the women in shotcrete!

RECOGNIZE YOUR TEAM WITH SHOTCRETE SPOTLIGHT

ASA members, here's your chance to highlight the individuals and teams in your companies that help you shine! Scan or click the QR code to learn more or nominate someone!

INTERNATIONAL POOL | SPA | PATIO EXPO

INTERNATIONAL POOL | SPA | PATIO EXPO 2025

October 19 – 21, 2025 (Pre-Conference)
October 22 – 24, 2025 (Expo & Conference)
Las Vegas Convention Center, North Hall | Las Vegas, NV
Details & Registration: poolspapatio.com

ASA will be presenting two shotcrete seminars at this show! Sign up to attend: **Quality Shotcrete for Pools – Know It, Demand It** (Pre-conference event on Tuesday, October 21, 2025). This seminar supports the *ACI Shotcrete Inspector Certification* as well as *WU Certified Watershape Shotcrete Specialist* credentials. You will have the option to take either ACI or WU exam at the end of the seminar. Registration for this seminar will also provide you with conference and expo passes for the main PSP show, where ASA will also present: **Shotcrete – The Good, the Bad and the Ugly** (conference event on Wednesday, October 22, 2025). This seminar will provide an overview on how proper shotcrete placement is essential for the durability and strength of the concrete pool shell.

WORLD OF CONCRETE®

WORLD OF CONCRETE 2026

January 20 – 22, 2026
Las Vegas Convention Center | Las Vegas, NV
Registration opens in September. Be sure to use ASA's Source Code: A17 for the greatest discounts and to support your Association!
Check out: Shotcrete.org/WOC for updates

ASA will again host our **Annual Membership Meeting** in South Hall, Tuesday evening (Jan 20). Be sure to come by to network and hear the latest Association updates.

Tuesday we will also present the full-day **ASA Shotcreter Education** seminar, which supports the ACI Shotcreter Certification program, while Wednesday we will host the **ASA Quality Shotcrete – Know It When You See It** seminar, supporting the ACI Shotcrete Inspector Certification. New this year, ASA will also have a 90-minute presentation under WOC's Advanced Concrete Repair track: **Shotcrete for Repair, Rehabilitation and Re-purposing**, Tuesday morning. As always, please stop by the ASA Booth in South Hall: **S10919** to greet ASA staff and members.


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VISIT AMERICAN SHOTCRETE ASSOCIATION AT BOOTH S10919
Push limits. Smash barriers. Break boundaries. And when you've conquered all those obstacles? You discover your full capacity for greatness. World of Concrete delivers all the real-world solutions that will crush your challenges and take your expertise to new heights. Growth opportunities are everywhere, whether you're getting hands-on with game-changing tools and tech or shaking hands with your future partners. Ready for maximum success? Nothing's standing in your way.
ACHIEVE PEAK PERFORMANCE
VIEW GLOBAL EVENTS

"PORTLAND CEMENT ASSOCIATION" IS CHANGING TO "AMERICAN CEMENT ASSOCIATION"

Washington, D.C. (May 7, 2025) — Today, Portland Cement Association, the national association representing U.S. cement manufacturers since 1916, announced it is changing its name to the American Cement Association (ACA). President and CEO Mike Ireland shared the news in Birmingham, AL, during the 67th IEEE-IAS/PCA Cement Conference.

Nearly 1200 cement industry professionals from around the world are attending the event this week, which is hailed as the cement and concrete industry's premier annual conference. Following today's announcement, the association will begin launching the new brand identity in June.

"The most important reason for the name change is that in recent years, U.S. cement manufacturers have expanded the types of materials they produce beyond portland cement, working to develop more lower-emission cements in an effort to decarbonize the industry and increase domestic cement manufacturing capacity. The name 'Portland Cement Association' no longer accurately reflects the modern mindset of today's manufacturers, or the materials they currently produce." Ireland said.

Lower-emissions cement consumption has grown more than tenfold since 2021 and now accounts for more than 60% of total cement consumed in the U.S. In 2024, all 50 state Departments of Transportation approved the use of portland-limestone cement (PLC). PLC reduces the carbon footprint of projects by up to 10%.

"Additionally, the rebranding makes it clear that we are a national association that speaks for cement manufacturers across the country," Ireland said.

During today's announcement, Monica Manolas, Region President — Ash Grove Cement , and ACA Board Vice Chair, shared a video with conference attendees, revealing the association's new slogan: Sustainable Cement for Resilient Concrete.

"The slogan summarizes the industry's commitment to staying the course with our Roadmap to Carbon Neutrality," Manolas said. "We continue to focus on developing new technologies and products to achieve not only net zero by 2050 but also to increase the capacity of American cement manufacturing to meet demand."

INTRODUCING WOMEN OF WATER: A MOVEMENT POWERED BY PHTA & POOLCORP

We're thrilled to announce the official launch of Women of Water (WOW)—a new special interest group powered by PHTA and POOLCORP designed to support, elevate, and connect women across the pool, spa, and hot tub industry.

Join us at the **International Pool Spa Patio Expo** in Las Vegas for the inaugural WOW event, featuring a transformational keynote session with award-winning speaker and author Heather Whelpley:

The Power of Grounded Confidence: How to Unleash Your Authenticity and Become Unshakeable

Heather will guide attendees through an empowering experience to break free from perfectionism and pressure—and lead with authenticity, purpose, and unshakable confidence.

Breakfast is included, and Heather will host a book signing at the PHTA booth immediately following the keynote.

Event Details:

- Friday, October 24
- 8:00 AM – 10:15 AM
- Heather Whelpley, Award-Winning Author & Speaker
- Admission included with a PSP Deck Expo Super Pass, Expo Pass, or Friday Day Pass

SHOTCRETE RELATED MEETINGS AT ACI FALL CONCRETE CONVENTION 2025

October 26 – 29, 2025 | Baltimore, MD | H = Hilton Baltimore Inner Harbor
More Information & Registration: **www.concrete.org**

Committee Code	Committee Name	Day	Time	Room
C661	Shotcrete Inspector Certification	Monday	12:30 PM - 1:30 PM	H - Marshall Room
C660	Shotcreter Certification	Monday	1:30 PM – 2:30 PM	H - Marshall Room
322	Concrete Pool and Watershape Code	Sunday	1:00 PM - 5:00 PM	H - Ruth
506	Shotcreting	Tuesday	8:30 AM - 11:30 AM	H - Calloway A&B
506-A	Shotcreting-Evaluation	Monday	10:30 AM – 11:30 AM	H - Marshall Room
506-B	Shotcreting-Fiber-Reinforced	Monday	11:30 AM - 12:30 PM	H - Marshall Room
506-C	Shotcreting-Guide	Monday	8:30 AM – 9:30 AM	H - Marshall Room
506-E	Shotcreting-Specifications	Monday	9:30 AM - 10:30 AM	H - Marshall Room
506-F	Shotcreting-Underground	Monday	2:30 PM - 3:30 PM	H - Marshall Room
506-H	Shotcreting-Pools	Monday	4:00 PM – 5:00 PM	H - Carroll A

DFI EDUCATIONAL TRUST AWARDS EIGHT SCHOLARSHIPS

Hawthorne, N.J. (July 7, 2025): Deep Foundations Institute (DFI) Educational Trust, the charitable arm of DFI, recently awarded eight scholarships to students pursuing careers in civil and geotechnical engineering.

THE SCHOLARSHIPS WENT TO THE FOLLOWING RECIPIENTS:

Charles J. Berkel Memorial Scholarship ($5000)
Camilla Marden, senior, University of Illinois

Langan Legacy Dennis J. Leary Memorial Scholarship ($6250)
Aaron Perez Araya, senior, University of Illinois at Urbana-Champaign

Larry P. Rayburn University of Cincinnati Civil Engineering Scholarship ($2500 each)
Pierson Kovik, freshman; Colin Mansell, freshman; Noah Recker, freshman; Austin Reynolds, freshman

Menard Carnegie Mellon University Scholarship ($5000 each)
Carlyle Najarian, junior; Gibrilla Kamara, senior

CLAUDIA HERNANDEZ JOINS NORMET AS DIRECTOR OF TUNNELING AMERICAS

ESPOO, Finland, July 14, 2025 /PRNewswire/ — Normet is proud to announce the appointment of Claudia Hernandez as Director of Tunnellng Americas, further reinforcing our commitment to advancing tunnelling excellence across both North America and Latin America. Claudia brings extensive hands-on experience in underground mining and tunnelling, with a strong focus on advanced sprayed concrete processes and modern tunnel support systems.

With over 25 years of industry experience, Claudia has held key technical and leadership roles supporting some of the world's most complex underground projects. Her background in applied engineering, site operations, and tunnel support technologies ensures that she brings both practical and design insight to the challenges faced in today's tunnelling environments.

"I'm pleased to be joining Normet. I genuinely believe in our bright future. Normet's strong commitment to innovation, sustainability, and leading-edge technology is inspiring. The team works together with passion and maintains a strong focus on the underground industry." - Claudia Hernandez.

SHOTCRETE CALENDAR

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

SEPTEMBER 8-11, 2025	**Breakthroughs in Tunneling** University of Denver | Denver, CO
SEPTEMBER 10, 2025	**Quality Shotcrete – Know It When You See It** Southern California Resource Center | San Bernardino, CA
SEPTEMBER 18, 2028	**Quality Shotcrete – Know It When You See It** ACI Central Texas Chapter Certification Facility | Pflugerville, TX
SEPTEMBER 19-21, 2025	**ACI Shotcreter Certification (Wet- & Dry-Mix)** Texan Gunite | Cedar Park, TX
OCTOBER 1-3, 2025	**ACI Shotcreter Certification (Wet- & Dry-Mix)** Minova | Millstadt, IL
OCTOBER 3-5, 2025	**ACI Shotcreter Certification (Wet- & Dry-Mix)** Applied Shotcrete | Sebastopol, CA
OCTOBER 10, 2025	**Quality Shotcrete – Know It When You See It** Midwest Resource Center | Elk Grove Village, IL
OCTOBER 19-22, 2025	**2025 ICRI Fall Convention** Intercontinental Hotel | Chicago, IL
OCTOBER 19-24, 2025	**International Pool | Spa | Patio Expo 2025** Las Vegas Convention Center | Las Vegas, NV
OCTOBER 22, 2025	**Quality Shotcrete for Pools – Know It, Demand It | IPSP (Pre-Show)** Las Vegas Convention Center | Las Vegas, NV
OCTOBER 23, 2025	**Shotcrete – The Good, the Bad, and the Ugly | IPSP** Las Vegas Convention Center | Las Vegas, NV
OCTOBER 26-29, 2025	**ACI Concrete Convention - Fall 2025** Hilton Baltimore & Marriott Baltimore Inner Harbor | Baltimore, MD
NOVEMBER 5-7, 2025	**ASA Fall Committee Meetings – 2025** Teams Meetings | Check calendar for details
NOVEMBER 8, 2025	**Quality Shotcrete – Know It When You See It** Hilton Garden Inn | San Mateo, CA
NOVEMBER 12-13, 2025	**Deep Foundation Institute (DFI) - Shotcrete Short Course** Georgetown, KY

SHOTCRETE CALENDAR

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

DECEMBER 4-6, 2025	**Watershape University Education Vacation** Embassy Suites Phoenix-Biltmore | Phoenix, AZ
DECEMBER 6, 2025	**Quality Shotcrete for Pools — Know It, Demand It** Embassy Suites Phoenix-Biltmore | Phoenix, AZ
DECEMBER 7-10, 2025	**ASTM Committee Meetings - C09 Concrete & Concrete Aggregates** Hilton Atlanta | Atlanta, GA
JANUARY 11-15, 2026	**Transportation Research Board - 105th Annual Meeting** Washington, DC
JANUARY 20, 2026	**ASA Shotcreter Certification Education | WOC** Las Vegas Convention Center | Las Vegas, NV
JANUARY 20, 2026	**Shotcrete for Repair, Rehabilitation and Re-purposing | WOC** Las Vegas Convention Center, Las Vegas, NV
JANUARY 20, 2026	**ASA General Membership Meeting & Shotcrete Reception | WOC** Las Vegas Convention Center | Las Vegas, NV
JANUARY 20-22, 2026	**2026 World of Concrete** Las Vegas Convention Center | Las Vegas, NV
JANUARY 21, 2026	**Quality Shotcrete – Know It When You See It | WOC** Las Vegas Convention Center | Las Vegas, NV
FEBRUARY 22-25, 2026	**MINEXCHANGE - 2026 SME Annual Conference & Expo** Salt Palace Convention Center | Salt Lake City, UT
MARCH 1, 2026	**ASA Contractor Qualification Education - Level I & II, Pool** La Fonda Resort | Santa Fe, NM
MARCH 2-3, 2026	**ASA Spring Committee Meetings - 2026** La Fonda Resort | Santa Fe, NM
MARCH 3, 2026	**Outstanding Shotcrete Project Awards Banquet** La Fonda Resort | Santa Fe, NM
MARCH 15-18, 2026	**2026 ICRI Spring Convention** JW Marriott Nashville | Nashville, TN
MORE INFORMATION	To see a full list, current updates, and active links to each event, visit www.shotcrete.org/calendar.

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SUSTAINING CORPORATE

Drakeley Pool Company LLC
Bethlehem, Connecticut
drakeleypools.com
Primary Contact: Bill Drakeley
bill@drakeleyindustries.com

Saffo Contractors Inc
Wilmington, North Carolina
saffocontractors.com
Primary Contact: Margot Janajra
margot@saffocontractors.com

South Shore Gunite Pools & Spas Inc
North Billerica, Massachussetts
ssgpools.com
Primary Contact: Robert Guarino
Reg@ssgpools.com

Thorcon Shotcrete & Shoring LLC
Littleton, Colorado
thorconshotcrete.com
Primary Contact: Michael Klemp
mike@thorconus.com

CORPORATE

Dome Technology, LLC
Idaho Falls, Idaho
dometechnology.com
Primary Contact: Adam Sullivan
adam.sullivan@dometechnology.com

JCL Shotcrete
Etobicoke, Ontario, CA
jclconcretepumping.ca/shotcrete
Primary Contact: Nicholas Petrie
nick.petrie@jclgroup.ca

Aloha Pools INC
Charlotte, North Carolina
poolsbyaloha.com
Primary Contact: Megan Bowling
megan@poolsbyaloha.com

Nelson Industrial Coatings
Bennett, Wisconsin
nelsonindustrialcoatings.com
Primary Contact: Shadly Nelson
nelsonindustrialcoatings@gmail.com

Harrison Western
Lakewood, Colorado
harrisonwestern.com
Primary Contact: Daniel Escobar
descobar@harwest.com

Aquatic Artists Luxury Pools, Inc.
Pittsboro, North Carolina
aquaticartistsinc.com
Primary Contact: John Doughty
aquaticartistsjohn@gmail.com

En-Tech Corp
Closter, New Jersey
en-techcorp.com
Primary Contact: Danielle Trainor
dtrainor@en-techcorp.com

Aarcomm Systems Inc
Coquitlam, British Columbia, CA
aarcomm.com
Primary Contact: Doug Graham
doug@aarcomm.com

UMA Geotechnical Construction Inc
Kernersville, North Carolina
team-uma.com
Primary Contact: Gordon Sitch
gsitch@team-uma.com

Engineering & Construction Innovations Inc
Oakdale, Minnesota
eciconstructors.com
Primary Contact: Donita Creek
dcreek@eciconstructors.com

Gunite Supply & Equipment Co
Cincinnati, Ohio
gunitesupply.com
Primary Contact: Larry Klein
lklein@mesa-ind.net

SUSTAINING CORPORATE COMPANY

SSG Shotcrete
North Billerica, Massachussetts
ssgshotcrete.com
Primary Contact: Mason Guarino
mguarino@ssgshotcrete.com

SUSTAINING CORPORATE ASSOCIATE

Taylor Saffo
Saffo Contractors Inc
Wilmington, North Carolina

Katrina Nyarko
Thorcon Shotcrete & Shoring LLC
Littleton, Colorado

Monte Vandeventer
Thorcon Shotcrete & Shoring LLC
Littleton, Colorado

Kerri Allmer
Drakeley Pool Company LLC
Bethlehem, Connecticut

Rick Schivera
Drakeley Pool Company LLC
Bethlehem, Connecticut

Allison Cope
Drakeley Pool Company LLC
Louisville, Kentucky

Ray Garcia
Dees Hennessey Inc
San Carlos, California

Martin Hansson
Sika STM - Shotcrete, Tunnelling, & Mining (USA)
South Jordan, Utah

CORPORATE ADDITIONALS

Armando Reyes
En-Tech Corp
Closter, New Jersey

Chris Haray
En-Tech Corp
Closter, New Jersey

INDIVIDUAL

Micah Silberman
SV Shotcrete Inc
Puyallup, Washington

Heather Spring
American Shotcrete LLC
Mesa, Arizona

Sandeep Pyakurel
Mott MacDonald
Oak Hill, Virginia

Kevin Hennessy
Island Construction Corporation
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Thorconshotcrete.com

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www.consolidatedshotcrete.ca

Ocean Rock
www.oceanrockart.ca

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www.ConForms.com

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www.nationwideshotcrete.com

A & B Gunite
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www.geo-rope.com

MAPEI Underground Technology Team
www.utt-mapei.com

PULLMAN
www.pullman-services.com

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COST of Wisconsin Inc.
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William Emfinger Construction Inc.
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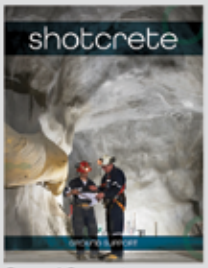

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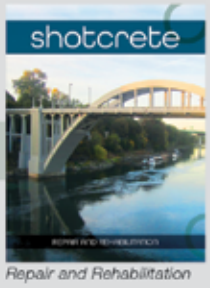

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