MAGAZINE
shotcrete
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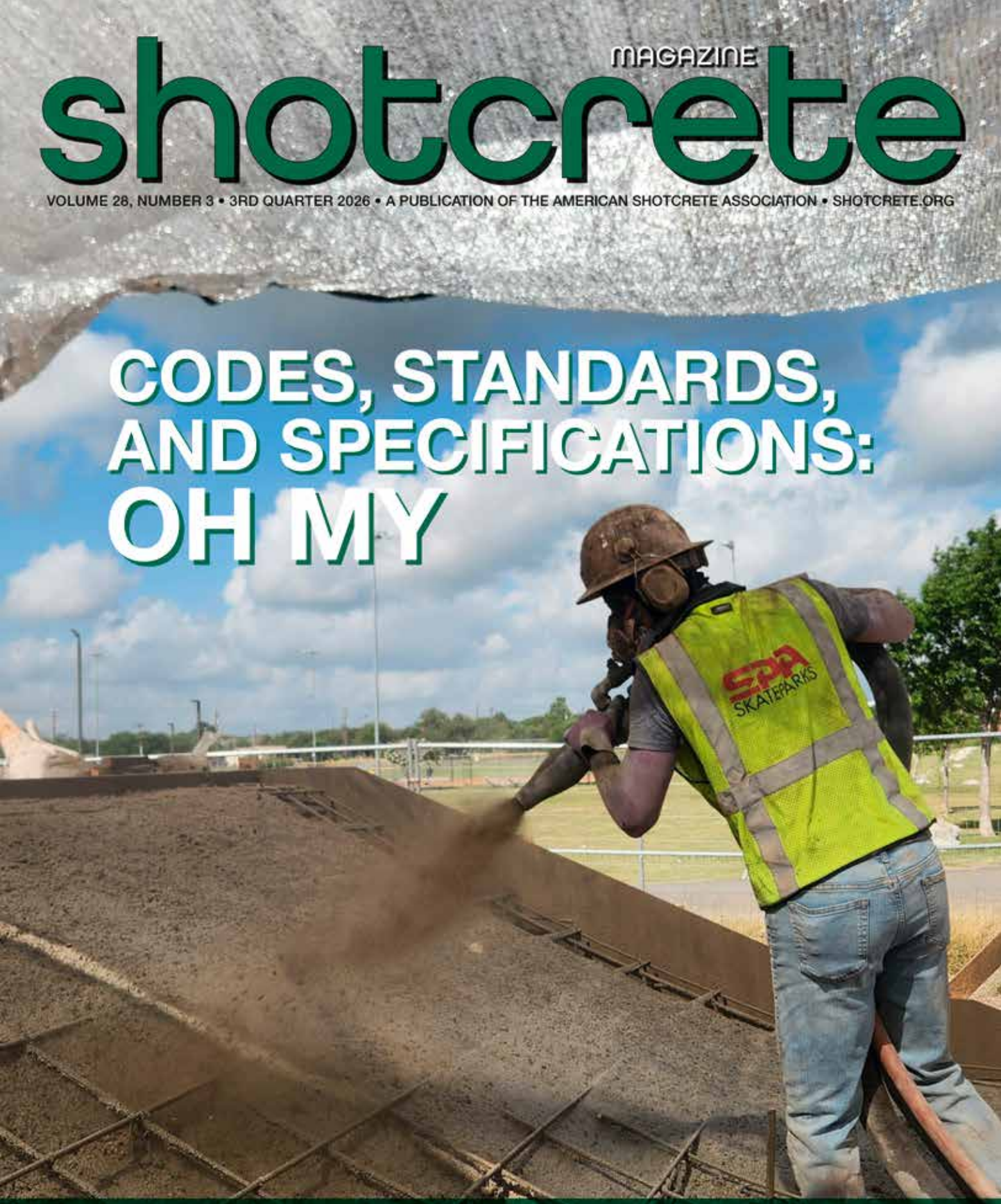
CODES, STANDARDS, AND SPECIFICATIONS: OH MY



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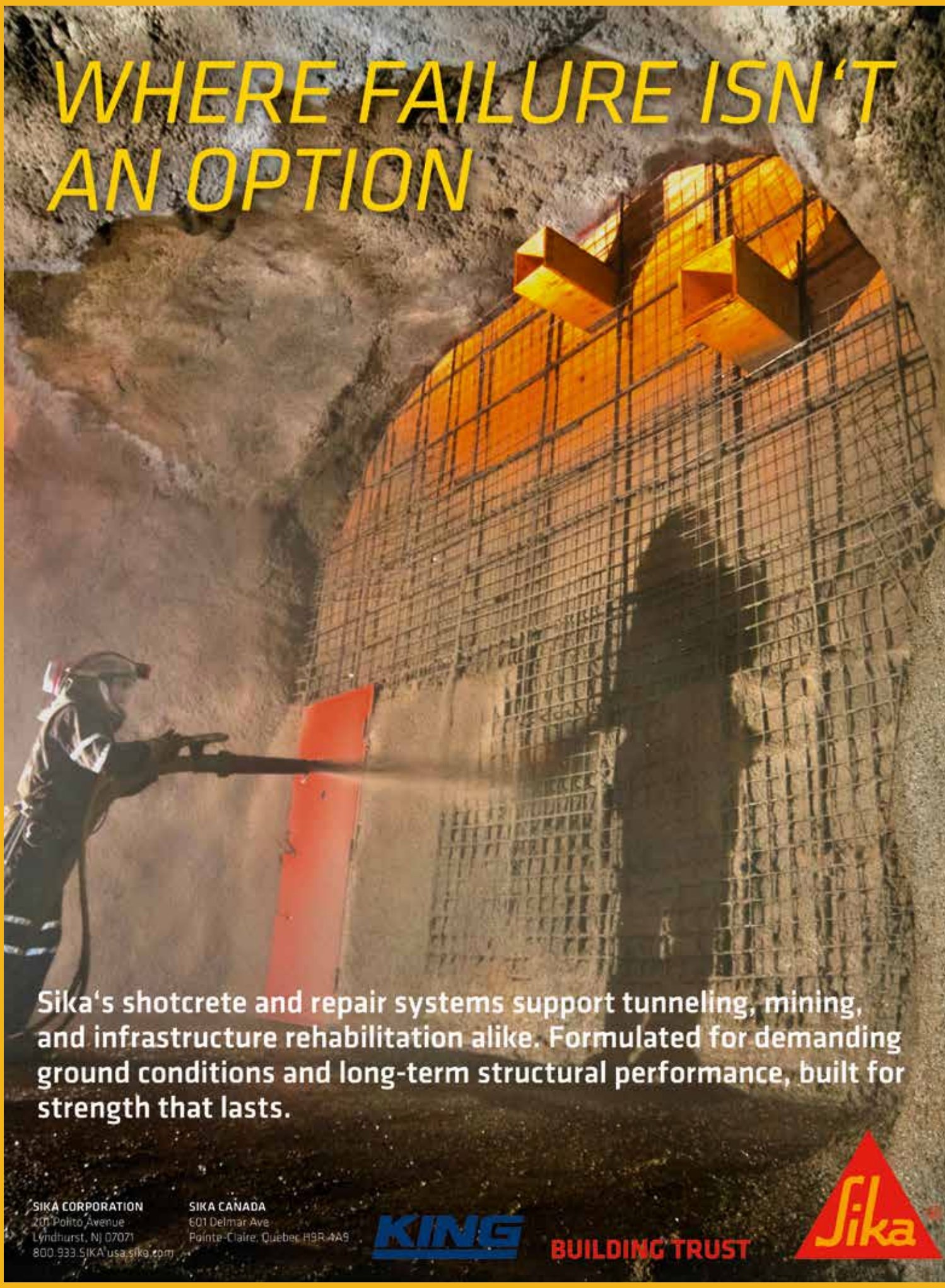
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FEATURES

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

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COVER PHOTO: *Providing shade to the area being shotcreted provides immense benefits while shooting in the heat, as seen in "Hot Weather Shotcreting with Liquid Nitrogen" on page 28.*

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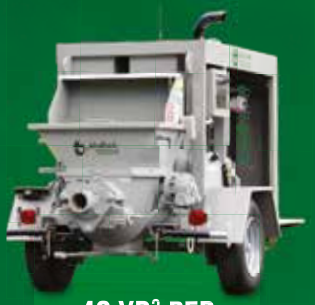
FORWARD TO THE BASICS



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There Is No 'I' In Team

By Jason Myers

I'm writing this article while watching another great playoff match in the World Cup. Two teams of different nations are playing for national pride, national honor, and of course a little prize money. Most of the team members play the season for a club team somewhere in the world. Most of their income and welfare come from that club team, and a lot of their endorsements and fame come from it, too. However, each of these players sets aside their club team allegiance every four years for one thing: Their country.

TOGETHER

The shotcrete industry is similar to this. On the surface, we all focus our time and effort toward whichever company gives us employment — but when we look deeper, we realize that we owe most of what we have to our own 'National Team', the American Shotcrete Association (ASA).

Think back on the people who've taught you what you know about the shotcrete industry. Look back at the documents that you or the engineers use, that govern and allow you to do what you do. If you follow the trail of that information, it will at some point connect to a member or team from the ASA.

It's so easy to get caught up in your company issues and put aside the value and importance of the National Team. Meanwhile, the ASA is working on education, safety, guidelines, training, and the paths to certification that allow our industry to function. It's not about one company, contractor, or person making the industry successful; the industry is successful because of all the members working together to advance safe and quality shotcrete placement.

ASA MISSION STATEMENT:

TO EXPAND AND ADVANCE GLOBAL UTILIZATION OF THE SHOTCRETE PROCESS FOR CONCRETE PLACEMENT

We do this by providing shotcrete leadership, knowledge, resources, qualification, certification, and education for the concrete industry.

EVERYONE

It takes a full roster to be successful. It's not only about the players that you see on the field, but the coaching staff, substitute players, training staff, management, and development teams and staff that all work together to make the team successful.

A person always has the option to try to do all of this on their own, but how much more successful are we by working together? The more members there are working on a project, the more perspectives we gain and can accomplish. No matter where or how you are involved, there are always objectives that will match your skills and passions. There's always a place for you to play on the team and that place is important!

ACHIEVES

What are we trying to achieve? The focus of one company or contractor is to 'win' the current project. The goal of the ASA is to improve the overall shotcrete industry.

The education, knowledge, and credibility the ASA has developed for the shotcrete industry in nearly thirty years is amazing. But just as a soccer team doesn't win a game just because they're wearing a great jersey, current ASA members can't get ahead by just wearing a pin: They need to figure out what they are going to do to help ASA move forward.

Are you helping to improve documents, write articles, develop and refine programs? Are you sharing your professional experience to help educate the engineers and construction managers of today and tomorrow? Working together as a team has maximum impact and makes overall success greater and, in many ways, easier.

MORE

Our shotcrete forefathers have accomplished a lot in the nearly thirty years of ASA. They put forth a lot of time and effort for the acceptance and improvement of the shotcrete industry that we benefit from today. The big questions are these: What are we going to accomplish in the next thirty years, and who is going to do it?

Just as your level of involvement does not limit your contributions or impact, it is also true that no company is an island, succeeding or failing, independently from others. We saw that in the 1970s, when everyone who could pick up a nozzle professed their ability to shotcrete. The result was poorly applied shotcrete, which then took decades

to rectify the stigma associated with shotcrete placement. ASA was largely born out of that need to help develop standards and education to show that shotcrete, when properly applied, is a structural, sustainable, functional, and impressive placement method for concrete! The industry can best advance when all involved are putting in their best efforts. This includes knowing the rules, training your team, investing in the right equipment, and growing through experience, both your own and others! How your team (company) fares affect the reputation of shotcrete placement in the concrete industry.

As the ASA continues, it is essential to maintain active, involved members to continue that momentum. Just as it takes players and training staff for the game to occur, it takes active members being involved and proactive for the industry to improve. If there are no players, then there is nothing to watch and you're sitting in an empty stadium or staring at a blank screen. True membership is active membership, and by working together, we can continue to build on the legacy that's been handed down to us.

There is no 'I' in Team. Only by working together can we achieve greater things on the local, national, and international levels. So often we get caught up in the problems that are right in front of us or get focused on the bottom line of the present shotcrete project. These things are very important, but they exist because of the hard work of previous active ASA members. We so easily forget that the reason we have our success and don't have to fight all of the issues ourselves is because of the ASA.

ASA is not about the individual — it's about the shotcrete industry that we all benefit from as a TEAM: "Together Everyone Achieves More".

The Strength Behind the Nozzle: WHY GREAT SHOTCRETE CREWS BUILD GREAT PROJECTS

By Derek Pay, Education and Safety Committee Chair

Walk onto almost any exceptional-looking shotcrete project and ask who gets the credit: Chances are the answer will be the person holding the nozzle. While the shotcreter certainly carries tremendous responsibility, anyone who has spent years in this industry knows the truth — outstanding shotcrete is never the product of one person. It's the result of an entire crew working together as one unit.

A successful shotcrete project is built long before material ever leaves the nozzle. It begins with preparation, communication, trust, and a team of professionals who understand that every position on the jobsite is equally important.

EVERY POSITION MATTERS

Every crew member has a role that directly affects quality, safety, and production. The pump operator maintains a consistent material flow and quickly recognizes changes in the system before they become costly problems. The shotcreter must constantly adjust for reinforcement congestion, shooting distance, air flow, rebound, encapsulation, and finish quality. The laborers remove rebound, prepare surfaces, keep hoses organized, monitor safety, and ensure the work area stays clean and efficient. Finishers shape and cut the surface while maintaining tolerances and architectural requirements.

Each position depends on the others. If one person falls behind, the entire operation slows down. If one person becomes careless, quality suffers. If communication breaks down, safety is often the first casualty. No one succeeds alone.

TRUST CANNOT BE BUILT OVERNIGHT

One characteristic separates average crews from exceptional ones: Trust. The best crews know each other's tendencies. They anticipate problems before they occur, often communicating with only a glance or a simple hand signal because they've spent hundreds of hours working together. That level of trust cannot be purchased — it is earned through shared challenges, difficult jobs, long days, and a commitment to helping one another improve.

When crew members remain together over time, production increases, mistakes decrease, and quality becomes consistent. New employees learn faster because experienced crew members take ownership in teaching the next generation. Great crews don't simply work together; they invest in one another.

COMMUNICATION IS THE MOST VALUABLE TOOL ON THE JOB

Every successful shotcrete project depends on communication. Before shooting begins, everyone should understand the sequence of work, material requirements,

safety concerns, finishing expectations, and individual responsibilities. During shooting, communication becomes even more critical: The shotcreter may need adjustments to water or air flow. The pump operator may recognize material changes. Finishers may identify areas requiring additional attention before final cut. Laborers often notice safety hazards developing around hose movement or rebound accumulation.

The strongest crews create an environment where every member feels responsible for the success of the project — not just their individual task.

PRIDE IS CONTAGIOUS

When every member takes pride in the finished product, shortcuts disappear. Crew members begin correcting problems before supervisors ever notice them. Equipment receives better maintenance. Cleanup improves. Safety standards rise naturally. Clients notice the difference, and that culture becomes contagious. New employees quickly understand what is expected, because excellence becomes the standard rather than the exception.

BUILDING FUTURE LEADERS

Every experienced shotcrete crew has a responsibility to develop those who will eventually replace them. Future shotcreters are standing beside us every day. Passing knowledge from one generation to the next is an investment in the future of our industry.

SAFETY IS A TEAM RESPONSIBILITY

Shotcrete projects involve high-pressure equipment, heavy hoses, elevated work, confined spaces, and constantly changing jobsite conditions. Safety cannot rest on one person's shoulders. The safest crews are those who genuinely care about one another and watch out for each other every day.

THE BEST TEAMS LEAVE THEIR EGO AT THE GATE

Successful crews understand that no position is beneath anyone. There are days when a shotcreter grabs a shovel, a foreman helps clean rebound, or a pump operator assists with cleanup. When egos disappear, teamwork flourishes.

THE LEGACY WE LEAVE

After more than two decades in shotcrete, I've learned that people rarely remember how many cubic yards of concrete were placed on a project. They remember the crews they worked alongside, the mentors who taught them, and the teammates who stayed calm under pressure. Our industry is built on concrete, steel, and craftsmanship, but its greatest strength has always been its people.

When an owner, contractor, and crew commit to working together with trust, communication, professionalism, and mutual respect, the result is more than quality shotcrete: It is a team capable of accomplishing extraordinary things. Because at the end of the day, the best shotcrete isn't placed by one person. It's built by an entire crew.

What is ASA?

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

In my travels and presentations as Executive Director over the years, I often get the question — What is ASA? If it's a brief encounter, my elevator pitch is an expansion of our mission statement: "ASA is the American Shotcrete Association, a nonprofit trade association dedicated to expanding and advancing global use of the shotcrete process for concrete placement. Our members are predominantly shotcrete contractors with an overwhelming desire to further the quality and acceptance of shotcrete placement, creating efficient, strong, durable concrete structures." Then I might need to explain what shotcrete is: "Concrete accelerated to a high velocity, 60 to 80 mph (100 to 130 kph) and then impacting and compacting in place, creating a strong, durable concrete system with minimal, if any, formwork."

But reflecting on what ASA is… it's a lot more than that. It's the people — members working in and with shotcrete; the programs we support — certification, qualification, and more; the interaction with code and standards-developing organizations to properly address shotcrete placement; and the ongoing education of engineers, contractors, owners, students, and field staff supporting quality shotcrete placement.

WE ARE OUR PEOPLE

Any successful association is the sum of the individuals who take its mission to heart. The members who have the passion and experience to recognize what's needed to move the association forward, and in turn advance the industry. ASA enjoyed the dedication and foresight of a core group of members when we started 28 years ago, and we continue to build on that today.

Though staff helps to organize and address the day-to-day issues of running the association and our programs, the volunteer members who are active in our Executive Committee, Board, and other committees are where true selflessness is on display. Every member has their unique perspective on what shotcrete is, and in truth, what the ASA is. The viewpoint of the shotcrete contractor and material or equipment supplier may vary, but all can see that working together advances our association to make it greater than the sum of its parts. Engineers and owners see how our diverse membership works together to make quality shotcrete placement the efficient, strong, and durable solution for concrete construction.

It's always eye-opening to see in-depth and open networking between our members at conventions. Likewise, collaboration within committee work demonstrates our commitment to sharing for the betterment of shotcrete.

WE ARE PROGRAMS WHICH SUPPORT SHOTCRETE PLACEMENT

The ASA has fully supported shotcreter and shotcrete inspector education and their respective ACI certification programs. ASA also developed and maintains the Contractor Qualification program that acknowledges successful shotcrete contractors who have demonstrated their commitment to building the company infrastructure to undertake a wide variety of shotcrete placement projects. We believe that knowledgeable, experienced shotcrete office and field staff exemplify the dedication to quality we look for in shotcrete placement day in and day out. ASA is the primary association conducting American Concrete Institute (ACI) shotcrete-related certifications worldwide.

We also promote quality shotcrete through seminars for engineers, architects, owners, and contractors. We are the shotcrete experts, but we share our experience and knowledge to have designers and owners recognize the benefits of shotcrete placement. Our seminars range from 1-hour talks given to ACI, International Concrete Repair Institute (ICRI) or Structural Engineers Association (SEA) chapters, online webinars spanning the globe, and full-day in-depth shotcrete short courses.

Our annual convention gives our members, and those interested in shotcrete, a venue to network and share. The convention brings together speakers with impactful presentations on current shotcrete practices and technology. It allows our committee members to collaborate face-to-face once a year on the initiatives which move ASA forward. The highlight of each convention has been our annual awards banquet where we recognize and celebrate that year's outstanding shotcrete projects from around the world.

We are also *Shotcrete* magazine, the only quarterly publication worldwide that focuses exclusively on shotcrete. The magazine brings together articles that cover the wide range of shotcrete projects, technical advances in materials and equipment, and safety topics for the crews who are shotcreting every day. The printed magazine is mailed to all our active members, and a PDF version is freely available on our website. The coolest aspect of the magazine is that

the large majority of our articles are volunteered from our members, not editorial or staff writing departments.

WE ARE THE RESOURCE FOR SHOTCRETE KNOWLEDGE

Standards-developing organizations (SDO), like ACI, ICRI, ASTM and IBC have very knowledgeable engineers, owners and contractors who have developed codes and standards governing the concrete industry for decades. But not all these SDOs have members with a wealth of shotcrete experience. ASA has many members who sit on ACI, ICRI, and ASTM committees to provide the shotcrete knowledge required to develop documents that properly cover quality shotcrete. This interaction with the other committee members in the SDOs helps improve the credibility and ultimately the acceptance of shotcrete placement. Through our decades of involvement in these SDOs, we are seeing engineers recognize that shotcrete knowledge flows from ASA and its members. We are their resource.

WHAT IS ASA TOMORROW?

What is ASA? Ultimately, it's our people who have dedicated their time and expertise to create and support programs that benefit the industry. We've enjoyed the active involvement of so many dedicated and passionate individuals who truly care about quality shotcrete placement. It's these people who created the foundation for ASA as an association to advance shotcrete, and helped make us what we are today.

Your interest, active involvement, and passion for quality shotcrete placement are a key part of ASA continuing and advancing tomorrow. Join us to make ASA an even stronger force in making shotcrete better!

Scan to learn more about becoming a member of the American Shotcrete Association!

European Shotcrete Tech

AN OVERVIEW OF PERMANENT SHOTCRETE LINING CODES AND STANDARDS FROM DIFFERENT JURISDICTIONS

By Andy Thompson

This article examines the range of codes and standards applicable to the design of permanent shotcrete (sprayed concrete) linings, for underground construction. The relevance of these codes and standards to the designer will be dictated to some degree by the location of the project. There is no single approach to the design of such linings, as the final use of the underground facility will be a primary driver (in conjunction with the ground that the facility is being constructed in). For the purposes of this paper, the codes and standards in Europe, the UK, North America, Australia, and Turkey (for seismic design) have been reviewed.

DESIGN APPROACH

EUROPE

As the use of shotcrete placement for permanent tunnel linings (especially for transportation projects) has become more commonplace, Europe has developed an integrated chain of standards from material specification through testing and structural design. This has created a standardized set of documents that can be utilized across multiple countries and jurisdictions, providing a consistent approach to the design and construction of such linings. Local annexes are developed for specific cases, such as the seismic design elements in Turkey.

While this provides a consistent framework for the design and construction of permanent shotcrete linings, it can introduce complexity and can in some cases be over-prescriptive. The "standard" suite of standards for permanent shotcrete linings is outlined below:

- EN 14487 defines sprayed concrete requirements
- EN 14488 defines testing methods
- EN 14651 establishes residual flexural strength testing
- EN 14889 governs the use of fibers
- Eurocodes provide structural and geotechnical design rules

In addition to the documents identified above, the EFNARC guidelines are used for testing and certification processes for shotcrete operators, together with the ITA guidelines.

UNITED KINGDOM

The UK generally follows a very similar approach to Europe, using the EN standards supplemented with UK-specific annexes. Given the extensive use of shotcrete placement on projects such as Crossrail and HS2, plus the analysis of the shotcreted designs and performance from the Crossrail project, there is an additional solid library of information that can also be deployed to inform the design process. The recently issued "Sprayed Concrete Linings in Soft Ground" guidelines from the British Tunnelling Society have attempted to provide additional clarity on certain areas of the design process, including:

- Lack of sprayed concrete lining (SCL) specific design standards or codes

Fig. 1: Shotcreter education in full swing

- Ground structure interaction using numerical modelling (clarity on use of load and material factors)
- Residual flexural tensile capacity and ductility of sprayed fiber-reinforced concrete
- Tensile capacity of plain and fiber-reinforced concrete
- Composite linings (SCL/membrane/SCL)
- Analysis of radial joints in SCL
- Permanent and temporary nature of SCL
- Advance rates in relation to strength gain

TURKEY

The country has largely adopted the European sprayed concrete framework, with the main difference being the use of country-specific concrete and seismic specifications: Reinforced Concrete TS 500 and Turkish Earthquake Building Code (TBEC 2018), respectively. With Turkey being in an active seismic zone, older tunnels have been retrofitted where possible to provide enhanced seismic protection, and newer tunnels are designed to allow for it. In addition, the recommendations of the ITA and EFNARC are typically also adopted.

NORTH AMERICA

Unlike Europe, in North America there is no clearly established suite of standards that are directly comparable to the European approach. ACI 506 documents are primarily related to concrete application standards, construction specifications, and quality control guidance. Structural design is typically performed in accordance with ACI 318 or CSA A 23.3 in the US and Canada, respectively. There is no dedicated shotcrete structural design code for SCL. Supplementing these codes and standards are Federal Highway Administration (FHWA) guidance documents and position/best practice papers published by the American Shotcrete Association (ASA).

The North American approach to SCL is heavily based on empirical and practical considerations and is well suited to contractor-driven delivery of shotcrete linings. As a less-integrated approach than that which has evolved in Europe, however, it can lead to a fragmented methodology for specifying and design (despite the best efforts of ASA). It can also lead to one-off project requirements that, while valid for a single project, are not contributing to the development of a standardized approach.

AUSTRALIA

The approach to specifying and design of permanent shotcrete linings in Australia appears to be a hybrid of the North American and European approaches. There is no comprehensive design code dedicated to permanent SCL, and the approach on recent major projects has been to supplement Australian standards with international guidance. For example, AS 3600 structural concrete design is used alongside CIA Z5 Shotcrete Recommended Practice and owner-developed specifications that may be supplemented with ITA and EFNARC guidelines. This provides a flexible approach to develop project-specific solutions, but that flexibility can lead to bespoke specifications and designs.

Region	Design Philosophy
Europe	Code-driven, performance-based, highly standardized
UK	European approach with project-specific owner enhancements
Turkey	European-style framework with enhanced seismic requirements
USA/Canada	Construction-specification driven; structural design separated from shotcrete placement standards
Australia	Structural code plus owner specification and industry guidance

Table 1

As outlined in Table 1, there appear to be two different approaches to codes and standards related to permanent shotcrete linings specifically for transportation tunnels:

1. **European System (Europe, UK, Turkey)**
   a. Eurocodes or Eurocode-derived national standards
   b. EN 14487 and EN 14488 for sprayed concrete
   c. Extensive use of EFNARC and ITA guidance
2. **North American / Australian System**
   a. Structural concrete codes (ACI 318, CSA A23.3, AS 3600)
   b. Shotcrete-specific guidance (ACI 506 or CIA Z5)
   c. Increasing use of performance-based design for fiber-reinforced shotcrete employing residual strength and energy absorption testing

In summary, the structural design of permanent shotcrete linings is almost always supplemented by ITA recommendations, EFNARC guidance, and project-specific owner requirements. This is primarily because the primary concrete design codes do not fully address ground-support interaction and tunnel lining behavior.

The European framework approach provides a comprehensive standardized approach that can be adopted for the design and construction of permanent shotcrete linings, as it covers the entire lifecycle of the process from material requirements to structural design integration, construction, and testing requirements. The approach adopted in Australia and North America will result in similar engineering outcomes but tend to rely more heavily on projects' specifications, owner requirements, and

Topic	Europe	United Kingdom	Turkey	North America (USA/Canada)	Australia
Primary concrete design code	Eurocode 2 (EN 1992) and Eurocode 7 (EN 1997)	BS EN 1992 and BS EN 1997 (Eurocodes with UK National Annexes)	TS 500 Reinforced Concrete Code	ACI 318 (USA), CSA A23.3 (Canada)	AS 3600 and often AS 5100 for transport infrastructure
Shotcrete-specific standard	EN 14487-1 and EN 14487-2	BS EN 14487	TS EN 14487-1 (Turkish adoption of EN 14487)	ACI 506R and ACI 506.2	Austroads ATS 5328, TfNSW B82, CIA guidance
Testing standards	EN 14488 series	BS EN 14488 series	TS EN 14488 series	ASTM C1550, C1609, C1604 and ACI testing methods	AS 1012 plus project-specific shotcrete testing
Fiber-reinforced shotcrete design	EN 14651 and EN 14889	BS EN 14651 and BS EN 14889	EN 14651 and EN 14889 adopted through European standards	ASTM performance tests and ACI 544 guidance	Predominantly performance-based using residual strengths and CIA guidance
Tunnel design methodology	ITA and EFNARC	BTS/ICE, ITA and EFNARC	ITA and EFNARC	FHWA, ACI, ITA	ITA, EFNARC and Australian Shotcrete Society guidance
Seismic design	Eurocode 8	Eurocode 8	TBEC 2018 (TBDY 2018)	ASCE 7 (USA), NBCC (Canada)	AS/NZS 1170

Table 2: Comparison of Codes and Standards

engineering judgement compared to the single integrated shotcrete design standard approach adopted in Europe.

OVERVIEW OF EUROPEAN CODES AND STANDARDS

The discussion below is not intended to be a side-by-side comparison of the various standards used in the US and Europe: It is intended to be a high-level summary of what each code or standard covers.

Structural Design Standards

EUROCODE 2 (EN 1992)

EN 1992-1-1: Eurocode 2 – Design of Concrete Structures

This is the principal structural design code used for reinforced concrete and fiber-reinforced shotcreted structures in Europe. It provides requirements for Ultimate Limit State (ULS) design, Serviceability Limit State (SLS) design, durability, crack control, reinforcement design, and structural concrete material properties.

When designing permanent shotcrete linings, Eurocode 2 would typically be used in conjunction with EN 14487-1 and 2.

When compared to ACI 318, Eurocode 2 requires a more detailed approach to serviceability, durability, long-term behavior, and crack control. This will require more explicit verification of crack widths and long-term deformation.

Eurocode 7 (EN 1997): Geotechnical Design

This is used for tunnel and ground-support applications because shotcrete placement is often part of the ground-support system, especially in SEM/NATM applications. This code covers the following areas, ground-structure interaction, partial safety factors, geotechnical load cases, and excavation support systems.

Shotcrete Material Standards

EN 14487-1

Sprayed Concrete – Definitions, Specifications, and Conformity

This is the primary European shotcrete standard and covers wet- and dry-mix shotcrete, material requirements, exposure classes, early-age strength classes, fiber-reinforced shotcrete, conformity, and quality control.

The current EN version is 2022/2023, but this can vary by country depending on national adoption of the EN.

EN 14487-2

Execution of Sprayed Concrete

This standard provides requirements for spraying operations, equipment, shotcreter qualifications, production control, and site execution procedures, and is the key standard used by contractors on European tunnel projects.

The North American equivalent for the above would be ACI 506.

Shotcrete Testing Standards

EN 14488 SERIES

Testing Sprayed Concrete

The EN 14488 series specifies test methods for shotcrete and includes the major elements listed in Table 3, which may also be specified for QA/QC and acceptance criteria:

Standard	Purpose
EN 14488-1	Sampling fresh and hardened concrete
EN 14488-2	Early-age compressive strength
EN 14488-3	Flexural strengths of fiber-reinforced beams
EN 14488-4	Bond strength
EN 14488-5	Energy absorption of fiber-reinforced shotcrete panels
EN 14488-6	Thickness determination
EN 14488-7	Fiber content determination

Table 3

Fiber-reinforced Shotcrete

EN14889 – FIBERS FOR CONCRETE

With the increasing use of fiber-reinforced concrete, EN14889 (Fibers for Concrete) has been developed and includes requirements for steel fibers, polymer fibers, conformity assessments, and material properties.

EN14651 – FLEXURAL TENSILE STRENGTH TESTING

Provides the residual flexural strength test used to characterize structural fiber-reinforced concrete and shotcrete.

EFNARC GUIDELINES

The European Federation of Producers and Applicators of Specialist Products for Structures (EFNARC) publishes guidance documents that are used extensively in European tunneling practice. These documents cover the following areas: Execution of spraying, shotcreter testing, test panel execution, etc. Although not a statuary guideline, these documents are treated as a best practice manual and will typically be specified as part of the construction specifications.

CONCLUSION

While there are differences in philosophy and approach between North America, Australia and Europe, it is doubtful if a permanent shotcrete lining designed for similar ground conditions and end-use will be significantly different. The process to reach that final design may be different, however, as will be the certification, testing, and QA/QC process during construction.

FURTHER READING

1. Sprayed Concrete Linings in Soft Ground, British Tunnelling Society, 2025
2. Permanent Sprayed Concrete Linings, ITA WG 12, 2020.

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, the A20 Round Hill Tunnels in the United Kingdom, and 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 Doesn't Have Cold Joints

By Charles Hanskat

A typical question on projects using shotcrete placement is, "How do you deal with cold joints when shotcrete placement is interrupted?" The brief answer is that we don't have cold joints — when we properly prepare the joint. To produce a monolithically acting placement, the receiving surface must be rough, clean, and brought to a saturated surface dry (SSD) moisture condition. A previous article in *Shotcrete* magazine, "**Shotcrete Placed in Multiple Layers does NOT Create Cold Joints**," explains the reasons we get excellent bond strength between shotcreted layers to create a final section that acts monolithically. This article explores more of the research that points to why shotcrete placement done properly does not create cold joints between placements.

What is a Cold Joint and Why is it a Problem?

Let's look at what a "cold joint" is. The American Concrete Institute (ACI), in Concrete Terminology (ACI CT-25), defines it as:

> "A joint or discontinuity resulting from a delay in placement of sufficient duration to *preclude intermingling and bonding of the material*, or where mortar or plaster rejoin or meet."

In form-and-pour concrete, this generally happens when concrete delivery is interrupted and the previously placed concrete has hardened such that the fresh concrete can't be vibrated into the hardened concrete. There is no intermingling and bonding of the fresh concrete to the hardened surface. The fresh concrete just sits on top of the original placement. You can see in Fig. 1 the distinct interface between the two placements in a form-and-pour wall.

This creates a poorly bonded disruption in the concrete, preventing the overall section from acting monolithically. Cold joints are often detrimental to the mechanical performance of the section. Here are the impacts commonly experienced with cold joints.

- **Impact on Structural Integrity and Strength:** Cold joints can significantly lower the compressive and flexural strength of the concrete. Depending on the location in the section, a cold joint can impact the designed load-transfer characteristics and overall load-carrying ability. The cold joint is essentially a tight crack that may degrade the stability of the section

Fig. 1: Prominent cold joint in a form-and-pour wall

- **Durability and Permeability Impact:** Because a cold joint is essentially a seam in the concrete, it creates a path for external exposure to penetrate the concrete. This increases liquid permeability, allowing moisture to seep deeper into the structure. When corrosive liquids penetrate through the joint, corrosion of the embedded reinforcement may further weaken the structure or require earlier repairs.
- **Aesthetic and Surface Impact:** While engineers consider cold joints a structural issue, they also have visual consequences for concrete surfaces intended to be left as cast concrete surfaces exposed to view. As seen in Fig. 1, there are visible seams that appear as distinct lines or "discolorations" on the finished surface. This is often unacceptable in architectural concrete and may require unplanned coatings to produce a uniform surface appearance.

When is a Shotcreted Construction Joint Not a Cold Joint?

The simple answer is when it's a strong enough bond for the two surfaces to work together. But what is "strong enough?"

Earl Felt with the Portland Cement Association (PCA) Research and Development Laboratories published research[1] in 1956 evaluating the properties needed to have a bonded overlay on a concrete pavement act monolithically. This research concluded that the flexural strength (modulus of rupture) of beams cast in two layers with a bonded topping was equal to the strength of monolithically cast beams if the *shear strength* at the bond interface was at least 200 psi (1.4 MPa).

Evaluating the bond shear strength of a two-layer system is difficult, generally requiring laboratory testing. Using a bond tensile strength test is generally much easier and can be routinely accomplished in the field[2]. ASTM C1583 *Standard Test Method for Tensile Strength of Concrete Surfaces and the Bond Strength or Tensile Strength of Concrete Repair and Overlay Materials by Direct Tension (Pull-off Method)* is commonly used for testing bond tensile strength, and the test equipment is readily available from a variety of suppliers. However, how do you equate the results of a bond tensile strength test to the bond shear strength?

Fortunately, research has provided the correlation between bond tensile and bond shear strengths. Johan Silfwerbrand with the KTH Royal Institute of Technology evaluated the bond shear strength in repaired concrete structures[3] using cast-in-place concrete test samples. He found that the ratio of the average shear bond strength and the direct tensile bond strength ranged from between 1.9 and 3.1 for cast-in-place samples.

In 2016, Michael Sprinkel, with the Virginia Transportation Research Council, published research[4] on the bond strength between a shotcrete overlay and reinforced concrete substrate on a Florida concrete cooling tower. He concluded, "The ratio between shear and tensile bond strength is about 3 to 4 for surfaces with a macro texture of 0.06 in. (1.5 mm) and increases as the macro texture increases to a ratio as high as 7." The macro texture was the surface profile.

If we consider an interface shear strength of 200 psi as the minimum recommended bond shear strength and use the surface profile of 0.06 in. (from Sprinkle's research), the direct tensile bond pull-off strength would need to be at least 67 psi (0.5 MPa). to ensure that the bond at the interface allows the overall section to act monolithically.

Fig. 2: High velocity shotcrete placement in a wall

Fig. 3: Initial paste-rich shotcrete placement without coarse aggregate

WHY DOES SHOTCRETE PLACEMENT CREATE ENOUGH BOND TO ACT MONOLITHICALLY?

What makes shotcrete placement different than cast-in-place? First, high velocity. The shotcrete material stream exiting the nozzle and impacting the receiving surface travels at 60 to 80 mph (100 to 130 kph). The material is fully mixed concrete when it impacts. For an analogy of the impact we get with shotcrete placement, imagine driving at 60 mph and hitting a concrete wall. That is the impact we get with shotcrete placement. In effect, we are blasting concrete onto the surface and, in effect, sandblasting as we place concrete (Fig. 2). This opens up the pores in the existing concrete surface and drives cement paste into the pores.

Second, there is a very cement paste-rich environment right at the interface. When we are first shooting against a hard concrete surface, much of the coarse aggregate bounces off as rebound, as there is no bed of cement paste to embed into (Figs. 3 and 4). Thus, the shotcrete process inherently creates a paste-rich layer right at the interface.

Fig. 4: Removed sample of initial shotcrete placement

For decades, engineers have specified a scrub coat of a paste-rich grout to help bond fresh concrete to existing concrete. Shotcrete accomplishes this with the high-velocity placement process. No extra work involved!

Third, ACI and ASA shotcrete documents stress that when shotcreting on a hardened concrete substrate (like a construction joint), we need three things to get the best bond:

- **A roughened surface:** The roughness should be established when the first placement is not fully hardened. Roughening techniques can include raking or using a stiff broom. We generally want to see at least the +/- 0.06 in. or an ICRI CSP (International Concrete Repair Institutes' Concrete Surface Profile) Level 5[5]. The roughened profile gives increased shear resistance and increases the surface area for the fresh concrete to bond to.

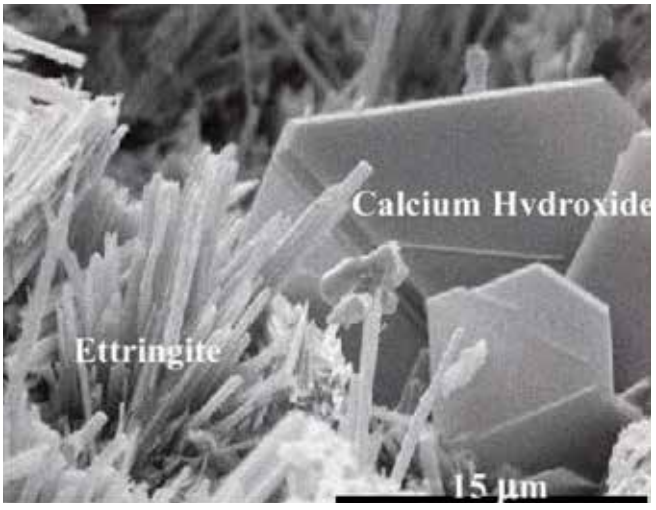

Fig. 5: Microphotograph of cement hydration products

- **The surface is clean:** Any contaminants on the surface can reduce the bond. We never want to use a bonding agent on the surface, as it will interfere with the process of driving cement into the pores of the concrete.
- **The surface is saturated surface dry (SSD):** SSD means we don't have standing water on the surface, but we have filled the surface pores with moisture.

With this preparation, we have a clean, roughened, and dampened concrete surface. We then drive fresh cement paste into the surface at over 60 mph (100 kph). The impact drives the cement particles into the pores. When the cement and water react and create hydration products (Fig. 5) an interlock is formed between the new and existing concrete. In most evaluations when taking cores or sawing samples, identifying the location of the interface is difficult to impossible (Fig. 6).

What bond tensile strengths do we get with shotcrete placement?

In the aforementioned article[6], I detailed results of a study on shotcrete bond to concrete repair surfaces that included work on multi-layer shotcrete bond conducted at Laval University[7]. Table 1 summarizes the testing from the Laval University research. The results showed a bond tensile strength of 260 to 300 psi (1.8 to 2.1 MPa). Using a conservative factor of bond shear to bond tensile strength of 3 yields an effective bond shear strength of 780 to 900 psi (5.4 to 6.2 MPa)

Sprinkel's results[4] showed the tensile bond strength is about the same for both hydro-blasted and mechanically blasted methods of surface preparation at 142.0 psi (0.98 MPa) and 139.8 psi (0.96 MPa), respectively. A specific surface profile wasn't noted, just the surface


Fig. 6: Intimate contact and full bond of new shotcrete placement (right, gray) with old concrete (left, beige)

	Type of Finish Between Layers in psi (MPa)			
Time	**None**	**Scratch**	**Scratch + wood**	**Broom roughen**
4 hours	300 (2.1)	260 (1.8)	300 (2.1)	275 (1.9)
1 day		300 (2.1)	300 (2.1)	
28 days		260 (1.8)		290 (2.0)

Table 1: Multi-layer bond strength in psi (MPa) (Boupré 1999)

preparation using either mechanical or hydro blasting. It was noted that an increased surface profile could raise the ratio of shear to tensile strength as high as 7. The bond shear strength was similar for both hydro-blasted and mechanically blasted methods of surface preparation: 1047.7 psi (7.22 MPa) and 972.7 psi (6.71 MPa), respectively. All these bond shear values far exceeded the 200 psi minimum to act monolithically.

Charles Hanskat *is the current ASA Executive Director. He received his BS and MS in civil engineering from the University of Florida, Gainesville, FL. Hanskat is a licensed professional engineer in several states. He has been involved in the design, construction, and evaluation of environmental concrete and shotcrete structures for over 35 years. Hanskat is also a member of ACI Committees 301, Specifications for Structural Concrete; 350, Environmental Engineering Concrete Structures; 371, Elevated Tanks with Concrete Pedestals; 372, Tanks Wrapped with Wire or Strand; 376, Concrete Structures for Refrigerated Liquefied Gas Containment; 506, Shotcreting; and Joint ACI-ASCE Committee 334, Concrete Shell Design and Construction. Hanskat's service to the American Society of Civil Engineers (ASCE), the National Society of Professional Engineers (NSPE), and the Florida Engineering Society (FES) in over 50 committee and officer positions at the national, state, and local levels was highlighted when he served as State President of FES and then as National Director of NSPE. He served as a District Director of Tau Beta Pi from 1977 to 2002. He is a Fellow of ACI, ASCE, and FES and a member of ACI, NSPE, ASTM International, AREMA, ICRI, and ASCC.*

THAT'S WHY SHOTCRETE DOESN'T HAVE COLD JOINTS

Full attention to the essentials of surface preparation (roughened, clean, SSD) is mandatory to produce the best bond of shotcreted concrete onto previously shotcreted or cast concrete. With the required surface preparation, proper concrete materials, and equipment, along with placing techniques, shotcrete can routinely achieve a bond tensile strength of 150 psi (1 MPa), providing bond shear strength of at least 450 to 1000 psi (3.1 to 6.9 MPa) of bond shear strength, and far exceeding the required 200 psi to act monolithically. No bonding agents or added polymers are needed to create a section that performs well. Shotcrete placement inherently creates an excellent bond to properly prepared concrete substrates whether the concrete is 100 years old or shot yesterday.

REFERENCES

1. Felt, E.J., "Resurfacing and Patching Concrete Pavement with Bonded Concrete," Proceedings of the Thirty-Fifth Annual Meeting of the Highway Research Board, V. 35, 1956, pp. 444-469.
2. ICRI 210.3R-2022 - Guide for Using In-Situ Tensile Pulloff Tests to Evaluate Concrete Surface Repairs and Bonded Overlays, International Concrete Repair Institute
3. Silfwerbrand, J., "Shear Bond Strength in Repaired Concrete Structures," Materials and Structures, V. 36, No. 6, July 2003, pp. 419-424.
4. Sprinkel, M, "Bond strength between shotcrete overlay and reinforced concrete base", Concrete Repair Bulletin January/February 2016, International Concrete Repair Institute, pp. 8-13.
5. ICRI 310.2R-2013 – CSP "Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, Polymer Overlays, And Concrete Repair" including physical chip with texture samples
6. Hanskat, C "Shotcrete Placed in Multiple Layers does NOT Create Cold Joints" Shotcrete, Spring 2014, pp 40-41.
7. Beaupré, D., 1999, "Bond Strength of Shotcrete Repair," Shotcrete, V. 1, No. 2, Spring, pp. 12-15.

SHOTCRETE INSPECTORS WANTED

Shotcrete Projects with ACI-Certified Shotcreters Need ACI-Certified Shotcrete Inspectors

DATE: October 22, 2026
TIME: 8:00 AM - 4:30 PM; exam following
LOCATION: Applied Shotcrete | Sebastopol, CA
PRESENTER: O. Duckworth (siroscar@sonic.net, 415.378.8178)

COSTS
Seminar*, Exam, Reference Pack: $799
Seminar* & Exam: $699
Exam Only: $350
Exam Retest: $300

QUESTIONS?
info@shotcrete.org
248.983.1702

*Breakfast (7:00 AM) & lunch included

REGISTRATION

https://tinyurl.com/bdd6thtd

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ASA's "Quality Shotcrete – Know It When You See It" Seminar Provides:

- Education that supports ACI's Shotcrete Inspector program
- Knowledge about industry standard shotcrete practice contractors can use

Besides ensuring that your crew delivers high-quality shotcrete placement on every project, having an **ACI-Certified Shotcrete Inspector** on your team also boosts your credibility in showing project owners (or less experienced inspectors) 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!

Leverage Your Hands-On Shotcrete Experience

BECOME AN ACI-CERTIFIED SHOTCRETE INSPECTOR

By Oscar Duckworth

There is an old saying with engineers and inspectors that you cannot have too many credentials. While that is true for many careers, it is underused in shotcreting. Knowledge and experience of successful concrete construction are the greatest career assets for those who work with shotcrete placement. Shotcreters know how the work is performed, and can immediately recognize shortcuts, hidden defects, and other red flags. So, why not leverage valuable experience by acquiring an ACI-Certified Shotcrete Inspector credential?

Transforming or supplementing a successful field career into an inspector role is a natural and rewarding progression for experienced workers of every profession. On typical projects, inspectors and other construction monitoring personnel are required by the owner and engineer of record. The inspector is responsible for observing the work and documenting that it is performed in accordance with the project specifications.

There is an acute shortage of ACI-Certified Shotcrete Inspectors in the United States. In fact, in many regions, shotcrete inspectors often travel significant distances to meet demand.

The ACI Shotcrete Inspector Certification program was launched in 2019 to help satisfy the strong demand for knowledgeable on-site shotcrete inspection personnel, and for current concrete inspectors who wish to obtain ACI Shotcrete Inspector credentials. Since the program's inception, shotcrete workers, designers, project superintendents, and others from many different shotcrete backgrounds have obtained ACI-Certified Shotcrete Inspector credentials, significantly benefiting the industry.

Inspectors want to help provide a quality product; however, disagreements with inspection personnel can arise about the use of shotcrete placement rather than traditional concrete casting methods.

Unfortunately, determinations of whether shotcrete placement is performed in strict accordance with the project specifications often appear to be inconsistent between inspectors. In many instances, inspection personnel draw conclusions from common misconceptions or from their experience with cast-in-place work. Disagreements regarding surface preparations, reinforcement spacing, material rejections, and cold joints are common.

Possessing an ACI-Shotcrete Inspector credential can be useful when differences of opinion arise, or when compliance or noncompliance issues are discussed. An ACI Shotcrete Inspector credential validates that the inspector's shotcrete-specific concrete knowledge is current and has been verified through an approved testing criterion. ACI Shotcrete Inspectors are qualified to perform shotcrete placement monitoring and verification that work was performed according to the project specifications and ACI SPEC 506.2-13(18), "Specification for Shotcrete."[1]

While ACI Certification may seem primarily beneficial to existing concrete construction inspectors, it has many benefits to builders who are subcontracting shotcrete

CP-61PACK

SHOTCRETE INSPECTOR REFERENCE PACKAGE

This binder pack includes program information, Job Task Analysis, a sample exam, and reprints of ACI and ASA technical resource materials covered by the program. Documents include:

- ACI 305R-10, "Guide to Hot Weather Concreting"
- ACI 305.1-14, "Specification for Hot Weather Concreting"
- ACI 306R-16, "Guide to Cold Weather Concreting"
- ACI 306.1-90(02), "Standard Specification for Cold Weather Concreting"
- ACI 506R-16, "Guide to Shotcrete"
- ACI 506.1R-08, "Guide to Fiber-Reinforced Shotcrete"
- ACI 506.2-13, "Specification for Shotcrete"
- ACI 506.4R-94(04), "Guide for the Evaluation of Shotcrete"
- ACI 506.6T-17, "Visual Shotcrete Core Quality Evaluation"
- ACI CCS-4(08), "Shotcrete for the Craftsman"
- ASA, "Safety Guidelines for Shotcrete"

placements on their projects, and even to shotcrete contractors. The benefits include:

- Visual recognition of quality shotcrete during shotcrete placement;
- Knowledge of how to communicate what is involved in quality shotcrete placement to the project team (project owners, engineers, and less experienced inspectors);
- Knowledge of the appropriate testing measures to verify the quality of the in-place concrete;
- Knowledge of what curing and protection methods are appropriate for a project; and
- Possession of an internationally recognized credential that backs up experience against concerns over specification requirements versus performance.

GETTING THE NECESSARY CREDENTIALS

Becoming an ACI-Certified Shotcrete Inspector requires more than knowledge about shotcrete. General concrete inspection knowledge is also required. While practical trade experience counts toward the certification qualifications, other prerequisites for becoming an ACI Shotcrete Inspector include:

- The successful completion of an open book written examination; and
- The successful completion of an ACI Concrete Field-Testing Technician—Grade I (CFTT-I) written exam (Current certification or successfully completed CFTT-I written exam within 1 year of a successfully completed Shotcrete Inspector written exam).

The ACI Shotcrete Inspector certification requires 3 years of satisfactory work experience in at least one of the following areas:

- Testing, inspection, and quality control of shotcrete;
- Supervision of shotcrete construction work; or
- Design of shotcreted structures.

Demonstration of satisfactory work experience may also be shown through attendance at the American Shotcrete Association (ASA) "Quality Shotcrete, Know It When You See It" full-day seminar, which counts as the equivalent of 1 year of field experience.

Gaining shotcrete experience on the job and through education is valuable. Completing the certification process validates shotcrete placement expertise to those in the concrete construction industry.

When the credential is obtained, it can be listed in a LinkedIn profile to easily allow owners, engineers, or builders to find the profile when searching for an ACI-Certified Shotcrete Inspector.

For more information, visit **www.concrete.org/certification**.

ACI Shotcrete Inspectors help ensure quality shotcrete placement

REFERENCES

1. ACI Committee 506, "Specification for Shotcrete (ACI SPEC-506.2-13) (Reapproved 2018)," American Concrete Institute, Farmington Hills, MI, 2013, 12 pp.

***Oscar Duckworth**, FACI, is an ACI-Certified Shotcreter with over 44,000 hours of nozzle time. He has worked as a shotcreter on over 2500 projects. Duckworth is currently an ASA/ACI Examiner for the wet- and dry-mix processes. A member of the American Shotcrete Association (ASA) and ASA Past President, he has served on the ASA Board of Directors and as a past Chair of the ASA Education Committee. He continues to work as a shotcrete consultant and certified shotcreter.*

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A Survey of Fiber Options

A GUIDE TO CHOOSING THE CORRECT FIBER OPTION FOR YOUR APPLICATIONS

By Mac Young

In today's concrete industry, while we are fortunate to have options, the wide variety can also create a paradox of choice: With dozens of commercially available fiber types and countless variations, how do you choose the right fiber for your application, performance requirements, and project goals?

This article provides a practical overview of fiber technology by explaining the primary role of fibers in concrete, the five key characteristics that differentiate them (including chemistry, length, shape, dosage, and delivery method [aspect ratio]), as well as the major fiber categories defined by these characteristics (macro and micro). By the end of this article, readers will have a stronger understanding of fiber technology and the difference in many unique fiber options on the market, as well as more confidence in selecting the right fiber for their specific project needs.

WHAT IS THE JOB OF FIBERS?

In the fiber industry, there's an old hyperbole about concrete: "You can guarantee three things about concrete — it's fireproof, it's theft-proof, and it's guaranteed to crack." While the first two are certainly debatable, the last one is an accepted reality of concrete. This brings us to the two primary jobs of fiber-reinforced concrete: The first is to extend the service life of concrete by delaying the formation of cracks, and the second is to help control and mitigate crack growth once cracking occurs.

WHAT TYPES OF CRACKING DO FIBERS HELP MITIGATE?

There are two main types of cracking that fibers can help reduce: Early-age plastic shrinkage cracking and hardened concrete cracking.

- **Plastic shrinkage cracking** occurs within the first few hours after placement, while the concrete is still in its plastic state. It develops when moisture evaporates from the concrete surface faster than bleed water can replace it, causing the surface to shrink and crack (Fig. 1).
- **Hardened concrete cracking** occurs after the concrete has cured and can result from a number of factors, including thermal movement, drying shrinkage, structural loading, and other external forces the concrete is exposed to throughout its service life (Fig. 2).

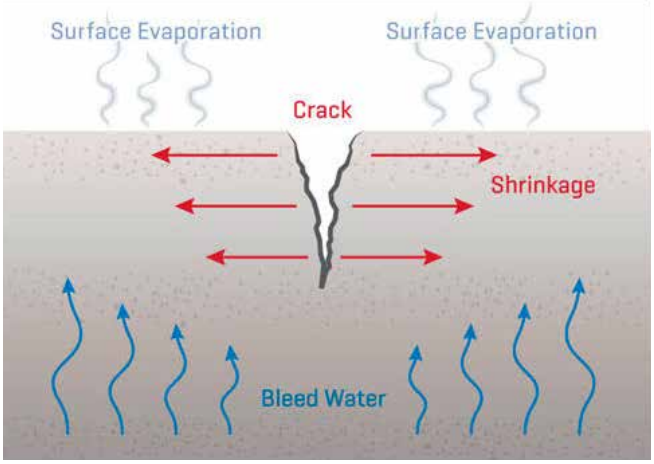

Fig. 1: Visual depiction of how plastic shrinkage cracks form

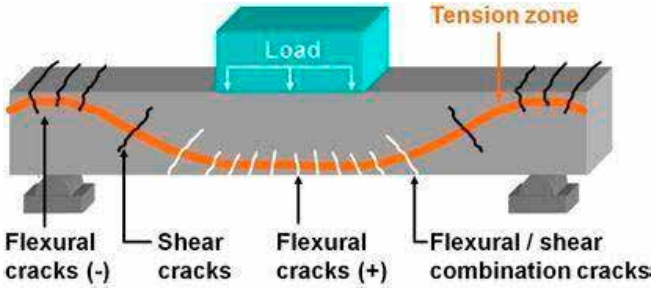

Fig. 2: Visual depiction of how structural hardened cracks can form

While fibers cannot always prevent these cracks from forming, they help bridge developing cracks, improving toughness and durability while limiting crack widths and extending the service life of the concrete.

UNDERSTANDING THE 5 KEY CHARACTERISTICS OF FIBER FOR YOUR APPLICATION

There's a lighthearted story I like to tell when explaining the importance of the five key characteristics of fiber. My grandmother wanted a lightweight, easy-to-walk dog, so she went to the local animal shelter looking for a beagle puppy. She picked out the cutest one she could find, took him home, and named him Thor. Well, Thor certainly lived up to his name — instead of growing into a beagle, he grew into a 120 lb (54 kg) rottweiler.

I use this story as an example because, just as

my grandmother should have understood the key characteristics of the type of dog she wanted, specifiers, engineers, contractors, and producers should understand the key characteristics of the fibers they are selecting. Knowing these characteristics helps ensure the fiber chosen will deliver the performance required for a specific application or project.

Fortunately, identifying the right fiber doesn't have to be complicated. Nearly every fiber can be evaluated by five key characteristics: Chemistry, length, shape, delivery method (aspect ratio), and dosage.

CHEMISTRY

The chemistry of a fiber is determined by what it is made of. In fact, most fibers, regardless of their brand name, are identified by their chemistry because it largely determines how they will perform and behave within the concrete matrix. For example, steel fibers behave differently than the more common polypropylene fibers, and polypropylene fibers behave differently than glass, basalt, acrylic, or cellulose fibers. As you can see, there are many different fiber chemistries available, each with its own unique characteristics (Fig. 3).

While each chemistry offers different performance benefits, there are three key characteristics that should be common among them all:

1. The fiber should be chemically stable, meaning it will not degrade or deteriorate over time.
2. It should be alkali resistant, so it can withstand the highly alkaline environment of concrete without breaking down.
3. The fiber should have low water absorption, so it does not significantly affect the available water needed for proper cement hydration. Unlike hydrophobic fibers (steel, polypropylene, carbon, etc.), natural hydrophilic fibers, like cellulose, will absorb water: They may help provide some internal curing benefits, but the concrete mixture design must account for the water demand of the fibers.

Fig. 3: An example of different microfiber chemistry: A) Polypropylene; B) Acrylic; C) Recycled Carbon Fiber; D) Basalt

LENGTH

Fibers are manufactured in a wide range of lengths to meet the performance requirements of specific applications (Fig. 4). In general, fiber length influences two primary performance characteristics:

1. The shorter the fiber, the more effective it is at controlling plastic shrinkage and early-age cracking.
2. The longer the fiber, the more effective it is at intersecting and bridging larger cracks that develop after the concrete has hardened.

Fibers ranging from approximately 3 to 18 mm (0.12 to 0.71 in.) are generally considered **microfibers**. These fibers are excellent at reducing plastic shrinkage cracking and

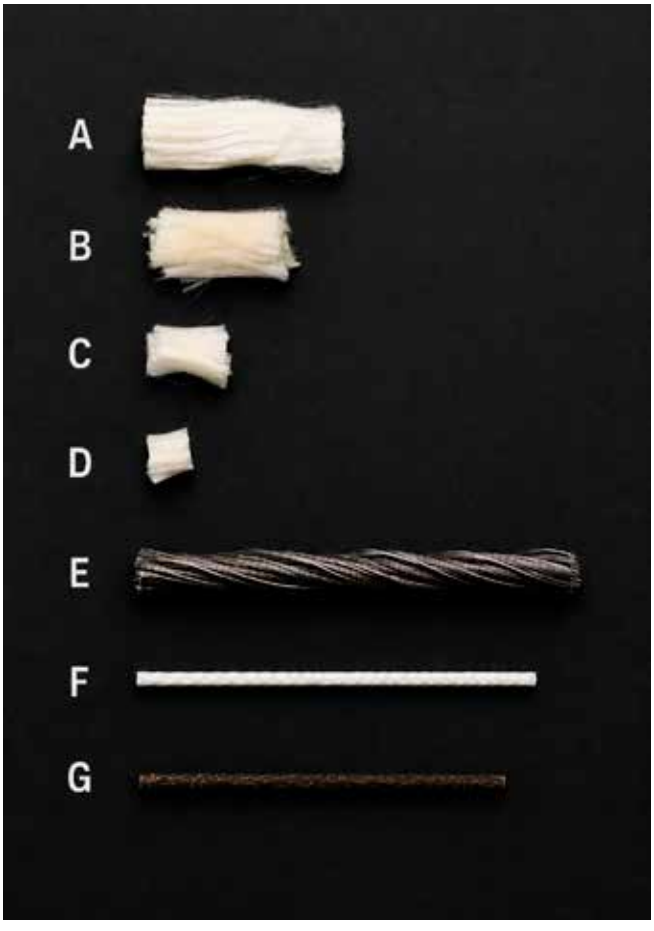

Fig. 4: Showing the differences in fiber size, as well as the size difference between macro and micro fibers. A) 18 mm (0.71 in.) micro; B) 12 mm (0.47 in.) micro; C) 6 mm (0.24 in.) micro; D) 3 mm (0.12 in.) micro; E) 54 mm (2.1 in.) macro; F) 48 mm (1.9 in.) macro; G) 38 mm (1.5 in.) macro

helping control early-age cracking while the concrete is still developing strength.

Fibers ranging from approximately 38 to 60 mm (1.5 to 2.4 in.) are generally considered **macrofibers**. Their longer length allows them to bridge larger cracks and improve the residual strength and toughness of concrete. When properly designed and dosed for the application, macrofibers can replace conventional reinforcing steel in certain applications.

SHAPE

The shape of a fiber (Fig. 5) plays a major role in how it integrates into a concrete mixture and, ultimately, how it performs. As with fiber length, variety is what allows engineers and contractors to tailor reinforcement to specific applications. While countless fiber designs exist, most can be grouped into four general categories.

- **Monofilament fibers** are comparable to a standard finish nail. They provide reinforcement, but their primary purpose is controlling plastic shrinkage cracking rather than carrying significant loads after cracking.
- **Fibrillated fibers** are more like a wood screw; their net-like or fibrillated structure creates greater mechanical interlock within the concrete matrix, improving crack resistance and load transfer. In many applications, they provide enough reinforcement to replace light-gauge welded wire reinforcement used for crack control.
- **Macro fibers** can be thought of as lag bolts. Their larger size and engineered geometry provide strong mechanical anchorage across wider cracks. When properly engineered and dosed, macro fibers can replace traditional welded wire reinforcement or even certain reinforcing steel applications by providing meaningful post-crack residual strength.
- **Ionic Bond fibers** are fibers whose performance relies not only on mechanical anchorage but also on enhanced interaction with the cement matrix. Fibers such as acrylic and cellulose have demonstrated improved adhesion or an 'ionic bond' within the concrete, allowing them to more effectively control plastic shrinkage cracking. In shotcrete placement, this increased cohesion can also reduce rebound and improve material retention, resulting in more consistent placement and higher application efficiency.

A useful way to think about the reinforcement provided by different fiber shapes is to compare them to common construction fasteners (Fig. 6).

ASPECT RATIO

Aspect ratio is arguably the least intuitive characteristic of a fiber, but it is also one of the most important. In the fiber industry you'll hear terms like 'denier' and 'linear density', but for the purpose of understanding fiber performance, think of aspect ratio as one simple question: How long is the fiber compared to how thick it is?

Aspect ratio plays a critical role in balancing reinforcement and workability. In general, the higher the aspect ratio, the better a fiber is at bridging cracks and reinforcing the concrete. The tradeoff is that high aspect ratio fibers are more difficult to disperse uniformly throughout the mixture and are more susceptible to balling. Lower aspect ratio fibers disperse much more easily but provide less crack-bridging capability.

So, how do manufacturers achieve excellent reinforcement while still maintaining good dispersion? One common solution is what many in the industry refer to as 'fooling the aspect ratio'. While the aspect ratio of the individual fibers never actually changes, the fibers are temporarily packaged in a way that behaves like a lower aspect ratio reinforcement during mixing. Twisted bundles, pucks, and other bundled fiber groupings enter the mixer as compact packages that disperse more easily throughout the concrete. As mixing continues, these bundles separate into individual filaments, allowing each fiber to regain its high

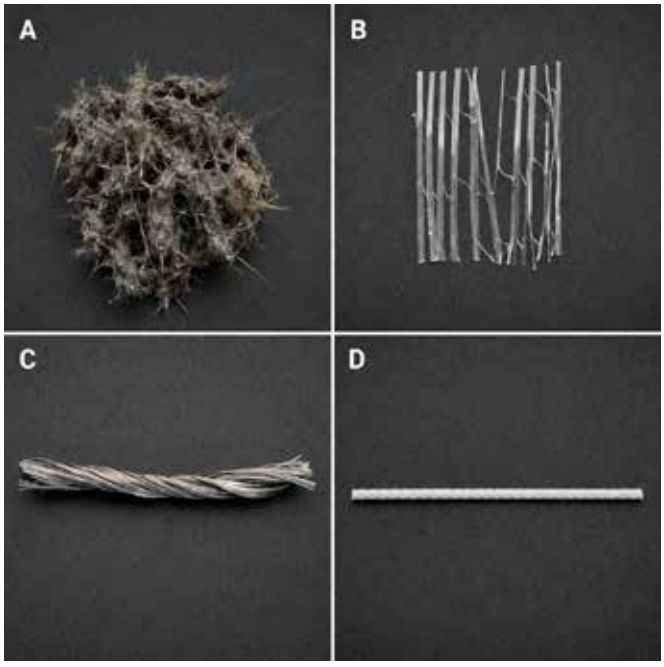

Fig. 5: Different fiber shapes: A) Monofilament; B) Fibrillated fiber; C) Macro twisted; D) Macro helictical stick

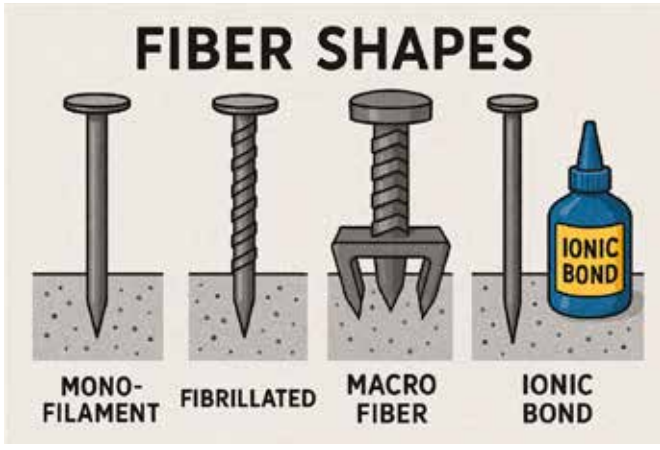

Fig. 6: Fiber shapes in terms of construction fasteners

aspect ratio and provide the reinforcement it was designed to deliver. This packaging strategy gives contractors the best of both worlds: Improved mixing and fiber distribution without sacrificing the reinforcing performance of high aspect ratio fibers.

DOSAGE

The amount of fiber introduced into a concrete mixture can have a significant impact on performance, fiber dispersion, and ultimately which applications it is capable of meeting. Anyone familiar with fibers, whether in shotcrete placement, slab on grade, or precast applications, can attest that fiber dosages are all over the map. Depending on the application, dosages can range from as little as 0.5 lb/yd^3 (0.3 kg/m^3) to more than 60 lb/yd^3 (36 kg/m^3).

This is where the first four key characteristics begin to come together. Understanding a fiber's chemistry, length, shape, and intended application provides a good indication of the dosage range required to achieve the desired performance. For example, steel fibers are typically dosed at much higher rates, often between 50 and 60 lb/yd^3 (30 and 36 kg/m^3) , while acrylic fibers are commonly dosed between 0.5 and 1 lb/yd^3 (0.3 and 0.6 kg/m^3) depending on the application. Likewise, longer fibers in the 38 to 54 mm (1.5 to 2.1 in.) range are generally used to provide residual strength reinforcement. In polypropylene macrofiber applications, there are commonly accepted ACI-engineered dosage rates of approximately 3, 5, and 7.5 lb/yd^3 (1.8, 3.0, and 4.4 kg/m^3) for replacing conventional temperature and shrinkage reinforcement in appropriate applications.

While there are always exceptions, understanding the first four key characteristics provides a practical starting point for determining the appropriate dosage. From there, project-specific performance requirements and engineering design can be used to fine-tune the final dosage.

		Micro					Macro		
	Fiber Type	**Micro PP**	**Acrylic**	**Cellulose**	**AR Glass**	**PVA**	**Basalt**	**Steel**	**Macro PP**
In Service Performance	Pumpability	☆☆☆	☆☆☆	☆☆☆	☆☆	☆☆	☆	☆	☆☆
	Mix Dispersion	☆☆	☆☆☆	☆☆☆	☆☆	☆☆	☆	☆	☆☆
	Sprayability	☆☆	☆☆☆	☆☆☆	☆☆	☆☆	☆	☆	☆☆
	Rebound	☆☆	☆☆☆	☆☆☆	☆☆	☆☆	☆	☆☆	☆☆
	Finishability	☆☆☆	☆☆☆	☆☆☆	☆☆	☆☆	☆	☆	☆
	Plastic Shrinkage Control	☆☆☆	☆☆☆	☆☆☆	☆☆	☆☆	☆☆	☆☆	☆☆
Placement Performance	Post Crack Strength	☆☆	☆☆	☆☆	☆☆	☆☆	☆☆☆	☆☆☆	☆☆☆
	Rebar Replacement						☆☆☆	☆☆☆	☆☆☆
	Wire Mesh Replacement	☆☆☆	☆☆☆		☆	☆	☆☆☆	☆☆☆	☆☆☆
	Durability	☆☆☆	☆☆☆	☆☆	☆☆☆	☆☆☆	☆☆☆	☆☆☆	☆☆☆
	Fire Resistance	☆☆	☆☆☆		☆☆☆	☆☆	☆☆☆	☆☆☆	☆☆☆

A Comparison of Fiber Options in Shotcrete Applications

Table 1: Structural reinforcement ratings assume engineered dosage rates and compliance with applicable design standards. The performance ratings presented in this chart are based on published engineering data, industry testing, and field experience. They are intended to serve as a general selection guide only. Final fiber selection should be based on project-specific performance requirements and the judgement of the specifying engineer, contractor, or concrete producer.

☆☆☆*: Excellent – One of the most effective fiber options for this performance characteristic.*

☆☆*: Good – Provides sufficient performance, although other fiber types may be better suited for this application.*

☆*: Limited – Provides some benefit but is generally not the preferred choice for this performance characteristic.*

: No stars – Not Recommended / Not Common Practice. This characteristic is generally not associated with or recommended for this fiber type.

CONCLUSION

The main objective of this article is to provide you with the tools to identify the type of fiber that might fit your needs based on its five key characteristics. Instead of naming multiple fibers (some you may have heard of and many you may not), it's far more valuable to understand how fibers work and what separates them in terms of their key characteristics, so the end user can make an educated decision on which fiber best fits their specific application. No fiber is a one-size-fits-all solution, but by understanding these five key characteristics, you can identify the fiber that is best tailored to your needs.

REFERENCES

1. ACI PRC 544.1r-96 (REAPPROVED 2023), *Report on Fiber-Reinforced Concrete*, American Concrete Institute, Farmington Hills, MI.
2. ACI PRC 506.1-21, *Guide to Fiber-Reinforced Shotcrete*, American Concrete Institute.
3. ACI PRC 506-22, *Shotcrete - Guide*, American Concrete Institute.
4. ACI PRC 544.3-08, *Guide for Specifying, Proportioning, and Production of Fiber-Reinforced Concrete*.
5. ACI PRC 544.4-18, *Guide to Design with Fiber-Reinforced Concrete*.
6. ASTM C1116/C1116M, *Standard Specification for Fiber-Reinforced Concrete*.
7. ASTM C1609/C1609M, *Standard Test Method for Flexural Performance of Fiber-Reinforced Concrete*.
8. Fiber Reinforced Concrete Association, *Fibers in Practice (FIP 7): Effect of Fibers on Concrete Properties*.
9. Fiber Reinforced Concrete Association, *Fibers in Practice (FIP 8): Design & Specification of Fiber-Reinforced Concrete*.

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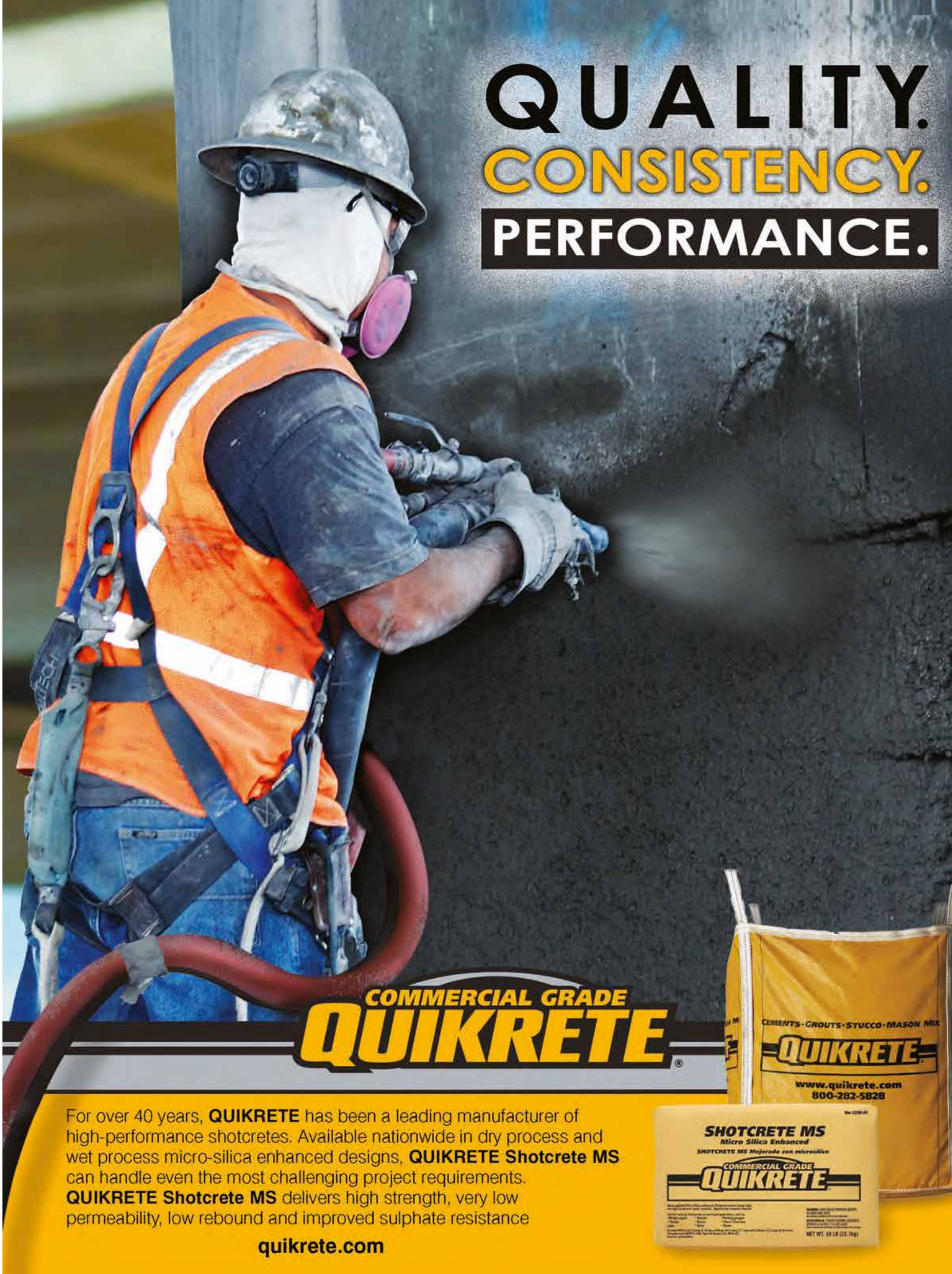

For over 40 years, **QUIKRETE** has been a leading manufacturer of high-performance shotcretes. Available nationwide in dry process and wet process micro-silica enhanced designs, **QUIKRETE Shotcrete MS** can handle even the most challenging project requirements. **QUIKRETE Shotcrete MS** delivers high strength, very low permeability, low rebound and improved sulphate resistance

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Fig. 1: Ready-mix truck being loaded with cooled aggregates via a NITROcrete liquid nitrogen cooling system

Hot Weather Shotcreting with Liquid Nitrogen

By Jamie Curtis

For shotcreters in the field, you know how difficult shotcrete placement can be; even on a good day. You're also aware of how this type of work is made exponentially more complicated when fighting a high-heat environment. Unless all precautions and preventative measures are utilized, the process can feel like a losing battle from the very beginning — even for the short period until initial set. Hot weather can adversely affect things like worker safety, productivity, pumpability, proper placement, material quality, meeting specifications, quality control, durability, and more.

The ACI SPEC 305.1-14(20) *Specification for Hot Weather Concreting* defines hot weather as: "One or a combination of the following conditions that tends to impair the quality of freshly mixed or hardened concrete by accelerating the rate of moisture loss and rate of cement hydration, or otherwise causing detrimental results: High ambient temperature, high concrete temperature, low relative humidity, and high wind speed." ACI SPEC 301 and ACI SPEC 305.1 also establish a default maximum concrete discharge temperature of 95 °F (35 °C), unless otherwise specified by the project or contract documents.

One of the key considerations for proper placement in hot weather is the concrete material temperature itself. For placement crews, cooler ready-mix concrete temperatures can reduce slump loss, improve workability, and delay set times. For the ready-mix concrete itself, properly cooled material will help meet specifications, reduce shrinkage and thermal cracking, and allow for an overall higher-quality finished product.

Material temperature is largely controlled by the batch plants themselves, and in particular, the temperature of the materials that are being mixed into it. Aggregate

represents the largest component of most concrete mixtures and is often responsible for creating the majority of the heat load in the batch, especially since they are typically stored outdoors in the summer heat. Batch plants typically have standard measures in place to mitigate hot aggregate. Precautions taken before batching often include shading stored materials from the sun or using water sprinklers to keep stockpiles cooler. Cooling the aggregate during batching can provide significant reductions in final concrete temperatures as the material arrives onsite and is placed within a 90-minute window. But how do you efficiently cool aggregates during batching?

Fig. 2: Insulated cryogenic liquid nitrogen storage tank

Liquid-nitrogen aggregate cooling systems have quickly emerged as one of the most effective ways to accurately control material temperature. Systems, such as the one provided by NITROcrete, provide cooling by dosing liquid nitrogen directly into the aggregate stream as it travels along the conveyor or, in many cases, at the point of aggregate discharge. With contact, the liquid nitrogen rapidly converts to gaseous nitrogen (a process known as phase change) and absorbs heat from the aggregate, lowering its temperature dramatically before entering the truck or mixing drum.

In large commercial projects, mass concrete pours (such as slabs, bridges, dams, walls, and columns) can build up internal heat leading to possible thermal cracking and durability issues. In more specialty shotcrete applications, the reduction of early-age plastic shrinkage cracking, increased pumpability and longer workability are the main objectives. In both scenarios, the benefits of cooler ready-mix concrete deliveries are appealing.

THE AGGREGATE COOLING SYSTEM

Aggregate cooling systems (Fig. 1) are automated cooling systems which ready-mix plants must have preinstalled to offer the product to its customers. However, the process and the ability to access it are becoming much more readily available across the United States.

Liquid nitrogen used for cooling concrete aggregates is at its boiling point of approximately –320 °F (-196 °C). When liquid nitrogen is dispensed on hot aggregate at the dispenser or conveyor belt, it immediately changes from liquid to gas. That is when it absorbs a large amount of heat (its latent heat of vaporization), reducing the aggregate temperature. This phase change is what drives the majority of cooling. It also explains why these systems must be sophisticated enough to ensure the proper supply of liquid being dosed to the aggregate, as to prevent a multiphase

Fig. 3: Dispensing heads apply the liquid nitrogen to the warm aggregates

(liquid nitrogen and vapor together) flow. Secondarily, the sensible heat (temperature change without changing the physical state; i.e. liquid stays liquid) accounts for very little of the heat transfer and cooling in comparison to the phase change. Aggregate entering at 120 °F (49 °C) may be cooled to 60 - 80 °F (16 - 27 °C), depending on a variety of factors.

The system consists of an insulated cryogenic liquid nitrogen storage tank, typically located next to the aggregate conveyors and a dispenser. Liquid nitrogen is stored in vertical or horizontal tanks at –320 °F (Fig. 2). Pre-insulated copper piping runs to a valve control box which regulates flow to the dispensing heads situated over the conveyor (Fig. 3). Dispensing heads, or 'dispensing nozzles', apply the liquid nitrogen to the warm aggregates (approximately 100 – 130 °F [38 – 49 °C]). The liquid nitrogen boils upon contact with the aggregate, and heat is immediately absorbed from the material. First, surface heat is removed. Next, heat from the center

as the particles conducts outward. Depending on the application, liquid nitrogen cooling can reduce aggregate temperatures by 20 - 50 °F (11 - 28 °C) or more. Finally, the liquid nitrogen instantly becomes a harmless nitrogen gas — those who have seen this process will remember a large fog cloud that develops and rolls through the plant as each load is cooled (Fig. 4).

Batch plants control dosing from the automated system, per load, to achieve the desired material temperature required on the job (Fig. 5). Special care is taken to adjust both the rate and the amount of aggregate that is being dispensed onto the conveyor. In addition, the speed at which aggregates pass under the heads and the amount of nitrogen applied to the material are both key to proper cooling. This ensures proper distribution of liquid nitrogen over the aggregate on the conveyor. The automated system control, typically in the batch house, provides precise, real-time control of cooling rates, enabling plant operators to quickly adjust liquid nitrogen flow to accommodate changing conditions in the field and consistently maintain target concrete temperatures throughout the various stages of production.

ADVANTAGES OF LIQUID NITROGEN AGGREGATE COOLING

Aggregate cooling can provide several key advantages over other more traditional cooling methods such as chilled water, ice, or even direct injection of liquid nitrogen. As a general rule, for every 10 °F (12 °C) increase in temperature of the ready-mix concrete, estimated set time is cut by 50%. This makes cool concrete critical to predicting set times for specific job types. Even at what is considered a light dose of 6 gal/yd³ (30 L/m³), one will discover multiple advantages in cooling aggregates, plus additional benefits over other more common methods. Consistent, predictable,

Fig. 4: As liquid nitrogen hits the warm aggregate, it instantly becomes a harmless nitrogen gas

Fig. 5: Automated aggregate cooling systems integrated into batch plant operations

and easily adjustable temperature control (via automated batching systems) makes this strategy very adaptable to ever-changing conditions.

Liquid nitrogen is a more sustainable cooling method. It reduces production-related impacts such as emissions, energy usage, and harmful particulate matter when compared to more traditional cooling methods like ice and chilled water. Benefits include:

HELPS MEET TEMPERATURE REQUIREMENTS

- Allows for hot weather concreting in higher ambient temperatures
- Helps meet specifications for specific concrete material temperature requirements

IMPROVED CONCRETE QUALITY

- Reduces plastic shrinkage cracking with decreased evaporation
- No impact on water-cement ratio
- Reduced thermal cracking caused by high internal temperatures during mass concrete pours

EXTENDS WORKING TIME

- Reduced risk of accelerated set times
- Slows rate of hydration by lowering temperature
- Ideal for high-strength mixtures with high cement content
- Beneficial for mass concrete pours
- Helpful for long transport times

IMPROVES WORKABILITY

- Improved workability and pumpability
- Retains slump longer and reduces potential for rapid slump loss
- Improved finishability
- Reduced rebound

IMPROVED WORKABILITY AND DECREASED EVAPORATION RATE

In hot weather, fresh concrete has a higher rate of slump loss, which can lead to workability and placement issues. When looking at the factors contributing to slump loss, consider water as it relates to an evaporation rate: Higher temperature ready-mix concrete has increased evaporation, resulting in water loss and decreased slump. More importantly, concrete's rheological properties, such as slump, are affected by the material's initial temperature immediately following batching and mixing. Evaporation during batching is directly related to slump loss. Liquid nitrogen immediately controls the temperature, thus properly managing the evaporation rate right from the beginning of batching each load. This provides the benefit of reduced shrinkage cracking in the finished concrete.

SELECTING THE RIGHT COOLING STRATEGY

While aggregate cooling is effective, it is also important to recognize that not all concrete mixtures contain coarse aggregate. The ideal cooling method depends on the specific shotcreted concrete mix being produced. Many shotcreted mixes use only fine aggregate (sand) and cementitious materials. so there is no coarse aggregate to cool. As a result, plant-based aggregate cooling is generally not a practical solution for these sand-only mixture designs. When shotcrete mixes contain only fine aggregate, the preferred solution is direct injection of liquid nitrogen in the batched concrete.

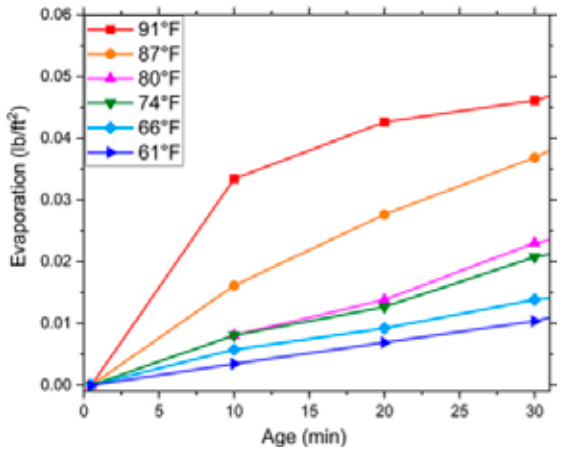
Rather than cooling the coarse aggregate during batching, injecting liquid nitrogen directly into the ready-mix truck during mixing is an available option. This approach cools the entire concrete mass, including sand, cementitious material, water, admixtures, etc. Because the entire batch is being cooled, injection can be used on virtually any shotcreted concrete mix design, including sand-only mixtures that cannot be cooled using plant-based coarse aggregate systems. The result is precise temperature control regardless of aggregate gradation, mix design, or batching location (Table 1).

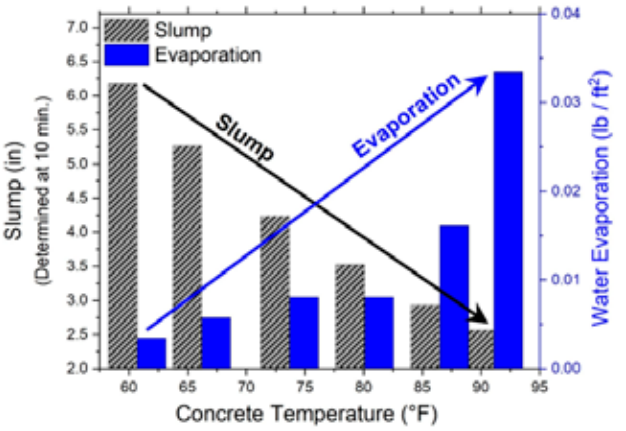
Mix Type	Aggregate Cooling	Direct Injection
Coarse Aggregate Shotcrete	Efficient Option	Less Efficient Option
Sand-Only Shotcrete	Not Applicable	Recommended
Plant-Based Cooling	Yes	No
Truck-Based Cooling	No	Yes
Cools Entire Concrete Mix	Yes	Yes
Water-Cement Ratio Impact	No	No

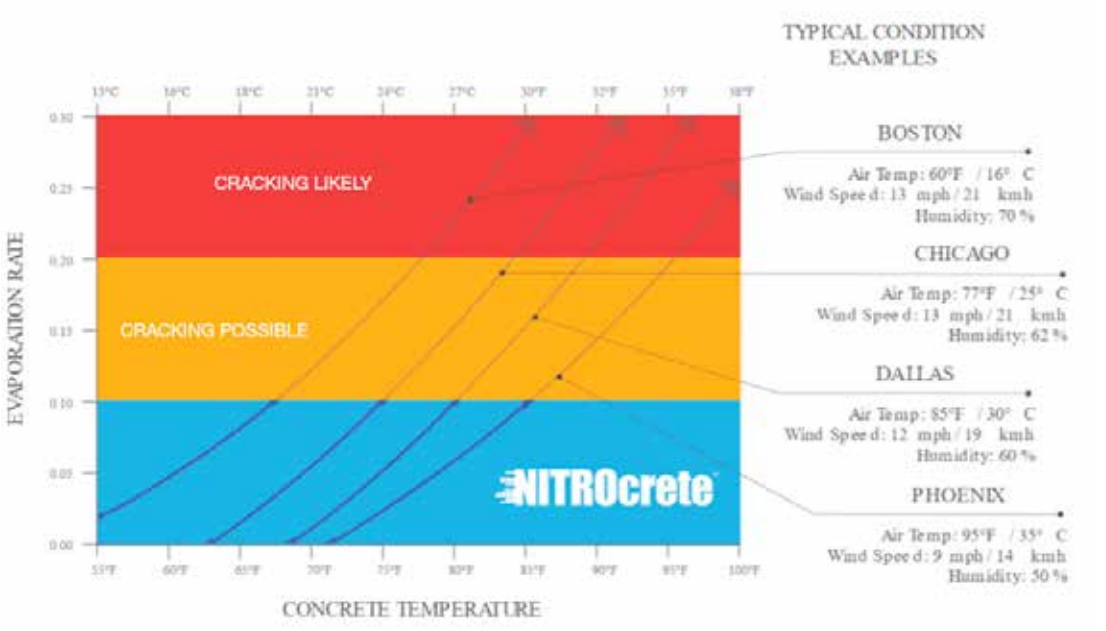
Table 1

COMBINING LIQUID NITROGEN WITH CONVENTIONAL HOT WEATHER TECHNIQUES

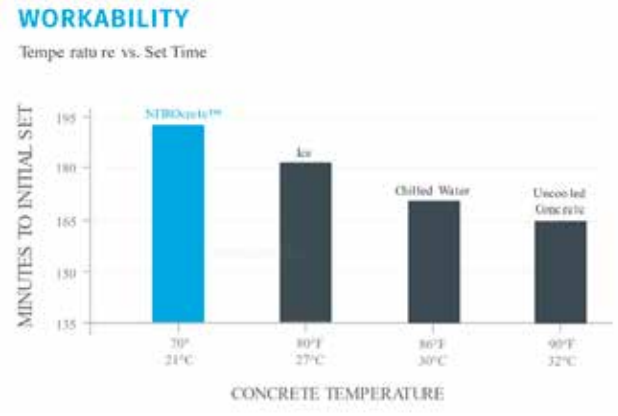
Combining other hot weather shotcrete precautions along with liquid nitrogen cooling can provide an enhanced and much more predictable placement environment to work in. The following techniques can address further concerns and

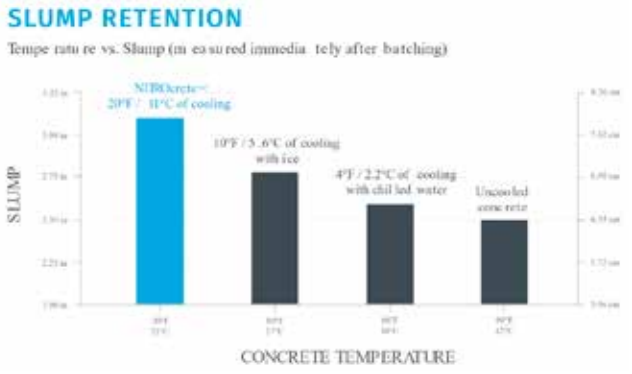






Graph Source: *NITROcrete™ Research and Development, 2019, based on NOAA weather data and ACI Materials Journal data 1998*





provide substantial benefits while working alongside the cooler material.

- Keeping substrate protected from the sun, cool and pre-saturated aggregates
- Casting or shooting early in the morning or later at night for cooler ambient temperatures
- Shading areas to be shotcreted (Fig. 6)
- Using misters or fog cannons to increase humidity in the air if required (Fig. 7)
- Protecting freshly placed concrete from high winds and direct sun
- Including a hydration stabilizer admixture to properly time the initial set time
- Applying evaporation retarders during placement if applicable
- Implementing an aggressive curing strategy with early wetting and an extended water curing period or using spray-on curing membranes with careful attention to full coverage and thickness

IN SUMMARY:

When planning any shotcrete project around hot weather, consider the return-on-investment of using liquid nitrogen. Aggregate cooling costs can vary geographically: Many plants will charge per cubic yard (m^3) by the desired delivered concrete temperature, such as 75/85/95 °F (24/29/35 °C), or by the gallons per cubic yard. Regardless, consider the value and the combined benefits your project will gain by having cooler material delivered to your jobsite.

In most cases, the benefits will outweigh the costs. Our shotcreting team prefers ready-mix concrete suppliers who have cooling capabilities installed (in particular nitrogen) when making a concrete ready-mix supplier selection. As ambient temperatures rise in summer, nitrogen cooling can become an invaluable option, especially as conditions can vary significantly daily. For safety, quality and feasibility, 'cool rocks' via liquid nitrogen can truly save the day.

Jamie Curtis *is President of SPA Skateparks and VP of CCP Shotcrete, both based in Austin, Texas. For more than 20 years he has combined his passion for skateboarding with expertise in concrete construction to deliver highly technical skatepark and commercial shotcrete projects across the United States. Jamie works from project planning through field execution to ensure the successful delivery of each project. He is an ACI-Certified Shotcreter, serves on the ASA Board of Directors, participates as a member of ASA's Education and Safety Committee, and always ensures both companies are ASA Sustaining Corporate Members.*

Fig. 6: Providing shade to the area being shotcreted provides immense benefits while shooting in the heat

Fig. 7: Utilizing a fog cannon to provide moisture in the air during hot weather shotcrete

Fig. 1: Large pool floor being placed with a line pump system and 4 in. (100 mm) concrete line on an indoor pool

The Advantages of Completing the Pool Floor First

A HYBRID CONSTRUCTION METHOD FOR LARGE COMMERCIAL SHOTCRETE POOLS

By Mason Guarino

As commercial swimming pools continue to increase in size and complexity, contractors are continually looking for ways to improve production without compromising quality. While some projects are ideally suited for an all-shotcrete approach and others are designed entirely as cast-in-place concrete structures, many large commercial pools can benefit from combining both methods.

At South Shore Gunite, we have found that placing the pool floor with conventional cast-in-place before shooting the walls can significantly reduce construction time, improve jobsite safety, and make better use of valuable shotcrete resources. This approach allows each construction method to do what it does best — conventional concrete casting for large horizontal slabs and shotcrete placement for complex vertical structures.

HOW COMMERCIAL POOLS HAVE CHANGED

When South Shore Gunite began constructing commercial pools in the late 1980s, most projects shared similar structural characteristics. Wall and floor thicknesses generally ranged from 8 to 12 in. (200 to 300 mm), and the majority of pools were less than 5000 ft^2 (460 m^2). These projects were ideal candidates for an all-shotcrete construction.

With two dry-mix shotcrete (gunite) crews working together, it was common to place between 300 and 600 yd^3 (230 and 460 m^3) during a commercial pool shoot. At that scale and with a manageable shotcrete workload, shooting the entire structure was both practical and efficient.

Around 2009, however, commercial pool construction began to change. Universities started replacing aging facilities with larger 50 m (160 ft) competition pools, municipalities expanded aquatic centers, and more pools were being constructed on sites with poor soil conditions that required substantially thicker floor slabs.

These changes resulted in projects with dramatically larger floor placements. Brown University's competition pool required approximately 14,000 ft^2 (1300 m^2) of floor area

and nearly 400 yd^3 (300 m^3) of concrete. Another project at Worcester Polytechnic Institute included floor thicknesses ranging from 12 to 24 in. (300 to 600 mm) and required more than 400 yd^3 of concrete.

Both projects were designed by a nationally recognized aquatic designer and detailed as cast-in-place structures. Rather than convert the entire project to shotcrete, we looked at where each construction method provided the greatest advantage. The solution was simple: Pour the floor conventionally and shotcrete the walls.

Since adopting this sequence, we have completed numerous commercial pool floors ranging from 300 to over 500 yd^3 (230 to 380 m^3) in a single working shift. Attempting to shotcrete the same volume would likely require several days, even with two experienced crews. During that time, our shotcrete crews can remain productive on other projects until the walls are ready for placement.

WHY COMPLETE THE FLOOR FIRST?

The most obvious advantage is production. An experienced flatwork contractor equipped with a boom pump can routinely place more than 400 yd^3 of concrete in a single shift with a crew of 12 to 18 workers. Placing the same volume with a traditional shotcrete crew of seven to ten people could require four to eight working days, depending on floor thickness and geometry.

For large floor slabs exceeding approximately 3000 ft^2 (280 m^2) or greater than 12 in. thick, conventional casting is simply the more efficient method (Fig. 1).

The schedule benefits extend beyond the floor placement itself. Contractors operating a single shotcrete crew often find that the crew becomes the bottleneck on multiple commercial projects. Qualified flatwork crews are generally much easier to schedule than experienced shotcrete crews. Having a flatwork contractor complete the slab allows the shotcrete crew to continue working elsewhere while the project progresses.

Another major benefit is the elimination of rebound management across the floor slab. While rebound is a normal part of shotcrete placement, removing it from under the reinforcement grid of thousands of square feet of flooring takes time. Rebound removal with the slab in place is much more efficient and allows the shotcrete crew to focus exclusively on the walls, where shotcrete offers its greatest advantages.

A BETTER WORKING PLATFORM

One often-overlooked benefit is how much easier every trade's work becomes after the floor is completed. Large commercial pools frequently require extensive scaffolding for wall construction. Setting scaffolding on finished concrete is significantly faster, safer, and more stable than working over crushed stone, excavated soil, or a completed reinforcing grid.

Once the slab is in place, carpenters can install wall forms from a solid surface. Ironworkers can tie reinforcing without balancing on floor reinforcing bar. Plumbers and electricians have a clean working platform for installing penetrations and embedded items. Inspectors have easier access throughout the project, and shotcrete crews work from stable footing rather than walking on top of reinforcing steel.

Simply put, every trade benefits from having a finished concrete floor beneath them.

ADDITIONAL ADVANTAGES

Completing the floor first also simplifies curing operations during periods of extreme weather. Whether thermal blankets are required during cold weather or evaporation control measures are necessary during hot weather, protecting one large concrete placement is considerably easier than continuously adjusting curing systems while portions of the structure are being shot over multiple days.

Quality control also becomes more efficient. Grade verification, reinforcing inspections, embedded items, and wall layout can all be completed from a finished concrete surface before wall placement begins.

IMPORTANT CONSIDERATIONS

Like any construction method, this approach requires planning and experienced crews. The flatwork contractor must understand how to place concrete on sloped surfaces. Without proper placement techniques, concrete naturally follows gravity, creating low areas near the top of the transition and excessive buildup near the bottom of the slope. Contractors unfamiliar with aquatic work can unintentionally create bellies that require correction later.

Placement sequencing is equally important. Concrete should be placed continuously to minimize potential cold joints, particularly near future wall locations. Using a concrete flatwork company with a good rapport with the local ready-mix company is highly beneficial.

The floor-to-wall construction joint also requires proper preparation before shotcrete placement. Although this adds an additional day to the schedule, the benefits gained during floor casting typically outweigh this minor delay.

Waterstops are another topic that frequently arises when discussing this construction sequence (Fig. 2). Over the years, we have successfully completed projects using PVC bulb waterstops, hydrophilic swelling waterstops,

Fig. 2: Core sample from a pool that had the floor cast-in-place and the walls shotcreted

Fig. 3: Roughened finish at the floor-wall joint to receive shotcrete

Fig. 4: Slurry blasting to clean a future wall joint location

and projects where no waterstop was specified. In our experience, leaks in commercial pools are far more likely to occur around penetrations than through properly prepared structural construction joints.

Regardless of the waterstop selected, careful surface preparation and proper shotcrete placement remain the most important factors in producing a watertight joint. PVC bulb waterstops can pose a rebound entrapment risk, as they can be difficult to shoot around. If you are forced to shoot in PVC waterstops, you can help ensure proper encapsulation by utilizing a helper with a small concrete vibrator adjacent to the shotcreter, lightly vibrating the concrete as it is placed immediately around the waterstop.

Embedded floor components also deserve special attention during concrete placement. Main drain pots and other large penetrations can float if surrounding concrete is placed too aggressively while still in a fluid state. We typically initially cast concrete halfway around these components (allowing the concrete to reach a stiff plastic state as opposed to a liquid state) before completing the placement around the penetration later. This minimizes buoyancy while maintaining a monolithic placement, avoiding cold joints.

OUR CONSTRUCTION SEQUENCE

The exact sequence depends on the size and depth of the pool. For larger pools with deep ends requiring significant scaffolding, we typically construct only the slab forms initially. If the floor slab is especially thick, additional bracing is installed to resist the lateral pressure created by the fresh concrete.

Concrete is generally placed using a boom pump with a 4 in. (100 mm) delivery line, although interior projects have also been completed successfully using both 3 and 4 in. (75 and 100 mm) line systems.

Whenever possible, we place concrete from the shallow end toward the deep end. Managing concrete downhill is considerably easier than pushing material uphill on sloped floor sections. Concrete slump is adjusted as necessary, depending on floor pitch to maintain placement control.

To maintain slab thickness, grade stakes are installed on approximately 10 to 14 ft (3 to 4.3 m) centers. Finishers establish grade around each stake, remove it during placement, and hand screed the surrounding area before bull floating the slab. The floor is then finished with an aggressive broom texture in preparation for the future finishes.

One field technique that has worked exceptionally well for us is using a manual lawn aerator hand tool to roughen the concrete along future surfaces while the concrete is still plastic. Unlike a rake, which tends to drag concrete across the surface, the aerator punches hundreds of small holes into the fresh concrete, increasing surface roughness without disturbing the overall profile (Fig. 3).

The following day, the construction joint is slurry blasted to remove laitance and expose clean, angular aggregate for optimal shotcrete bond. If specified, a hydrophilic

Fig. 5: ACI-certified shotcreter Mason Guarino working with a blow pipe operator to ensure a monolithic floor-wall joint is shotcreted

waterstop is then installed and mechanically fastened before shotcreting begins (Fig. 4).

During wall placement, the blow pipe operator continuously cleans the receiving surface ahead of the shotcreter. Rather than immediately building the wall to full thickness, the shotcreter first establishes a deliberate 1 to 2 in. (25 to 50 mm) bond layer by spraying directly into the prepared joint while advancing approximately 15 to 20 ft (4.6 to 6.1 m) along the wall. Once this initial layer has been placed, the shotcreter returns to the starting point and builds the wall to full thickness (Fig. 5).

This intentional first pass serves two important purposes: It establishes an excellent bond with the prepared floor joint while also creating a surface that directs rebound away from the construction joint as wall thickness increases. By concentrating on creating the bond first, subsequent wall placement becomes faster, cleaner, and more consistent.

CONCLUSION

This hybrid construction method is certainly not intended to replace all shotcrete construction. For many commercial pools — and for most residential pools — shooting the entire structure remains the most efficient approach. However, as commercial aquatic facilities continue to grow in size, floor placements exceeding several hundred cubic yards are becoming increasingly common. In these situations, completing the floor conventionally before shooting the walls allows each construction method to be used where it performs best.

The result is a faster schedule, improved crew utilization, safer working conditions, simpler quality control, and a finished product that maintains all of the structural and performance advantages expected from a properly constructed shotcrete pool.

Sometimes the most efficient solution isn't choosing one construction method over another — it's knowing when to combine both.

Mason Guarino *is the General Manager of South Shore Gunite Pools & Spas in Massachusetts, where he oversees the company's residential pool construction and shotcrete operations. He earned a Bachelor of Science in Construction Management from Wentworth Institute of Technology and has worked in the construction industry since 2000. Throughout his career, Mason has managed a wide range of shotcrete and concrete construction projects, from custom residential and commercial swimming pools to large-scale infrastructure and heavy civil work throughout New England. His experience includes overseeing shotcrete operations on major aquatic facilities, as well as managing high-volume structural concrete projects outside of the pool industry. He is passionate about improving construction methods, increasing jobsite efficiency and safety, and sharing practical field experience that helps advance the shotcrete industry.*

Fig. 1: The completed, sculpted, and stained shotcrete wall provides permanent support for the roadway above while creating an architectural finish for the redeveloped site. The finished retaining wall combines soil nail stabilization with sculpted concrete facing, preserving usable site area while supporting Northern Avenue above.

Sculpted Shotcrete Solution Supports Retail Redevelopment in Maryland

By Michael Close, P.E.

The redevelopment of a former Sears building in Hagerstown, Maryland presented an unusual stabilization challenge: Engineers had determined that the building's exterior wall had effectively become a retaining structure, supporting the roadway above it.

The building along Northern Avenue had been in place since the early 1960s. As plans moved forward to redevelop the site into a new Sheetz convenience store, the structure was scheduled for demolition. During design evaluation, however, Langan Engineering determined the building's exterior wall was helping retain the slope supporting Northern Avenue. Removing the structure through conventional demolition methods could have compromised the roadway above the site.

GeoStabilization International (GSI) was brought into the design phase to evaluate stabilization alternatives before demolition activities could begin. The project included soil nail stabilization and the refacing of two walls with sculpted and stained shotcrete, creating both structural support and an architectural finish for the completed site.

EXISTING STRUCTURE SUPPORTING ROADWAY

When the Sears building was originally constructed, the grade of Northern Avenue sat approximately 15 to 20 ft (4.6 to 6.1 m) above the building floor elevation. Over several decades, the exterior wall became a load-bearing element for the roadway embankment. As such, before demolition could start, the wall had to be stabilized. The work was particularly unusual, though, because the exterior wall of the

fully standing building had to be stabilized from inside the building before demolition could proceed.

Several site constraints complicated the work:

- Available working space was limited to approximately 20 ft (6.1 m) between the building wall and roadway.
- Active utilities along Northern Avenue required coordination during design and construction.
- Soil nails extending into the roadway embankment required right-of-way permitting and review.
- An adjacent form-and-pour retaining wall also required rehabilitation and aesthetic improvement as part of the redevelopment effort.

The team ultimately expanded the scope to stabilize and reface that adjacent wall as well, addressing both walls under one coordinated effort. The project did not impact Northern Avenue traffic throughout construction.

DESIGN-PHASE COLLABORATION

GSI participated during design development to help evaluate stabilization options and construction sequencing before demolition began. The project team reviewed multiple approaches intended to balance retained wall height, nail geometry, utility conflicts, permitting considerations, and constructability. The design prioritized maximizing usable land area to minimize land consumed by unusable slopes.

Alternatives considered during design included stabilizing the exposed wall with longer soil nails (with full height backfill behind the wall), using berm configurations to reduce retained wall height, removing soil behind portions of the wall to shorten the wall height (thus shortening the soil nail lengths), and adjusting nail layouts to minimize right-of-way impacts beneath Northern Avenue.

Early coordination allowed the project team to address utility locations and permitting requirements before mobilization to reduce potential conflicts during construction.

SCULPTED SHOTCRETE FACING

The sculpted and stained shotcrete scope was not part of the original project plan. During design, the team proposed sculpted and stained shotcrete facing as an alternative to constructing a separate architectural wall or earth berm in front of the stabilization system. The shotcrete finish allowed the structural wall and architectural finish to function as a single system.

Shotcrete was well suited for the site conditions because of its ability to conform to complex geometries without the need for traditional formwork. This flexibility allowed the team to create a finished wall surface while addressing the structural requirements of the soil nail wall system. The ability to place shotcrete directly against the wall face also helped simplify construction sequencing (as compared to approaches that would have required separate forming or additional wall construction).

This approach eliminated the need for a secondary retaining or screen wall, reduced site footprint requirements, increased usable site area for circulation and operations, and produced a finished surface designed to resemble natural rock consistent with the new site design.

The sculpted finish was part of the shotcrete facing, not just a veneer applied after construction. By sculpting and staining the shotcreted concrete surface, the team

Fig. 2: Crew members sculpt the shotcreted facing to create a natural rock appearance integrated into the retaining wall system.

Fig. 3: Crews shotcreted over a reinforced soil nail wall facing during construction.

created the appearance of natural rock while maintaining the functionality and durability of the retaining system. The final surface also improved the appearance of an adjacent retaining wall that previously had a standard form-and-pour concrete finish.

CONSTRUCTION AND PROJECT OUTCOMES

By the end of the project, the team stabilized the wall system supporting Northern Avenue, refaced retaining walls with sculpted and stained shotcrete, and created an architectural finish that became part of the redevelopment of the final site design. The completed stabilization system allowed demolition and redevelopment activities to proceed while maintaining full support for the roadway above the site.

The project demonstrated how early collaboration between the engineer of record and specialty contractor influenced both constructability and final site use. Involving the specialty contractor during design also allowed engineering tradeoff analysis to occur before mobilization, rather than during active construction.

The finished wall system combined structural stabilization and architectural treatment within a single installation, eliminating the need for additional retaining or screening walls elsewhere on the site.

LESSONS LEARNED

The Long Meadow Shopping Center project reinforced the value of early coordination when addressing complex site constraints and eliminating any impacts to Northern Avenue. By bringing GSI into the design phase, the team was able to evaluate stabilization options, permitting considerations, and sequencing challenges before demolition of the former Sears Building, allowing for the site construction to begin safely and smoothly.

The project also showed how soil nail walls with sculpted shotcrete facing can combine structural stabilization and architectural treatment within a single system. Instead of constructing a separate retaining wall, the finished shotcrete face became part of the final site design while preserving usable space within the development footprint.

Early coordination of utilities, right-of-way considerations, and wall geometry helped the team identify and address potential conflicts before crews mobilized. For constrained redevelopment projects, assessing these factors early helped identify options before work began in the field.

***Mike Close**, P.E., is a Project Development Engineer at GeoStabilization International with 38 years of experience in civil and geotechnical engineering. He holds both a Bachelor of Science and a Master of Science in Civil Engineering from Michigan State University, with graduate-level specialization in structural and geotechnical engineering. Mike began his career with the Michigan Department of Transportation, where he focused on bridge design and construction. He later moved into consulting, where he launched a bridge design unit for URS Greiner (now part of AECOM) before spending several years with manufacturers specializing in bridges, retaining walls, and geosynthetic systems — giving him a uniquely broad perspective that spans design, manufacturing, and field application. A licensed professional engineer in Michigan, North Carolina, South Carolina, Virginia, and Maryland, Mike is based in Clayton, North Carolina, where he is an active member of the American Society of Civil Engineers and has served as past president of the Eastern Branch of the North Carolina Section.*

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The Hidden Cost of Nozzle Wear:

HOW A 10% INCREASE IN NOZZLE DIAMETER REDUCES AIR VELOCITY BY 17%

By Raúl Bracamontes

In shotcrete operations, nozzle condition is often underestimated. Crews typically monitor pump output, airflow, slump, and accelerator dosage — but nozzle wear rarely receives the same level of attention. From a fluid mechanics standpoint, however, nozzle wear has a direct and measurable effect on air velocity, impact energy, consolidation, and ultimately shotcrete placement quality. This article explains the phenomenon mathematically, and translates it into practical field implications.

For this article, most comments refer to a wet-mix shotcrete nozzle tip with a manufactured internal diameter of 38 mm (1.5 in.).

THE PHYSICS BEHIND NOZZLE WEAR

To understand how the shotcrete nozzle works requires basic fluid mechanics. Bernoulli's principle is fundamental to understanding how the nozzle works in the shotcrete process.

Bernoulli's principle explains the relationship between pressure, velocity, and potential energy. It states that when the velocity of a fluid increases, its pressure decreases, and vice versa, assuming the total energy in the flow remains constant.

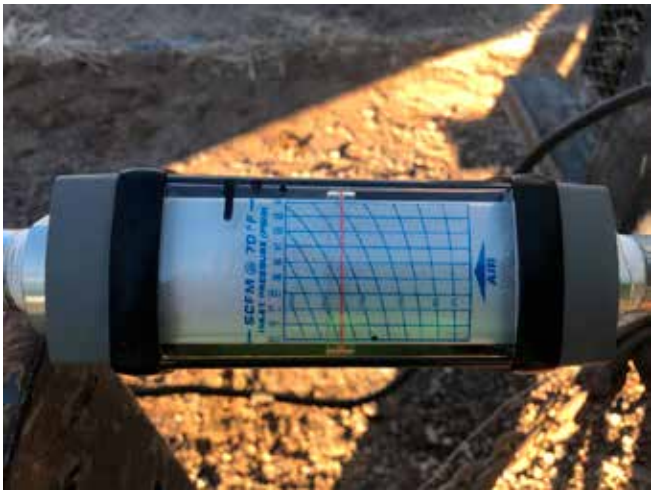
IN THE KNOW: The compressor supplies both air pressure and air volume, and the air must be free of oil and water. Air pressure is measured using a manometer, and airflow can be verified using a flowmeter.

In a shotcrete nozzle, compressed air pushes the concrete mixture. As the air passes through a reduced cross-section inside the nozzle, several things occur:

1. The flow area decreases
2. Air pressure decreases
3. Air velocity increases

This increase in velocity allows the concrete to exit the nozzle with high kinetic energy, which is essential for proper compaction against the receiving surface. Several phenomena occur simultaneously inside the nozzle:

1. **Flow Acceleration:** Compressed air accelerates as it passes through the reduced cross-section.



Figs. 1 and 2: Manometer (ABOVE) for pressure measure and flowmeter (BELOW) for airflow measurement

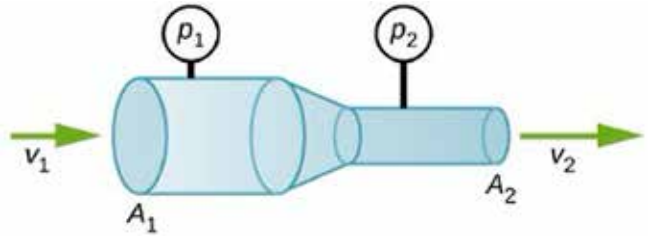
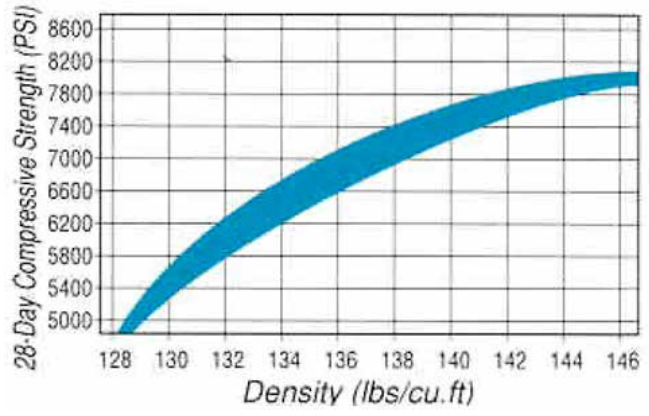
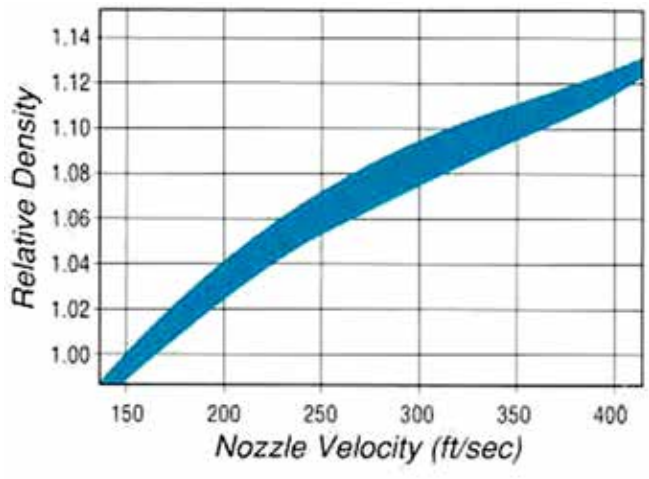


Fig. 3: Bernoulli Nozzle

Fig. 4: Shooting wet-mix shotcrete





2. **Particle Entrainment:** Cement, sand, and aggregate particles are carried and accelerated by the air stream.
3. **Mixing with Water (Dry-Mix Process):** In dry-mix shotcrete, water is introduced at the nozzle and mixed turbulently with the dry concrete material.
4. **High-Speed Projection:** The material impacts the receiving surface at approximately 20 to 35 m/s (65 to 115 ft/s) depending on the equipment and setup.

This velocity produces compaction and adhesion to the substrate. In other words, this provides the structural bond which is the hallmark of quality shotcrete placement.

For wet-mix shotcrete, the air introduced at the nozzle must be sufficient to separate and accelerate each of the concrete particles, allowing proper consolidation when they impact the receiving surface.

According to ACI 506, for wet-mix hand-spray shotcrete using a 2 in. (50 mm) hose, compressors should typically provide:

- Volume 200 to 375 CFM (5.6 to 10.6 m^3/min)
- Pressure 100 to 125 psi (6.9 to 8.3 bar)

This airflow helps generate exit velocities of approximately 27 to 36 m/s (60 to 80 mph), which are necessary for proper shotcrete placement. This level of force, however, will eventually wear out the material at the nozzle. This both increases the internal diameter of the nozzle and weakens the nozzle membrane from containing the force of material outflow.

AIRFLOW AND THE CONTINUITY EQUATION

Airflow through a shotcrete nozzle follows the continuity equation:

$Q = A\ V$

Where:

Q = Volumetric flow rate (m^3/s or ft^3/s)

A = Cross-sectional area (m^2 or in^2)

V = Air velocity (m/s or ft/s)

For a given compressor, the volumetric flow rate (Q) is essentially constant. Therefore,

$$V = \frac{Q}{A}$$

If the nozzle diameter increases due to wear, the cross-sectional area (A) increases. In other words, when airflow (Q) remains constant, the velocity (V) must decrease, affecting your exit velocity and thus compaction and substrate adhesion.

MATHEMATICAL EXAMPLE: 10% NOZZLE WEAR

For this example, we assume the nozzle tip is rigid enough that air pressure does not further deform it. In practice, thinner nozzles may expand slightly under pressure, which can further increase the diameter.

ORIGINAL NOZZLE DIAMETER

38 mm (0.038 m) (1.5 in.)

$$A_1 = \frac{\pi(0.038)^2}{4} = 0.00113\,m^2$$

$$A_1 = 0.00113\,m^2$$

Equivalent area: 1.77 in²

WORN NOZZLE DIAMETER (10% INCREASE)

41.8 mm (0.0418 m) (1.65 in.)

$$A_2 = \frac{\pi(0.0418)^2}{4} = 0.00137\,m^2$$

$$A_2 = 0.00137\,m^2$$

Equivalent area: 2.14 in²

AIRFLOW CONVERSION

Given airflow: 10.6 m³/min (375 CFM)
Converted to seconds:

$$Q = \frac{10.6}{60} = 0.1767\,m^3/s$$

$$Q = 0.1767\,m^3/s$$

Equivalent: 6.22 ft³/s

AIR VELOCITY CALCULATION

WITH A NEW NOZZLE

$$V_1 = \frac{0.1767}{0.00113}$$

$$V_1 = 155.8\,m/s$$

Equivalent: 511 ft/s

WITH A 10% WORN NOZZLE

$$V_2 = \frac{0.1767}{0.00137}$$

$$V_2 = 128.7\,m/s$$

Equivalent: 422 ft/s

VELOCITY LOSS

$$\text{Velocity Loss (\%)} = \left(1 - \frac{V_2}{V_1}\right) \times 100$$

$$= \left(1 - \frac{128.7}{155.8}\right) \times 100 \approx \mathbf{17.4\%}$$

Result: ≈ 17.4% reduction in air velocity

WHAT DOES A 17% VELOCITY REDUCTION MEAN?

In shotcrete placement, impact energy (E) is directly related to velocity. Note that m in the equation is the mass of the concrete.

$$E = \frac{1}{2}mV^2$$

Because kinetic energy depends on the square of velocity, even a moderate reduction in velocity (17.4%) results in a much larger reduction in impact energy. This affects:

- Consolidation
- Bond to substrate
- Encapsulation of reinforcement
- Rebound
- Surface density
- Long-term durability

Even if pump output and compressor settings remain unchanged, shotcrete quality may decrease simply because the nozzle is worn, if the shotcreter remains at the same distance.

FIELD COMPENSATION: MOVING THE NOZZLE CLOSER

Impact force also depends on distance from nozzle to substrate. As the material travels through the air, velocity decreases due to drag and turbulence. If nozzle wear reduces exit velocity, the only way to partially compensate (without increasing airflow) is to reduce the shooting distance.

For a 10% diameter increase:

Original distance
1.0 m (3.3 ft)

Required adjustment
0.26 m (0.85 ft) closer

New distance: 0.74 m (2.4 ft)

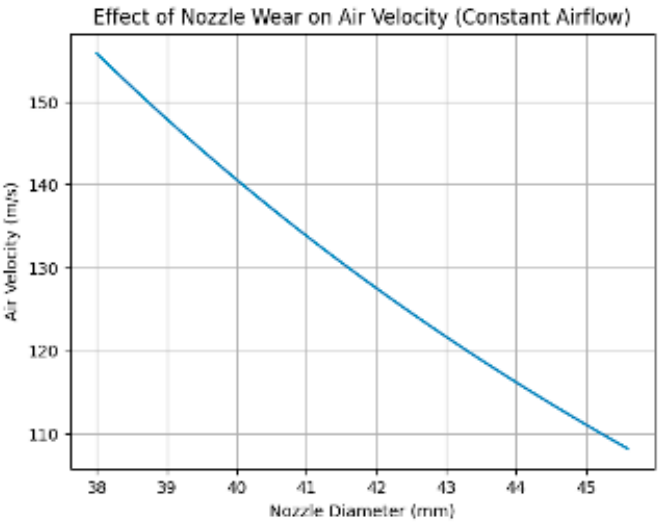
This helps recover some of the lost impact energy. Some shotcreters may rely on this to compensate for the decrease in velocity. Rather, the need for this compensation should be taken as an indicator that the nozzle has exceeded its useful life and should be replaced.

THE COMPRESSOR MYTH

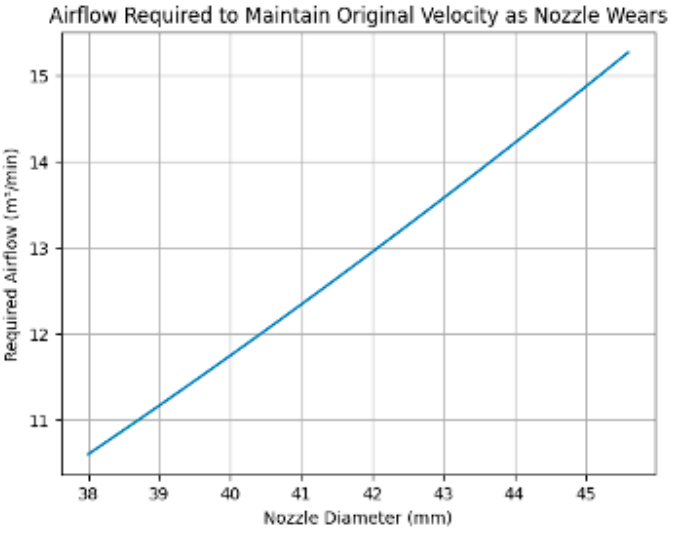
A common field reaction is: “Let’s add more air.” Mathematically, to maintain the same exit velocity:

$$Q_{new} = A_{worn} \cdot V_{original}$$

This requires higher compressor airflow (CFM).



Effect of nozzle velocity wear on air velocity (constant air flow) keeping the nozzle at the same distance



Example:

Nozzle Wear	Required Airflow
0%	10.6 m³/min (375 CFM)
10%	≈ 12.8 m³/min (452 CFM)
20%	≈ 15.3 m³/min (540 CFM)

Because area increases with the square of the diameter, airflow demand increases rapidly. However:

- Compressors may not have reserve capacity
- System efficiency decreases

The correct solution is not to continually increase airflow. The correct solution is to replace the nozzle.

WHEN SHOULD A NOZZLE BE REPLACED?

Although project conditions vary, here is a practical rule: A 10% increase in internal diameter results in approximately a 17% reduction in air velocity and a significant loss in impact energy. In practice, losses may be even greater if

the nozzle deforms under air pressure. At this point, nozzle replacement is strongly recommended.

Nozzle wear is not cosmetic. It represents a measurable reduction in consolidation energy.

CONCLUSION

Nozzle wear is a hidden quality variable in shotcrete placement. A seemingly small 10% increase in nozzle diameter produces:

- 17% reduction in air velocity
- Significant loss of impact energy
- Reduced consolidation and adhesion

In shotcrete placement: Energy equals quality. Maintaining proper nozzle geometry is not optional — it is a fundamental quality control requirement.

***Raúl Armando Bracamontes Jiménez**, Ing., graduated from ITESO University (Instituto Tecnológico y de Estudios Superiores de Occidente) in 1994 with a degree in civil engineering and has worked in the concrete industry in 26 countries ever since. He is currently the owner of Bracamontes Consulting LLC, providing specialized consulting services in shotcrete and concrete technology worldwide. Bracamontes is fluent in Spanish and English and has authored multiple publications and delivered numerous courses on shotcrete. He is an ACI Certified Shotcrete Inspector and Approved Examiner. He is a member of the ACI American concrete institute and participates in 506 committees Instituto Mexicano del Cemento y del Concreto (IMCYC), Instituto Peruano del Cemento Y del Concreto (IPCYC), and the American Shotcrete Association (ASA). Raúl also serves as the Spanish Translation Editor for Shotcrete Magazine, published by ASA.*

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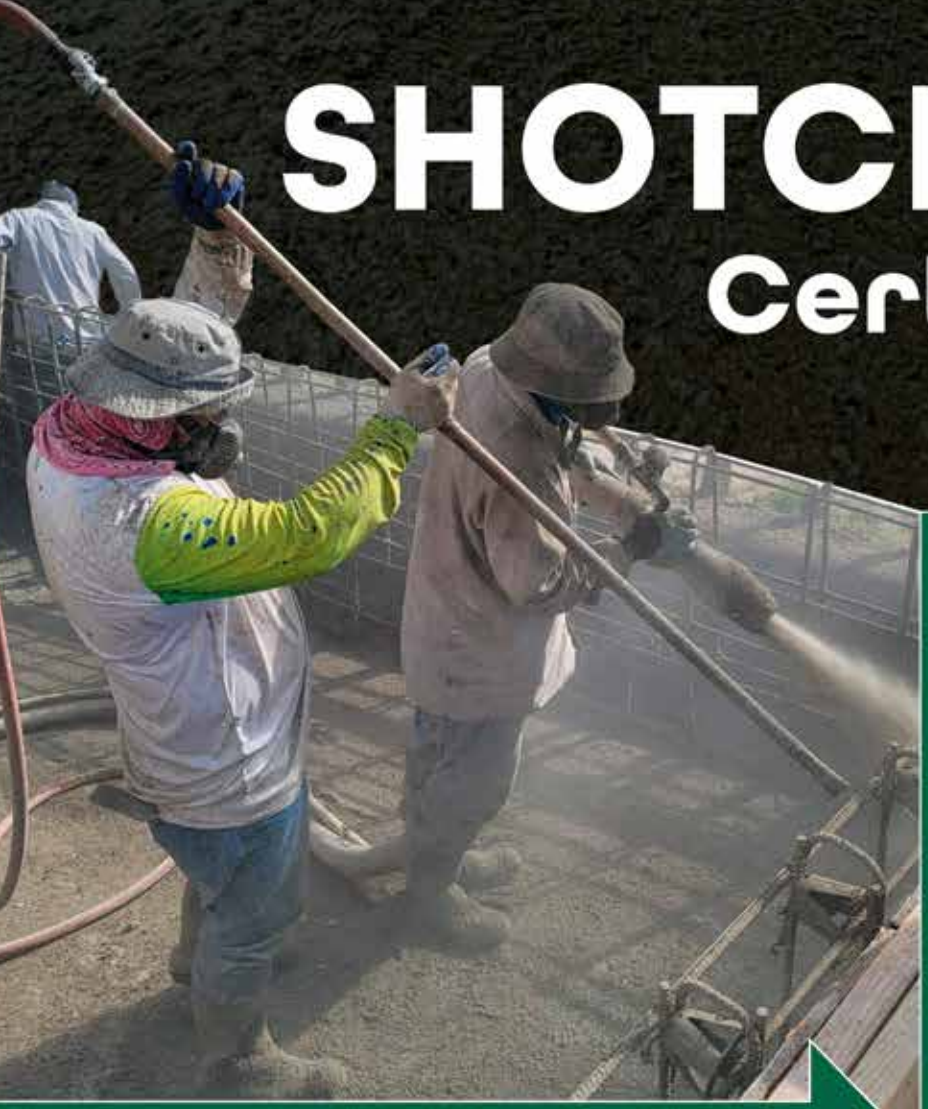

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Clearing the Line

WATER VS. AIR AND THE SAFETY RISKS OF CLEANING SHOTCRETE DELIVERY HOSES

By Derek Pay

At the end of a shotcrete placement day, the work is not finished when the last material is placed. One of the most important tasks — and potentially most dangerous — still remains: Clearing the shotcrete delivery hose.

For many crews, cleaning the line is so routine that it can become almost automatic. The crew has spent hours shotcreting, everyone is tired, the concrete truck is waiting to leave, equipment needs to be cleaned, and people are ready to go home. Unfortunately, this is exactly when complacency can turn a routine procedure into a serious incident.

There are two common methods used to clear a shotcrete delivery system: Compressed air and water. Both can move material through a hose, but they do not present the same hazards. The fundamental difference comes down to one simple fact: Air is compressible, while water is essentially incompressible. That difference matters tremendously when energy is introduced into a delivery hose filled with concrete.

THE HIDDEN ENERGY OF COMPRESSED AIR

When compressed air is used to clear a shotcrete hose, energy can accumulate behind the concrete remaining in the line. If the material moves freely and the system remains unobstructed, the line may clear without incident. However, if a blockage, restriction, kink, hardened section of material, or other obstruction develops, compressed air can continue storing energy behind it. The danger comes when that obstruction suddenly breaks free.

At that moment, the stored compressed air can rapidly expand, accelerating concrete, cleaning balls, plugs, aggregate, sand, and other debris through and out the end of the hose. The discharge can occur with tremendous force and little warning.

The hose itself can also become a serious hazard. A sudden pressure release or rapid movement of material can cause violent hose kicking or whipping. Anyone standing near the discharge end, near an unsecured hose, or within the potential line of fire may be exposed to severe injury.

The greater the volume of compressed air trapped in the system, the greater the potential stored energy. This is why clearing long delivery lines with compressed air deserves particular caution. A long hose or pipeline can contain a significant volume of compressed air, and if that stored energy is suddenly released, the results can be violent and unpredictable.

Compressed air also does not necessarily give the crew a clear indication of exactly what is happening inside the hose. Pressure may be building even though nothing appears to be moving at the discharge end. That silence should never be mistaken for safety.

LESSONS FROM THE FIELD: PERSONAL EXPERIENCE AT OCEANSIDE CONSTRUCTION

Over the years, I have personally witnessed numerous incidents and near-misses associated with using compressed air to clear shotcrete delivery systems. These are not theoretical risks or hazards that exist only in a safety manual: They are real events I have seen occur on active jobsites.

I have seen shotcrete violently discharged over houses, vehicles, concrete trucks, equipment, and surrounding work areas, costing hundreds of thousands in insurance claims. I have witnessed personal injuries caused by the sudden and unpredictable release of stored energy within a delivery system. In one incident, two workers were violently thrown into each other. In others, hoses have lifted workers off the ground and slammed them back down, while uncontrolled hoses have kicked and whipped workers in the face and other parts of the body.

One of the more severe hazards I have witnessed occurs after the majority of the concrete has left the line. Workers may assume the danger has passed, but residual sand, small aggregate, cement paste, and other debris can remain inside the hose. When compressed air finally breaks through, that material can be violently expelled at high velocity.

I have personally seen a worker struck directly in the face by this residual material. The violent spray of sand, small aggregate, and cementitious debris left the worker with extensive concrete burns and severe skin irritation across the face, not to mention a laceration to the face as well. Incidents like this demonstrate that the danger does not end when the main mass of concrete exits the hose. In fact, the final moments of clearing a line can be among the most unpredictable.

These experiences have shaped the way we approach hose clearing at Oceanside Construction. When you've witnessed hoses lifting people off their feet, workers slamming into one another, uncontrolled hoses whipping violently, and residual material blasting personnel in the face, the hazards of compressed air become impossible to dismiss as simply part of the job.

The issue is not whether compressed air can successfully clear a shotcrete delivery system — it can. The issue is the amount of stored energy involved, and what can happen when that energy is suddenly and unpredictably released.

This is one of the primary reasons I believe water, when practical and compatible with the equipment and project conditions, offers a significant safety advantage over compressed air.

WHY WATER CAN REDUCE THE RISK

Water behaves differently because it is incompressible. When water is used to push material through the hose, it does not store large amounts of compressed energy in the same way that compressed air does. This is the primary safety advantage of water.

If material stops moving while clearing with water, the system does not have the same large, pressurized reservoir of compressed air waiting to rapidly expand when the obstruction releases. Pressure can still exist — and a pressurized water system must still be treated seriously — but the potential for explosive expansion is substantially reduced compared with compressed air.

In practical terms, water provides a more controlled pushing force through the delivery line. The operator can monitor the flow and movement of material without relying on a large volume of compressed air behind the concrete.

This does not mean water makes hose clearing risk-free. A blocked hose under hydraulic pressure can still release suddenly. Fittings can fail. Hoses can move. Concrete and debris can still be expelled with significant force. No one should ever stand directly in front of the discharge end of a hose, regardless of the cleaning method being used.

But from the standpoint of stored energy, the difference is significant: Compressed air stores energy through compression; water does not store energy in the same way.

THE PROJECTILE HAZARD

One of the greatest concerns when clearing any concrete delivery line is the possibility of turning material or cleaning equipment into a projectile. With compressed air, a cleaning ball or plug can potentially accelerate to high velocity. The same is true of chunks of concrete, aggregate, or other debris inside the hose. If the end of the hose is pointed toward a person, vehicle, structure, window, or piece of equipment, the consequences can be severe.

This is why the discharge area must always be controlled. No employee should stand directly in front of the hose outlet (and yes, this does bear repeating). The discharge end should be securely restrained and directed into an appropriate containment area. The entire crew should understand when clearing is about to begin, who is controlling the pressure source, and who has authority to stop the process. Communication is not optional. The pump operator, shotcreter, and ground personnel must know exactly what is happening before pressure is introduced into the line. A simple misunderstanding — one worker believing the line is depressurized while another introduces air or water — can have catastrophic consequences.

> "What is perhaps the most important rule in hose clearing is also a simple one: Never disconnect, loosen, strike, or attempt to open a delivery line until positive verification has been made that all pressure has been relieved."
>
> **– Derek Pay**

NEVER OPEN A PRESSURIZED LINE

What is perhaps the most important rule in hose clearing is also a simple one: Never disconnect, loosen, strike, or attempt to open a delivery line until positive verification has been made that all pressure has been relieved. A hose that appears inactive may still contain trapped pressure.

If a blockage occurs, the crew must not assume that shutting off the air compressor, pump, or water source automatically means the pressure is gone. Trapped compressed air energy may remain behind the obstruction.

Before opening any coupling or connection, the system must be isolated, the pressure source shut down, and stored pressure safely relieved and verified according to the equipment manufacturer's procedures and the contractor's established safety program.

No one should ever place their face or body over a coupling while loosening it. No one should attempt to physically manipulate a pressurized hose to force a blockage through. The pressure must be removed first.

FATIGUE AND THE END-OF-DAY MENTALITY

One reason hose-clearing incidents deserve special attention is timing. This task usually happens at the end of a placement, when fatigue is highest. The crew may have been working for eight, ten, or twelve hours. Everyone wants to finish washing out, load the equipment, and head home. That creates an environment where shortcuts become tempting. This is precisely when discipline matters most.

The final twenty minutes of the job deserve the same attention as the first twenty minutes. A successful shotcrete placement is not complete until the line has been safely cleared, the equipment has been cleaned, and every member of the crew is accounted for and uninjured. Production pressure should never dictate an unsafe clearing procedure.

THE JOB IS NOT OVER UNTIL THE LINE IS CLEAR

Experienced shotcrete crews understand that some of the most dangerous moments on a jobsite happen during tasks that have been performed hundreds of times before. Familiarity can create confidence, but it can also create complacency.

Clearing a shotcrete hose is not just cleanup. It is a pressurized operation involving heavy equipment, concrete, hoses, couplings, and potentially significant stored energy. It deserves a defined procedure, trained personnel, clear communication, and complete respect for the forces involved.

Whether clearing with water or compressed air, the principles remain the same: Control the energy, secure the discharge area, keep people out of the line of fire, never open a pressurized system, and never allow the desire to finish quickly to override safe procedure.

The last material out of the hose should never be the most dangerous part of the job.

WATER VS. AIR: WHICH IS SAFER?

From a stored-energy standpoint, water offers a significant safety advantage because it is incompressible and does not accumulate expandable energy in the same way that compressed air does.

Compressed air can be used successfully when proper equipment, procedures, pressure limitations, containment, training, and communication are in place. However, the potential energy stored in compressed gas creates an additional hazard that should never be underestimated.

Where water cleaning is practical and compatible with the equipment, project, environmental requirements, and manufacturer's recommendations, it can provide a more controlled method of clearing a delivery line and reduce the risks associated with the sudden expansion of compressed gas.

After more than 20 years working in the shotcrete industry and witnessing both successful operations and serious failures, my conclusion is simple: The safest cleaning method is the one that minimizes stored energy, controls the discharge, and reduces the possibility of an unpredictable, violent release. In my experience, water provides a clear advantage in accomplishing that goal.

Establishing a Safe Hose-Clearing Procedure

- Confirm a written, job-specific hose-clearing procedure is in place and understood by all crew members
- Assign and verify who is authorized to control the air, water, or pressure source
- Establish clear communication between pump operator, shotcreter, and ground crew before starting
- Secure and properly position the discharge end into a designated containment area
- Clear all personnel from the line of fire and maintain exclusion zones
- Verify equipment limits and do not exceed maximum allowable pressures
- Begin clearing using the approved method (water or air) while monitoring flow and hose behavior
- If material stops moving, stop the operation and follow the defined blockage procedure — do not improvise
- Maintain continuous communication throughout the clearing process
- Shut down and isolate the pressure source once clearing is complete or if an issue arises
- Relieve and positively verify all pressure is removed before loosening or opening any coupling
- Ensure all required personal protective equipment is worn at all times
- Exercise stop-work authority immediately if unsafe conditions are observed

Derek Pay *is the owner of Oceanside Construction in Salt Lake City, UT. He received his BA from the University of Utah in Salt Lake City, UT, and has been in the shotcrete industry for about 20 years. He is a certified wet-mix shotcreter in vertical and overhead techniques and currently installs shotcrete throughout the Intermountain West.*

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Limpieza de la Línea

AGUA VS. AIRE Y LOS RIESGOS DE SEGURIDAD AL LIMPIAR LAS MANGUERAS DE CONCRETO LANZADO

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

Al finalizar la jornada de colocación de concreto lanzado, el trabajo no termina cuando se aplica el último material. Aún queda una de las tareas más importantes —y potencialmente más peligrosas—: limpiar la manguera de conducción de concreto lanzado.

Para muchas cuadrillas, la limpieza de la línea es una tarea tan rutinaria que puede llegar a realizarse casi de forma automática. Después de varias horas lanzando concreto, todos están cansados, el camión revolvedor está esperando para retirarse, el equipo necesita ser lavado y todos desean regresar a casa. Desafortunadamente, es precisamente en ese momento cuando la complacencia puede convertir un procedimiento rutinario en un grave accidente.

Existen dos métodos comunes para limpiar un sistema de conduccion de concreto lanzado: aire comprimido y agua. Ambos pueden desplazar el material a través de la manguera; sin embargo. no presentan los mismos riesgos. La diferencia fundamental se reduce a un principio muy sencillo: el aire es compresible, mientras que el agua es prácticamente incompresible. Esa diferencia es de enorme importancia cuando se introduce energía en una manguera de suministro llena de concreto.

LA ENERGÍA OCULTA DEL AIRE COMPRIMIDO

Cuando se utiliza aire comprimido para limpiar una manguera de concreto lanzado, puede acumularse energía detrás del concreto que permanece en la línea. Si el material se desplaza libremente y el sistema permanece sin obstrucciones, la línea puede limpiarse sin incidentes. Sin embargo, si se produce un bloqueo, una restricción, un doblez, una sección de material endurecido o cualquier otra obstrucción, el aire comprimido puede seguir acumulando energía detrás de ella. El peligro aparece cuando esa obstrucción se libera repentinamente.

En ese momento, el aire comprimido almacenado se expande rápidamente, acelerando el concreto, las pelotas de limpieza, tapones, agregado, arena y otros residuos a través de la manguera y expulsándolos por su extremo. La descarga puede producirse con una fuerza extraordinaria y prácticamente sin previo aviso.

La propia manguera también puede convertirse en un peligro importante. Una liberación súbita de presión o el rápido desplazamiento del material puede provocar movimientos violentos o latigazos de la manguera. Cualquier persona que se encuentre cerca del extremo de descarga, junto a una manguera sin asegurar o dentro de la posible trayectoria del material puede sufrir lesiones graves.

Cuanto mayor sea el volumen de aire comprimido atrapado dentro del sistema, mayor será la energía potencial almacenada. Por esta razón, la limpieza de líneas largas de suministro con aire comprimido requiere especial precaución. Una manguera o tubería de gran longitud puede contener un volumen considerable de gas comprimido y, si esa energía almacenada se libera repentinamente, las consecuencias pueden ser extremadamente violentas e impredecibles.

Además, el aire comprimido no siempre proporciona a la cuadrilla una indicación clara de lo que está ocurriendo dentro de la manguera. La presión puede estar aumentando aunque aparentemente no haya movimiento en el extremo de descarga. Ese silencio nunca debe interpretarse como una condición segura.

LECCIONES APRENDIDAS EN EL CAMPO: MI EXPERIENCIA PERSONAL EN OCEANSIDE CONSTRUCTION

A lo largo de los años, he sido testigo de numerosos incidentes y cuasi accidentes relacionados con el uso de aire comprimido para limpiar sistemas de suministro de concreto lanzado. No se trata de riesgos teóricos ni de peligros que existan únicamente en un manual de seguridad; son situaciones reales que he visto ocurrir en obras en plena operación.

He visto concreto lanzado expulsado violentamente sobre viviendas, vehículos, camiones de concreto, maquinaria y áreas de trabajo circundantes, generando reclamaciones de seguros por cientos de miles de dólares. También he presenciado lesiones personales causadas por la liberación repentina e impredecible de la energía almacenada dentro de un sistema de suministro. En un incidente, dos trabajadores fueron lanzados violentamente uno contra el otro. En otros casos, las mangueras levantaron a trabajadores del suelo para luego arrojarlos nuevamente, mientras que mangueras fuera de control golpearon violentamente el rostro y otras partes del cuerpo de los trabajadores.

Uno de los peligros más severos que he observado

ocurre después de que la mayor parte del concreto ha salido de la línea. Los trabajadores pueden asumir que el peligro ha terminado; sin embargo, dentro de la manguera aún pueden permanecer arena, agregado fino, pasta de cemento y otros residuos. Cuando el aire comprimido finalmente rompe esa obstrucción, ese material puede salir expulsado violentamente a alta velocidad.

Personalmente vi a un trabajador recibir el impacto directo de ese material residual en el rostro. La violenta descarga de arena, agregado y residuos cementicios le provocó extensas quemaduras por concreto, una severa irritación de la piel en toda la cara y, además, una laceración facial. Incidentes como este demuestran que el peligro no termina cuando la mayor parte del concreto sale de la manguera. De hecho, los últimos momentos durante la limpieza de una línea pueden ser los más impredecibles.

Estas experiencias han moldeado la forma en que abordamos la limpieza de mangueras en Oceanside Construction. Cuando uno ha visto mangueras levantar personas del suelo, trabajadores golpeándose violentamente entre sí, mangueras fuera de control azotando con violencia y material residual impactando directamente el rostro del personal, resulta imposible minimizar los riesgos del aire comprimido como si fueran simplemente parte del trabajo.

> “Quizás la regla más importante durante la limpieza de una manguera sea también una de las más simples: nunca desconecte, afloje, golpee ni intente abrir una línea de suministro hasta haber verificado de manera positiva que toda la presión ha sido liberada.”
>
> **– Derek Pay**

El problema no es si el aire comprimido puede limpiar con éxito un sistema de suministro de concreto lanzado; puede hacerlo. El verdadero problema es la cantidad de energía almacenada que implica y lo que puede ocurrir cuando esa energía se libera de manera repentina e impredecible.

Esta es una de las principales razones por las que considero que el agua, cuando resulta práctica y compatible con el equipo y las condiciones del proyecto, ofrece una ventaja significativa en materia de seguridad frente al uso de aire comprimido.

POR QUÉ EL AGUA PUEDE REDUCIR EL RIESGO

El agua se comporta de manera diferente porque es incompresible. Cuando se utiliza agua para impulsar el material a través de la manguera, no almacena grandes cantidades de energía comprimida de la misma manera que el aire comprimido. Esta es la principal ventaja del agua desde el punto de vista de la seguridad.

Si el material deja de moverse durante la limpieza con agua, el sistema no contiene el mismo gran volumen de gas comprimido presurizado esperando expandirse rápidamente cuando la obstrucción se libera. Aun puede existir presión —y un sistema presurizado con agua siempre debe tratarse con la debida precaución—, pero el potencial de una expansión explosiva se reduce considerablemente en comparación con el aire comprimido.

En términos prácticos, el agua proporciona una fuerza de empuje más controlada a través de la línea de suministro. El operador puede supervisar el flujo y el movimiento del material sin depender de un gran volumen de gas comprimido detrás del concreto.

Esto no significa que el uso de agua haga que la limpieza de la manguera esté exenta de riesgos. Una manguera obstruida bajo presión hidráulica aún puede liberar presión de forma repentina. Los acoples pueden fallar. Las mangueras pueden moverse. El concreto y otros residuos todavía pueden ser expulsados con una fuerza considerable. Nadie debe situarse directamente frente al extremo de descarga de una manguera, independientemente del método de limpieza que se esté utilizando.

Sin embargo, desde la perspectiva de la energía almacenada, la diferencia es significativa: el aire comprimido almacena energía mediante la compresión; el agua no almacena energía de la misma manera.

EL RIESGO DE LOS PROYECTILES

Una de las mayores preocupaciones al limpiar cualquier línea de suministro de concreto es la posibilidad de que el material o los elementos de limpieza se conviertan en proyectiles. Con aire comprimido, una pelota o un tapón de limpieza puede acelerarse hasta alcanzar una velocidad muy elevada. Lo mismo puede ocurrir con trozos de concreto, agregado u otros residuos que permanezcan dentro de la manguera. Si el extremo de la manguera está orientado hacia una persona, un vehículo, una estructura, una ventana o un equipo, las consecuencias pueden ser extremadamente graves.

Por esta razón, el área de descarga siempre debe mantenerse bajo control. Ningún trabajador debe colocarse directamente frente a la salida de la manguera (y sí, vale la pena repetirlo). El extremo de descarga debe sujetarse firmemente y dirigirse hacia un área de contención

adecuada. Toda la cuadrilla debe saber cuándo está por comenzar la limpieza, quién controla la fuente de presión y quién tiene la autoridad para detener el proceso. La comunicación no es opcional. El operador de la bomba, el lanzador de concreto lanzado y el personal de apoyo deben saber exactamente lo que está ocurriendo antes de introducir presión en la línea. Un simple malentendido —como que un trabajador crea que la línea está despresurizada mientras otro introduce aire o agua— puede tener consecuencias catastróficas.

Establecimiento de un Procedimiento Seguro para la Limpieza de Mangueras

- Confirmar que exista un procedimiento escrito y específico para la limpieza de mangueras en la obra, y que todos los miembros de la cuadrilla lo comprendan.
- Designar y verificar quién está autorizado para controlar la fuente de aire, agua o presión.
- Establecer una comunicación clara entre el operador de la bomba, el lanzador de concreto lanzado y el personal de apoyo antes de comenzar.
- Asegurar y posicionar correctamente el extremo de descarga dentro de un área de contención designada.
- Mantener a todo el personal fuera de la línea de fuego y establecer zonas de exclusión.
- Verificar los límites operativos del equipo y no exceder las presiones máximas permitidas.
- Iniciar la limpieza utilizando el método aprobado (agua o aire), mientras se supervisan continuamente el flujo del material y el comportamiento de la manguera.
- Si el material deja de moverse, detener la operación y seguir el procedimiento establecido para obstrucciones; no improvisar.
- Mantener una comunicación continua durante todo el proceso de limpieza.
- Apagar y aislar la fuente de presión una vez finalizada la limpieza o si surge algún problema.
- Liberar completamente la presión y verificar de manera positiva que el sistema esté despresurizado antes de aflojar o abrir cualquier acople o conexión.
- Asegurar que todo el personal utilice en todo momento el equipo de protección personal (EPP) requerido.
- Ejercer de inmediato la autoridad para detener los trabajos si se observan condiciones inseguras.

NUNCA ABRA UNA LÍNEA PRESURIZADA

Quizás la regla más importante durante la limpieza de una manguera sea también una de las más simples: nunca desconecte, afloje, golpee ni intente abrir una línea de suministro hasta haber verificado de manera positiva que toda la presión ha sido liberada. Una manguera que parece inactiva todavía puede contener presión atrapada.

Si ocurre una obstrucción, la cuadrilla no debe asumir que apagar el compresor de aire, la bomba o el suministro de agua significa automáticamente que la presión ha desaparecido. La energía del aire comprimido puede permanecer atrapada detrás de la obstrucción.

Antes de abrir cualquier acople o conexión, el sistema debe aislarse, la fuente de presión debe apagarse y la presión almacenada debe liberarse de manera segura y verificarse de acuerdo con los procedimientos establecidos por el fabricante del equipo y el programa de seguridad del contratista.

Nadie debe colocar el rostro o cualquier parte del cuerpo sobre un acople mientras lo afloja. Tampoco se debe intentar manipular físicamente una manguera presurizada para forzar el paso de una obstrucción. Primero debe eliminarse completamente la presión.

LA FATIGA Y LA MENTALIDAD DE FINAL DE LA JORNADA

Una de las razones por las que los incidentes durante la limpieza de mangueras merecen especial atención es el momento en que suelen ocurrir. Esta tarea normalmente se realiza al final de una colocación, cuando la fatiga alcanza su nivel más alto. Es posible que la cuadrilla haya estado trabajando durante ocho, diez o incluso doce horas. Todos quieren terminar de lavar el equipo, cargar la maquinaria y regresar a casa. Esto crea un ambiente en el que los atajos comienzan a parecer tentadores. Precisamente en ese momento es cuando la disciplina cobra mayor importancia.

Los últimos veinte minutos del trabajo merecen la misma atención que los primeros veinte. Una colocación de concreto lanzado no puede considerarse completada hasta que la línea haya sido limpiada de manera segura, el equipo haya sido lavado y todos los integrantes de la cuadrilla estén presentes y sin lesiones. La presión por mantener la producción nunca debe justificar un procedimiento de limpieza inseguro.

EL TRABAJO NO TERMINA HASTA QUE LA LÍNEA ESTÁ LIMPIA

Las cuadrillas con experiencia en concreto lanzado saben que algunos de los momentos más peligrosos en una obra ocurren durante tareas que se han realizado cientos

de veces. La familiaridad puede generar confianza, pero también puede generar complacencia.

La limpieza de una manguera de concreto lanzado no es simplemente una tarea de aseo. Es una operación presurizada que involucra equipo pesado, concreto, mangueras, acoples y una cantidad potencialmente significativa de energía almacenada. Merece un procedimiento claramente definido, personal debidamente capacitado, comunicación efectiva y un respeto absoluto por las fuerzas involucradas.

Ya sea con agua o con aire comprimido, los principios son los mismos: Ya sea que la limpieza se realice con agua o con aire comprimido, los principios fundamentales siguen siendo los mismos: controlar la energía, asegurar el área de descarga, mantener a las personas fuera de la línea de fuego, nunca abrir un sistema presurizado y nunca permitir que el deseo de terminar rápidamente prevalezca sobre un procedimiento seguro.

El último material que sale de la manguera nunca debería ser la parte más peligrosa del trabajo.

AGUA VS. AIRE: ¿CUÁL ES MÁS SEGURO?

Desde el punto de vista de la energía almacenada, el agua ofrece una ventaja significativa en materia de seguridad porque es incompresible y no acumula energía susceptible de expandirse de la misma manera que el aire comprimido.

El aire comprimido puede utilizarse con éxito cuando se cuenta con el equipo adecuado y se aplican procedimientos apropiados, límites de presión, sistemas de contención, capacitación y una comunicación efectiva. Sin embargo, la energía potencial almacenada en el gas comprimido genera un peligro adicional que nunca debe subestimarse.

Cuando la limpieza con agua es práctica y compatible con el equipo, las condiciones del proyecto, los requisitos ambientales y las recomendaciones del fabricante, puede proporcionar un método más controlado para limpiar una línea de suministro y reducir los riesgos asociados con la expansión repentina del gas comprimido.

Después de más de 20 años trabajando en la industria del concreto lanzado y de haber presenciado tanto operaciones exitosas como fallas graves, mi conclusión es sencilla: el método de limpieza más seguro es aquel que minimiza la energía almacenada, controla la descarga y reduce la posibilidad de una liberación violenta e impredecible. Según mi experiencia, el agua ofrece una clara ventaja para lograr ese objetivo.

Derek Pay *es propietario de Oceanside Construction, con sede en Salt Lake City, Utah. Obtuvo una licenciatura (BA) en la Universidad de Utah, en Salt Lake City, y ha trabajado en la industria del concreto lanzado durante aproximadamente 20 años. Es lanzador certificado de concreto lanzado por vía húmeda en aplicaciones verticales y sobre cabeza, y actualmente instala concreto lanzado en toda la región del Intermountain West de los Estados Unidos.*

Don't Pull the Pin!

SNAP COUPLINGS IN SHOTCRETE APPLICATIONS

By Michael Cetnar

Shotcreting is changing; not only where it's used, but in how it's delivered. Today's projects demand longer reach, tighter schedules, and more consistent placement. Crews are pushing concrete farther by hose — often hundreds of feet — into areas that are harder to access and less forgiving. At the same time, the concrete mixtures are denser, production rates are higher, and placement windows are tighter. Shotcrete delivery systems must maintain pressure over longer distances and for longer durations.

Pumps are working harder to overcome friction, elevation, and distance. As hose runs get longer and output increases, backpressure rises. The delivery system must remain stable under load throughout the entire placement cycle, because sustained pressure differs from peak pressure. It exposes weak points, magnifies wear, and puts more demand on every connection in the system.

Couplings sit at the center of that risk. They carry the load and absorb vibration. They experience the full effect of pressure, movement, and material flow. When they're selected, installed, or maintained incorrectly, the consequences can appear quickly and catastrophically.

While two-bolt couplings should be used whenever possible due to their more secure locking method, snap couplings are often used in portions of the laydown system that may need to be moved or detached frequently. However, snap couplings have one of the highest rates of employee injury in our industry.

This is not something to be taken lightly. Poor quality, damaged, and worn-out couplings can fail, resulting in severe injury and property damage. Anyone on the job site could open the coupling (intentionally or accidentally) without knowing the system is still under high pressure.

> **Safety pins must be installed on all snap couplings — they are the most effective, and least costly, safety tools in your truck.**

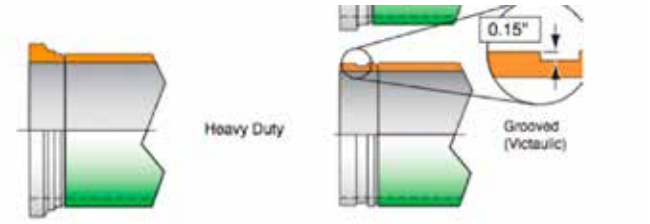
Couplings are manufactured using two methods: Cast and forged. Forged couplings offer greater strength and ductility than comparable cast designs. Ductility is the measure of a metal's ability to stretch without breaking. Forged couplings will stretch and deform at failure, resulting in a gradual pressure drop. However, when a cast coupling fails, it can crack, resulting in a violent eruption that endangers anyone working near the system. All couplings should be carefully inspected before and after use to ensure that cracked or damaged couplings are removed from service.

Fig. 1: CF snap coupling

GROOVED COUPLINGS DO NOT HAVE SUFFICIENT PRESSURE RATING

Grooved end clamps (Victaulic) should not be used when shotcreting or concrete pumping. Today's pumps, especially trailer pumps, can exceed 1200 psi (8.3 MPa) of working pressure in the delivery system. Using rubber hoses in the delivery system increases pump pressure due to increased friction within the hoses. Grooved end couplings are generally rated at 500 – 750 psi (3.4 – 5.2 MPa). These clamps do not approach the working pressure of today's shotcrete pumps. Both ASME (American Society of Mechanical Engineers) and CSA (Canadian Standards Association) have prohibited their use for concrete pumping applications. The ASA (American Shotcrete Association) also "strongly discourages" their use, particularly in high-pressure systems.

The use of grooved-end connections in the shotcrete industry has persisted because grooved-end clamps and connections are lighter than their raised-end, heavy-duty (HD) counterparts. Users of these grooved-end connections are prioritizing lighter weight over safety. The groove is cut into the hose body or pipe, thinning the engagement area where the clamp connects. As the hose body/pipe wears from pumping material, this area becomes progressively



thinner. Thinning in this area can cause the clamp's engagement area to detach or fail when a plug or blockage occurs in the delivery system.

RISKS OF WORN-OUT CLAMPS

While many of these safety considerations must be observed by operators on the job site, there is a vital safety policy that must come from the leadership at any pumping contractor: **The proactive removal of worn components should be emphasized as a vital, approved practice.**

The longer a clamp, pipe, or hose is in service, the greater the cumulative wear and damage. This damage compounds when excessive force is required to install the clamp, increasing unnecessary risk. It's crucial to remove worn-out components from service and replace them with new ones at the first sign of problems. The cost of a new clamp is minimal compared to the potential costs of failure in use. Failure of just one clamp can result in severe injury to nearby personnel, costly litigation, damage to nearby objects, significant material losses, and downtime at the job site for everyone who depends on the pump's delivery.

> **The operational philosophy of "run to failure" must be addressed and discouraged by the highest levels of your organization.**

SAFE USE OF SNAP CLAMPS

Snap clamps are ideal for system locations where rapid changes are needed or where the clamps are frequently opened and closed. However, even when installed properly, snap clamps are more likely to open than their bolted counterparts. External forces acting upon the handle, such as snags or blows from moving objects, can create accidental disengagement. Several safety considerations must be addressed when using snap couplings.

COUPLING CHOICE AND SYSTEM DESIGN

- Use bolted couplings whenever possible; snap couplings are not as strong as two-bolt couplings.
- Snap couplings must be regularly inspected, maintained, and adjusted properly.
- External mechanical loading will reduce working pressure. Proper use of supporting brackets can reduce bucking and pulsing stresses at your coupled connections.

Fig. 3: Hose caddy

Fig. 4: Skid pan

- Use hose caddies and skid pans. These low-cost accessories offer significant benefits that should be considered for all laydown systems, particularly when snap couplings are in use. Both items protect your clamps from accidental disengagement and from wear caused by the operating system's friction and vibration. The skid pan is very helpful for jobs where a coupling connected to pipe or hose is moved over steel bar reinforcement. It improves safety and efficiency for your team operating that portion of the pumping system.

VISUAL INSPECTION

Each coupling should be inspected prior to installation. If any of the following conditions are found, the coupling should be removed from service.

- Excessive wear on the body of the coupling: Cracks or dents are visible in the body of the coupling, or the embossed pressure rating is too worn to be read.
- The coupling shows bent, broken, or distorted links or pins in the handle: A damaged coupling reduces the system's safe operating pressure. Repeated usage and opening/closing can damage or bend the coupling, requiring great force to close and putting a large strain on the handle.

- The safety pin cannot be properly inserted due to alignment, debris in the hole, or damage to the handle.
- Excessive wear, affecting the contact surfaces of the coupling with the lip of the pipe's weld end: This can increase local stresses on portions of the coupling.
- For adjustable snap couplings, damaged threads or concrete build-up: These can prevent the coupling from closing properly.
- Although not part of the clamp, dirty, dented, or damaged connection points (pipe end and hose body ends) should not be used.: Make sure the edges are also not rolled or thinned on these ends.

INSTALLATION AND OPERATION

- Ensure gaskets are free of concrete residue and properly lubricated, and that the coupling cavity is clean with no residual concrete that may impede its engagement with the weld end.
- Examine the coupling and gasket for cracks or tears that may prevent a proper seal.
- ALWAYS WEAR EYE PROTECTION. Eye injuries are among the most common on job sites and can lead to serious long-term complications for an injured team member.
- ALWAYS INSERT THE SAFETY PIN. Due to the possibility of accidental opening, every snap coupling must be fitted with a safety pin at installation. Only safety pins designed for the job should be used with snap clamps. Pins should be removed only after confirming that the system is not under pressure.

If you choose to use snap couplings, be mindful of the risks, be alert for signs of wear and tear, and take all recommended safety precautions.

Michael Cetnar *has more than 30 years of experience in the concrete and shotcrete pumping industry and has been with Con Forms for over 10 years. His career includes roles as a pump operator, fleet manager, and project leader on a wide range of challenging construction projects. Michael is actively involved in industry safety and certification efforts. He is a member of the American Shotcrete Association (ASA), American Concrete Pumping Association (ACPA), and Canadian Standards Association (CSA), and supports concrete pump operator certification initiatives through the Crane Certification Organization (CCO). His combination of hands-on operational expertise and commitment to industry safety provides a practical perspective on concrete and shotcrete pumping applications.*

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Monday, November 16

8:00 AM - 5:00PM

Join this ASA seminar and learn how to evaluate 40+ critical quality factors. Protect your projects and ensure the durable results your clients expect.

Register now and master shotcrete quality control.

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Pedro Zamora
Dees-Hennessey, Inc.

Nominated by Ray Garcia

In the early hours of the morning, as the sun is just starting to provide color to the horizon and before the first load of fresh concrete has even arrived on site, you can often find Pedro Zamora already walking the project. While most people are just beginning their day, Pedro is studying every detail, noting the potential challenges and planning solutions to ensure his crew is set up for success. It's this preparation that has become one of his trademarks — and one of the reasons so many successful projects bear his fingerprint.

For more than 35 years, Pedro has dedicated his career to the structural shotcrete industry. His career began at Johnston Western in 1991 where he worked under Larry Totten (a past ASA president), who helped shape the early years of his career. Looking back, Pedro attributes those early years to the superintendent he would become. "I built most of my knowledge in those early years as a finish shotcreter with Larry's guidance," he recalls.

He eventually made his way to Dees-Hennessey, Inc., growing to a higher level of quality, safety, and production. His many years of proven shotcreter experience led to his inevitable climb through the ranks to become a foreman and superintendent over multiple crews.

Pedro has built a reputation for steady leadership, technical expertise, and a calm presence that gives confidence to everyone around him. Some of these skills have been honed through trips to ASA conventions and conversations with past presidents and current members. Whether it's a complex retaining wall, structural foundation, or architectural feature, he approaches every project with the same mindset: Prepare thoroughly, communicate clearly, and never compromise on quality.

When asked which project stands out most over the course of his career, Pedro doesn't hesitate. With a knowing grin, he recalls working on the rolling hills of the living roof that would include skylights to allow natural lighting to shine through for the multitude of visitors enjoying the exhibits of the California Academy of Sciences in San Francisco (Fig. 1). Designed by architect Renzo Piano, who described it as, "lifting up a piece of the park and putting a building underneath," the roof required extraordinary precision.

"The slopes had to be exact, and transitioning to the skylights were a tough feature to figure out," Pedro explained. "The plants would follow the face of the shotcrete, so the hills had to look completely natural. Then you add the skylights that had a completely different curve."

To accomplish the desired look, the crew installed a flexible rod system that would create the flowing contours of the roof, and the top forms of the skylights had to be oversized to allow for a smooth transition. The concrete mixture had to be wet enough to flow smoothly through 1200 ft (370 m) of delivery line, yet tacky enough to build the steep slopes without sloughing off. Every day required careful planning to meet production goals while maintaining the exact architectural profile.

When asked if there was ever a project that got away, Pedro smiled and said it wasn't a specific project at all. "I wish I had worked on more architectural shotcrete. Specifically rock sculpting projects when I was a shotcreter and finisher. That would have been fun." The artistic side of shotcrete was a real draw for him. But while project qualifications ultimately led him down different paths, his passion for the craft never faded.

Now, after three and a half decades in the industry, Pedro is preparing for a well-earned retirement. While he says he's ready for this next chapter, he admits it will be difficult to step away completely. The daily challenges, the

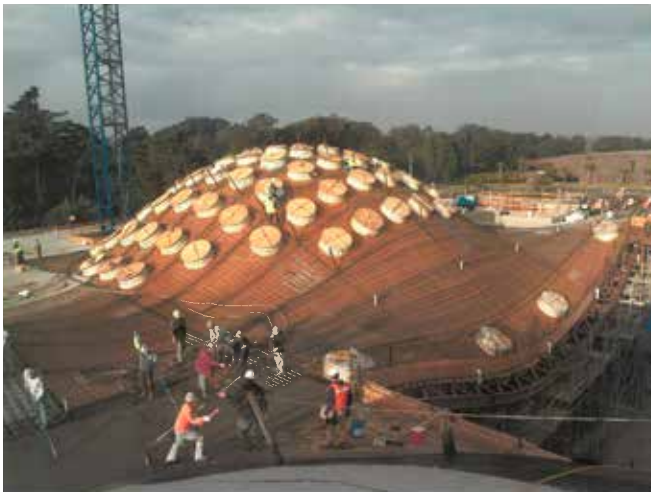

Fig. 1: The 'rolling roof' of California Academy of Sciences in San Francisco, in progress.

problem-solving, and the satisfaction of watching a project come together have become part of who he is. For now, he plans to remain involved by consulting before eventually slowing down.

As Pedro begins this new chapter, his impact on Dees-Hennessey and the shotcrete industry is undeniable. His leadership has shaped projects throughout the Bay Area, but perhaps more importantly, it has shaped the people who have worked alongside him. His commitments to quality, preparation, and craftsmanship have set a standard that will continue long after his final project is complete.

From everyone at Dees-Hennessey: Thank you, Pedro, for your dedication, your leadership, and the example you've set over the past 40 years. We wish you nothing but the very best in retirement. Your legacy will continue to inspire the next generation of shotcrete professionals.

SHOTCRETE SPOTLIGHT NOMINATIONS

Highlight the individuals or teams that make your company shine. Scan or click the QR code to learn more or nominate someone!

KING BUILDING TRUST

Sika®

UNITING WORLD CLASS REPAIR, SHOTCRETE, AND TUNNELING SOLUTIONS TO BUILD THE FUTURE OF INFRASTRUCTURE CONSTRUCTION

In infrastructure construction, performance isn't optional, it's everything. That's why Sika's Infrastructure Division has joined forces with King, North America's trusted leader in prepackaged shotcrete and concrete repair solutions. Together, they offer a fully integrated portfolio engineered for the most demanding environments. From high performance shotcrete and advanced admixtures to structural repair mortars, protective coatings, injection systems, and TBM technologies, Sika delivers the reliability, efficiency, and innovation your projects depend on.
This partnership is more than an acquisition: It's a commitment to building safer tunnels, stronger structures, and more resilient infrastructure, one application at a time.

WHAT SIKA BRINGS TO YOUR PROJECT

- **Expanded Shotcrete Solutions:** Wet-mix, dry-mix, and specialty formulations
- **Structural & Infrastructure Repair Materials:** High performance mortars, grouts, and rehabilitation systems for concrete restoration
- **Advanced Admixture Technologies:** Engineered for strength, durability, and early performance
- **Waterproofing & Injection Systems:** Coating and waterproofing for challenging conditions
- **TBM Solutions:** Complete solutions for mechanized tunneling

A LEGACY OF EXPERTISE

Since 1985, KING, a Sika Brand, has been a trusted resource for both dry-mix and wet-mix shotcrete. Its reputation is built on high quality materials supported by one of the industry's most knowledgeable technical teams.

Sika's shotcrete and infrastructure experts bring hands on expertise in equipment operation, training, placement techniques, material design, and specification development. Sika is not just a supplier — they are a complete repair and shotcrete resource.

SIKA'S RENEWED FOCUS ON THE U.S. MARKET

Sika's Infrastructure team sharpened its focus on the U.S. shotcrete market, reinvesting in the people, plants, and technical support that contractors, owners and authorities rely on for repair, shotcrete, and tunneling work. This renewed commitment means faster local support, deeper technical resources, and a broader product offering backed by Sika's global R&D network.

INVESTING IN THE NORTHEAST: A NEW ANCHOR PLANT

Sika is backing that commitment with a significant investment: A brand new Northeast Anchor Plant in New Jersey. The facility will produce a full line of Sika shotcrete and repair materials alongside Sika's broader portfolio of repair mortars, grouts, and specialty concrete products. This puts critical materials closer to Northeast contractors and shortening lead times on the region's biggest infrastructure and tunneling projects as well as complying with the Build America, Buy America Act.

INNOVATION BACKED BY A CENTURY OF EXPERIENCE

With more than 100 years of global experience, Sika continues to lead the industry with cutting edge shotcrete and repair technologies. Our research, development, and worldwide production capabilities ensure consistent, proven solutions for every application.

As experts in both wet-mix and dry-mix processes, Sika provides the optimal shotcrete system for any project. Our deep involvement in tunneling, repair, and major infrastructure work makes us the ideal partner for owners, designers, and contractors seeking performance, economy, and long term durability.

ADVANCING GEOPOLYMER SOLUTIONS FOR WASTEWATER & TRENCHLESS REPAIR

Looking ahead, Sika is investing heavily in geopolymer technology to meet the growing demand for corrosion resistant rehabilitation in wastewater and stormwater infrastructure. These geopolymer based systems are engineered for pipe, manhole, and culvert repair, offering long term chemical resistance in environments where traditional cementitious materials fall short. It's a natural extension of the Sika portfolio and a preview of where the future of infrastructure repair is headed.

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SOLOMON COLORS, INC.

Founded in 1927 by Robert C. Solomon, Solomon Colors began as a pioneer in transforming mining byproducts into pigments for the cement and mortar industries. Over nearly a century, the company has grown into a global leader in architectural concrete enhancement. It is headquartered in Springfield, Illinois, as a family- and employee-owned enterprise emphasizing innovation, quality, and exceptional customer service with an average employee tenure exceeding a decade. The company has expanded its offerings through strategic acquisitions over the years, including Brickform for decorative products and Lythic for polished concrete solutions.

Today, Solomon Colors is the largest U.S.-owned producer of iron oxide pigments and a trusted supplier of integral and liquid colors, precision dispensing systems, and advanced reinforcement solutions. The company serves ready-mix concrete producers, contractors, distributors, architects, and precast manufacturers across North America, with facilities in Springfield, Illinois and Rialto, California, and training centers in Texas and Illinois. Solomon Colors also maintains active memberships in key industry organizations, including the American Shotcrete Association (ASA), American Concrete Institute (ACI), National Ready Mixed Concrete Association (NRMCA), and others, reflecting its commitment to advancing concrete technology and best practices.

A standout product in Solomon Colors' portfolio is UltraFiber 500, an alkali-resistant cellulose microfiber reinforcement that meets the ASTM D7357 standard specification for Cellulose Fibers for Fiber-Reinforced Concrete. UltraFiber 500 is made in the USA and has been in use for more than 20 years. It's known for its ability to improve finishing quality, control cracks, enhance hydration, and bond with concrete, and is also marketed as an "invisible" fiber, meaning it doesn't typically appear as a noticeable blemish in the finished concrete.

KEY DETAILS ABOUT ULTRAFIBER 500:

- **Properties:** It is a cellulose fiber that is alkali-resistant and provides excellent secondary reinforcement (not a structural reinforcement).
- **Benefits:** Improved finishing quality, crack control, better hydration and bonding, and an invisible fiber for decorative concrete.
- **Dispensing:** It is designed for use with our automated dispensing systems using 600 lb (270 kg) bulk bags or provided in 1 or 1.5 lb (0.45 or 0.68 kg) water-soluble bags.

Fig. 1: Mount Pleasant LRT station on Toronto's Eglinton Crosstown line. The 2022 ASA Infrastructure Project of the Year Award-Winner incorporated UltraFiber 500 micro-cellulose fibers in the 70% slag shotcrete mixture for its 1.5 m (4.9 ft) thick, heavily reinforced underground walls. All photos courtesy of Shaun Radomski, M.Sc., P.Eng. Senior Materials Engineer Thurber Engineering Ltd.

Fig. 2: Final coat was shot, cut, and finished to the specified line and grade of shooting wires. UltraFiber 500 alkali-resistant cellulose fiber was incorporated into the mixture to enhance pumpability, shootability, adhesion, cohesion, stackability, and finishability of the mixture.

- **Applications:** It is suitable for various concrete applications, including slabs, decks, paving, shotcreting, and architectural/decorative work.
- **Invisible:** Unlike polypropylene fibers, UltraFiber500 is hydrophilic, does not float, and is virtually unnoticeable in finished concrete.
- **Renewable Resource:** It is derived from renewable resources, unlike polypropylene fibers.

Independent testing has found the use of the UltraFiber500 fibers in shotcrete applications to be very beneficial! When added to the shotcreted concrete mixture, the UltraFiber500 enhances pumpability, shootability, adhesion, cohesion, stackability, and finishability of the mixture. The fiber also controls plastic and autogenous shrinkage cracking. It has been reported to mitigate excess bleeding of mixtures common with the use of newer L1 (low carbon) cement. Shotcrete contractors report that due to the fiber's ability to reduce rebound and build out in thicker layers, the cost to add the fibers is more than offset by the savings in labor and material!

Fig. 3: Wooden floats were used to close the surface.

Fig. 4: In this close-up review of the steel trowel finish wall, the shotcrete mix incorporates 70% slag cement and UltraFiber 500, displaying excellent finishability, creating finished surfaces without any pulls or tears.

Solomon Colors supports UltraFiber 500 with comprehensive technical resources, including automated dispensing systems, environmental product declarations (EPDs), and ICC certification for sustainability credits. The company's dedicated technical team and distribution network ensure seamless integration and performance for shotcrete professionals globally.

Solomon Colors continues to drive innovation in the concrete industry, delivering reliable, high-quality solutions that enhance project outcomes and longevity.

Fig. 5: The finished surfaces were free of voids, sags, tears, or plastic shrinkage cracks attributed to the use of the UltraFiber 500 Cellulose Micro-Fiber.

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Using AI to Write About Shotcrete?

HERE ARE SOME THINGS TO KEEP IN MIND

By Cara Baker

Many shotcrete professionals have valuable knowledge and experiences to share, but not everyone considers themselves a writer. If this is you, AI might seem like a useful (even downright magical) tool for drafting a project story or sharing lessons learned from the field.

It's true that AI can help organize your thoughts and get words on the page, but it works best when it's paired with your expertise. If you're using AI to help write an article about shotcrete, keep these tips in mind.

UNDERSTAND WHAT AI DOES WELL — AND WHAT IT DOESN'T

While AI can be a useful tool for creating a first draft, organizing information, and helping overcome the challenge of getting started, it doesn't understand shotcrete the way an experienced contractor, engineer, shotcreter, or owner does.

It generates text based on patterns in existing information. As a result, it can sometimes confuse shotcrete with conventional cast-in-place concrete, or overlook important details about materials, placement methods, equipment, or project requirements.

So it's important to think of AI not as a subject matter expert, but as more of a writing assistant.

DOUBLE-CHECK INDUSTRY TERMINOLOGY

A quick review of industry terminology can go a long way. Shotcrete professionals rely on precise language, and readers familiar with the industry will notice when something doesn't sound quite right.

AI may occasionally misuse technical terms or choose wording that sounds convincing but lacks accuracy. Before submitting your article, review the terminology to ensure it reflects industry standards, accepted practices, and your own lived experience.

ADD YOUR REAL-WORLD EXPERIENCE

Your experience is what makes an article valuable. A shotcrete mining project is very different from a swimming pool, a repair project, or the latest architectural juggernaut. While AI can help create a framework for your story, *it doesn't know* what happened on your project site, what challenges your team faced, or what lessons were learned along the way.

Adding those details can help transform a generic article into one that other industry professionals can learn from.

LESS IS MORE

AI also likes to overly embellish sentences, becoming repetitive and redundant in an attempt to increase the word count. *Don't be fooled into thinking that quantity is more important than quality.* Make sure you read through to see if those extra words are really adding value to the article you want to write. Remember: Only you have the real-world background and knowledge that add *depth* to the content — not just a higher word count.

VERIFY FACTS, FIGURES, AND CLAIMS

AI will present information with confidence — even when that information is incomplete, outdated, or incorrect. If your article includes statistics, project data, historical information, production rates, material properties, or references to standards and specifications, take the time to verify them. Confirming facts before submitting helps maintain the credibility of both you and your article.

YOUR EXPERTISE IS WHAT READERS TRULY VALUE

At the end of the day, readers are interested in *your* experience — not the AI's. The most interesting and useful shotcrete articles feature the practical knowledge of people who work with shotcrete every day.

AI can help tell the story, but your expertise is what makes it accurate, credible, and worth reading. AI cannot replace industry knowledge: It is simply tool that, used thoughtfully, can help you share your knowledge and experiences more effectively.

asa Sustaining Corporate Members

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

Thorcon Shotcrete & Shoring LLC
Thorconshotcrete.com

Consolidated Shotcrete Inc.
www.consolidatedshotcrete.ca

Structural Technologies
www.structuraltechnologies.com

The Quikrete Companies
www.quikrete.com

CROM LLC
www.cromcorp.com

Master Builders
www.master-builders-solutions.com

Prestige Gunite & Shotcrete Inc
www.prestigeconcrete.com

Saffo Contractors Inc.
www.saffocontractors.com

Construction Forms
www.ConForms.com

RAM Construction Services
www.ramservices.com

Geo-Rope Ltd. (Canada)
www.geo-rope.com

Sika STM - Shotcrete, Tunneling & Mining (Canada)
can.sika.com

Sika Corporation (USA)
usa.sika.com

Western Shotcrete Equipment
www.wseshotcrete.com

Valme North America Inc.
www.valme-na.com

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www.macleanengineering.com

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CanCrete Equipment Ltd.
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www.conselinc.com

Baystate Shotcrete LLC
www.baystateshotcrete.com

Drakeley Pool Company LLC
drakeleypools.com

Imerys
www.imerys.com

Fortified Structural Solutions
www.fortifiedstructuralsolutions.com

MAPEI Underground Technology Team
www.utt-mapei.com

Top Gun of Virginia
Shotcrete & Gunite Services
www.topgungunite.com

A & B Gunite
www.abpoolsub.com

Dees-Hennessey Inc.
www.deeshenn.com

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www.pullman-services.com

COST of Wisconsin Inc.
www.costofwisconsin.com

Madison Concrete Construction
www.madisonconcrete.com

Ocean Rock
www.oceanrockart.ca

South Shore Gunite Pools & Spas Inc
ssgpools.com

Artisan Skateparks
www.artisanskateparks.com

Kaaterskill Kahncrete
www.kahncrete.com

Torshot Construction LImited
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Curtis Concrete Pumping
www.curtisconcretepumping.com

Coastal Gunite Construction Company
www.coastalgunite.com

R-E-D Industrial Products
www.redindustrialproducts.com

REED Shotcrete Equipment
www.reedpumps.com

Nationwide Shotcrete Inc.
www.nationwideshotcrete.com

CIFA
www.cifa.com/en

STRATA LLC
www.stratasgc.com

american shotcrete association | asa

ASA NETWORKING DINNER

October 11, 2026 | Atlanta, GA

Join ASA leaders and members for an evening of networking during the ACI Concrete Convention. It's a great opportunity to build relationships and exchange ideas within the shotcrete community. Location and time will be announced soon.

ASA BOARD OF DIRECTORS MEETING

October 29, 2026 | Virtual (Microsoft Teams)

Stay informed on the latest initiatives shaping the future of the shotcrete industry. Hear updates from leadership and committee chairs as they share the progress of key projects.

For a complete list of upcoming events visit **www.shotcrete.org/calendar**.

WORLD OF CONCRETE by informa

WORLD OF CONCRETE 2027

January 19 - 21, 2027

Las Vegas Convention Center | Las Vegas, NV

Make plans now to join the American Shotcrete Association (ASA) at World of Concrete 2027, taking place January 19 - 21, 2027, at the Las Vegas Convention Center in Las Vegas, Nevada.

Registration opens in September: Be sure to use ASA Source Code **A17** to receive the greatest discounts while supporting your Association.

Visit **shotcrete.org/WOC** for the latest event updates, registration information, and ASA activities throughout the week. While you're there, don't miss the ASA Annual Membership Meeting on Tuesday evening, January 19, in South Hall. It's a great opportunity to network with fellow members, hear the latest Association news, and learn what's ahead for the ASA.

asa SHOTCRETE CONVENTION

A FRESH LOOK FOR OUR ANNUAL CONVENTION

ASA's annual event has a new look! To better reflect the identity and growth of our flagship conference, we've introduced a refreshed brand for what is now simply known as the ASA Shotcrete Convention. While the look has changed, our commitment remains the same, which is bringing together the shotcrete industry for world-class education, networking, innovation, and collaboration.

Watch for the new branding as we prepare for the 2027 ASA Shotcrete Convention and stay tuned for registration and event details in the coming months!

QUALITY SHOTCRETE MEETS QUALITY APPAREL

The American Shotcrete Association (ASA) is proud to partner with Lands' End to offer high-quality ASA logo apparel and products exclusively for our members. Just as ASA is committed to advancing excellence in shotcrete through education, certification, and industry leadership, we're excited to provide quality gear that reflects that same commitment to excellence.

From polos and outerwear to hats and accessories, you'll find professional apparel that's perfect for the jobsite, the office, conferences, and industry events. Visit MyASA, the association's online member community to access the ASA logo wear store and represent your Association wherever you go.

PREMIER EXPOSURE, BEYOND THE PAGE

Advertising in *Shotcrete* magazine now has enhanced benefits. Take your advertising even further by reserving a full-page advertisement in all four 2027 issues by the Early Bird deadline, November 1st: These ***Premier Advertisers*** receive exclusive added value, including issue release announcement emails, complementary social media promotion with each issue, and NEW for 2027, a dedicated Premier Advertisers feature in the first-quarter issue of *Shotcrete* magazine showcasing your company logo, contact information, and a company profile. Reserve your space early and let ASA help boost your brand's exposure throughout the year.

The 2027 Media Kit is now available! Visit **shotcrete.org/mediakit** and lock in your 2027 advertisement by November 1st for early bird benefits!

american shotcrete association asa

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CONNECT WITH THE SHOTCRETE COMMUNITY AT ACI FALL 2026

The ACI Concrete Convention will be held October 11 - 14, 2026 in Atlanta, GA, at the Hilton Atlanta. All convention events, committee meetings, and social functions will take place at the Hilton Atlanta. Committee meetings and social events are open to in-person attendees only. Consider attending the shotcrete-related committee meetings listed in Table 1.

Committee Code	Committee Name	Day	Time	Room
322	Concrete Pool and Watershape Code	Sunday	1:00 PM - 5:00 PM	406-407
C660	Shotcreter Certification	Monday	12:30 PM - 1:30 PM	401-402
C661	Shotcrete Inspector Certification	Monday	1:30 PM - 2:30 PM	401-402
506	Shotcreting	Tuesday	8:30 AM - 11:30 AM	220
506-A	Shotcreting-Evaluation	Monday	10:30 AM - 11:30 AM	224
506-B	Shotcreting-Fiber-Reinforced	Monday	11:30 AM - 12:30 PM	224
506-C	Shotcreting-Guide	Monday	9:30 AM - 10:30 AM	224
506-E	Shotcreting-Specifications	Monday	8:30 AM - 9:30 AM	224
506-F	Shotcreting-Underground	Monday	2:30 PM - 3:30 PM	224
506-H	Shotcreting-Pools	Monday	3:30 PM - 4:30 PM	224

Table 1

Building the Future

ACI FOUNDATION APPROVES FUNDING FOR IMPORTANT RESEARCH

The American Concrete Institute (ACI) Foundation Board of Trustees has approved funding for three important research initiatives aimed at advancing concrete industry practices, improving durability guidance, and supporting innovation across the construction sector. The projects include developing objective metrics for evaluating formed concrete surface finishes to improve consistency in specifications and contracts; creating unified durability design criteria to better protect infrastructure from chemical attack and harmonize guidance across multiple ACI committees; and validating innovative auxetic reinforcement systems that can enhance concrete confinement, improve seismic resilience, reduce steel congestion, and support automated and additive manufacturing processes. Learn more here: **https://tinyurl.com/528hhj5k**

ACI FOUNDATION OPENS APPLICATIONS FOR FELLOWSHIPS

The ACI Foundation is now accepting applications for its 2027–2028 fellowships, scholarships, and student excellence awards, offering financial support and professional development opportunities to undergraduate and graduate students pursuing concrete-related degrees. The program includes 50 fellowships and scholarships for eligible students, along with two student excellence awards for students studying in qualifying Middle East and North Africa (MENA) countries. Fellowship recipients receive a USD $10,000 educational stipend, travel support to attend two ACI Concrete Conventions, potential internship opportunities, and industry recognition, while scholarship recipients receive a USD $5,000 educational stipend (with two scholarships awarded in CAD) and recognition through ACI Foundation publications and platforms. The deadline to submit applications is November 1, 2026. Additional information is available at **www.acifoundation.org/scholarships**.

BUILDING TRUST

SIKA OPENS LARGE-SCALE MORTAR PRODUCTION PLANT IN NJ

Sika has opened a new, modern production facility for mortar products in Bridgeton, NJ, the largest in the United States. This highly automated site allows Sika to significantly expand its manufacturing capacities in the northeastern part of the USA, efficiently servicing the growing customer demand in key metropolitan areas. See the full story here: **https://tinyurl.com/3ffsna4x**

CMHA LAUNCHES INDUSTRY PLEDGE ON WEBSITE

Columbia, Maryland — June 8, 2026 — The Construction Mental Health Alliance (CMHA), a newly formed 501(c)(3) nonprofit, announced the official launch of its Industry Pledge, now available on the organization's website. The pledge includes measurable goals and invites construction leaders across North America to protect the physical and mental health of their workforce by committing to:

- Preventing traumatic brain injuries (TBIs) and head injuries
- Improving mental health and reducing suicide in construction
- Managing fatigue and reducing mental and physical stress
- Improving health, wellness and fitness

Learn more here: **https://tinyurl.com/y5yvjfk2**

MASTER BUILDERS SOLUTIONS ADDS NORTH CAROLINA, FLORIDA ADMIXTURE PRODUCTION SITES

Master Builders Solutions has strengthened distribution and customer service capabilities with the opening of advanced admixture production facilities in the Greensboro, NC. and Orlando, FL metro areas, both designed to optimize water or material recycling practices and resource conservation. Learn more here: **https://tinyurl.com/278yntcz**

DFI 51ST ANNUAL CONFERENCE TO ADDRESS GLOBAL SEA LEVEL RISE CHALLENGES

The Deep Foundations Institute (DFI) will host its 51st Annual Conference (DFI51) in Orlando, FL, from November 2–5, 2026, under the theme "Sea Level Impacts: Navigating Challenges Together." The event is expected to attract more than 1500 professionals from engineering, construction, policy, finance, insurance, and flood management sectors to examine the wide-ranging impacts of sea level rise. For more information on DFI51 or to register visit **dfi-events.org/dfi51**.

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:

My gunite pool was built at the wrong depth. After 2 months of curing, the company corrected the depth by jackhammering the deep end out to make it deeper. After they shot the gunite, the joint area began cracking across the entire width of the pool. Groundwater is weeping through the crack. Is this a cold joint that did not bond correctly? Does a modified shell have the same integrity and life expectancy of a monolithic shell? I'm in an area with a high water table, so groundwater is pushing through the cracks.

ANSWER:

In general, when new dry-mix shotcrete (gunite) is placed against concrete that has already cured and gained strength, proper surface preparation is essential for good bond. To achieve good bond, we require a clean, roughened surface brought to a saturated surface dry (SSD) moisture condition. Cracking and groundwater seepage at that joint could result from inadequate surface preparation, poor shotcrete placement, or inadequate curing of the new shotcrete, causing drying shrinkage at the joint. It may well be a combination of all those factors.

A modified concrete pool shell with new concrete shot onto old concrete can perform monolithically, but its long-term integrity and durability depend on the repair details, including:

- How the existing surface was prepared (roughening, cleaning, SSD condition)
- The concrete mixture being shot has proper cement content, and corresponding hardened strength of at least 4000 psi (28 MPa) at 28 days
- Reinforcement continuity and coverage across the joint
- Proper equipment to place the concrete at high velocity
- Placement techniques to maximize impact and keep rebound and trimmings out of the structural section
- Continuous wet curing for at least 7 days after placement

Because this is a serviceability and durability issue, with groundwater entering the pool through the joint, the best next step is to have a licensed engineer with pool experience evaluate the cracking and seepage on-site and provide a repair specification. Also, be cautious about fully draining the pool in a high water table area without engineering guidance. You can use our Buyers Guide at **Shotcrete.org/Buyers-Guide** to help you find qualified shotcrete contractors who work in your region.

This past article from *Shotcrete* magazine details the bond between layers of shotcreted concrete and why, when done properly, it acts as a monolithic concrete section: **Shotcrete.org/wp-content/uploads/2020/05/2014Spr_TechnicalTip.pdf**

QUESTION:

How feasible is it to obtain 6000 psi (41 MPa) concrete compressive strength for shotcrete?

ANSWER:

With the proper mixture design and materials, we have consistently placed concrete with 6000 psi at 28-day strength. We generally see shotcreted concrete mixtures designed between 4000 and 8000 psi (55 MPa). Some high-strength mixtures can achieve over 10,000 psi (69 MPa).

QUESTION:

We are looking at some test work samples with the state DOT to deal with efflorescence on highway walls. Have you guys come across any good products over the years that have been specified? Do you have recommendations to try to either deal with pre-occurrence or post-occurrence preventatively with efflorescence issues on any projects?

ANSWER:

Efflorescence results from water entering the concrete and leaching free lime (calcium hydroxide) from the pores. Usually, efflorescence is most noticeable at cracks. So, reducing cracking with microfiber or enhanced curing may reduce the effect. Some material suppliers offer a water-repellent admixture that is supposed to reduce efflorescence. After construction, applying a water-repelling sealer, such as a silane, can also help, though it will need recoating at some point in the future to stay effective. Another option may be using a portland cement-based modified polymer coating that provides a semi-smooth waterproofing finish that resists hydrostatic pressure.

SHOTCRETE FAQS

QUESTION:

I am a building official in Florida and have a technical question about a pool that was partially shot with gunite (dry-mix shotcrete) and finished four days later. I have photos of the way it was left after the first day's shoot (Fig. 1). I need an expert to tell me if the way it was left was appropriate

ANSWER:

The construction joints look good. We want them sloped downward at about a 45° angle and roughened when leaving for the day (or weekend). When restarting shotcrete placement, the surface should be cleaned and wetted to a saturated surface dry (SSD) condition. This can be accomplished with a pressure washer, so you won't need a lot of water. Also, the reinforcing bars look fairly clean of previously shot material, so they should be fine for encasement.

If you have questions about the bond at the construction joint in the pool, you may find our ASA position statement addressing monolithic pool shotcrete shell helpful: It is available on our pool portal (**pools.shotcrete.org**).

SHOTCRETE CALENDAR

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

SEPTEMBER 16, 2026	**ACI Shotcrete Inspector Certification: Quality Shotcrete, Know It When You See It** | ACI Mid-Atlantic Resource Center | Columbia, MD
OCTOBER 7-9, 2026	**ACI Shotcreter Certification (Wet- & Dry-Mix)** Minova | Millstadt, IL
OCTOBER 11, 2026	**ASA Fall Networking Dinner** TBD | Atlanta, GA
OCTOBER 11-13, 2026	**Shotcrete Committee Meetings | ACI Fall Convention** Hilton Atlanta Hotel | Atlanta, GA
OCTOBER 11-14, 2026	**ACI Concrete Convention - Fall** Hilton Atlanta Hotel | Atlanta, GA
OCTOBER 18-21, 2026	**ICRI 2026 Fall Convention** Gila River Resort & Casino Wild Horse Pass | Chandler, AZ
OCTOBER 22, 2026	**ACI Shotcrete Inspector Certification: Quality Shotcrete, Know It When You See It** | Applied Shotcrete | Sebastopol, CA
OCTOBER 23-25, 2026	**ACI Shotcreter Certification (Wet- & Dry-Mix)** Applied Shotcrete | Sebastopol, CA
OCTOBER 29, 2026	**ASA Fall Board of Directors Committee Meeting** Virtual Teams Meeting
NOVEMBER 16, 2026	**PSP Pre-Con: Quality Shotcrete - Know It, Demand It** Ernest N. Morial Convention Center | New Orleans, LA
NOVEMBER 17, 2026	**Shotcrete – The Good, the Bad, and the Ugly** | International Pool | Spa | Patio Expo 2026 | Ernest N. Morial Convention Center | New Orleans, LA
NOVEMBER 17-19, 2026	**International Pool | Spa | Patio Expo 2026** Ernest N. Morial Convention Center | New Orleans, LA
DECEMBER 6-9, 2026	**ASTM Committee Meetings — C09 Concrete & Concrete Aggregates** Hyatt Regency Jacksonville Riverfront | 225 East Coastline Drive | Jacksonville, FL

SHOTCRETE CALENDAR

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

DECEMBER 18-20, 2026	**ACI Shotcreter Certification (Wet- & Dry-Mix)** Texan Gunite | Cedar Park, TX | *Primarily Spanish Session
JANUARY 18-21, 2027	**2027 World of Concrete** Las Vegas Convention Center | Las Vegas, NV
MARCH 7-9, 2027	**2027 ASA Shotcrete Convention & Technology Conference** Hilton Nashville Downtown | Nashville, TN
MARCH 8-9, 2027	**ASA Spring Committee Meetings** ASA Shotcrete Convention | Hilton Nashville Downtown | Nashville, TN
MARCH 9, 2027	**Outstanding Shotcrete Project Awards Banquet** Hilton Nashville Downtown | Nashville, TN
MARCH 21-24, 2027	**ACI Concrete Convention** Caesars Palace Las Vegas | Las Vegas, NV
JUNE 6-9, 2027	**ASTM Committee Meetings – C09 Concrete & Concrete Aggregates** Hyatt Regency O'Hare | Rosemont, IL
DECEMBER 2, 2026	**C2241 Quality Shotcrete for Pools – Know It, Demand It** WU Fall Session | UCSD Park & Market | San Diego, CA
DECEMBER 2-4, 2026	**WU Fall Session** UCSD Park & Market | San Diego, CA
DECEMBER 5-8, 2026	**ASTM Committee Meetings – C09 Concrete & Concrete Aggregates**Hilton Sheraton New Orleans Hotel | New Orleans, LA
MORE INFORMATION	To see a full list, current updates, and active links to each event, visit www.shotcrete.org/calendar.

2026 Open Shotcreter Certification Sessions

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

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

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

For details, visit shotcrete.org/calendar

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