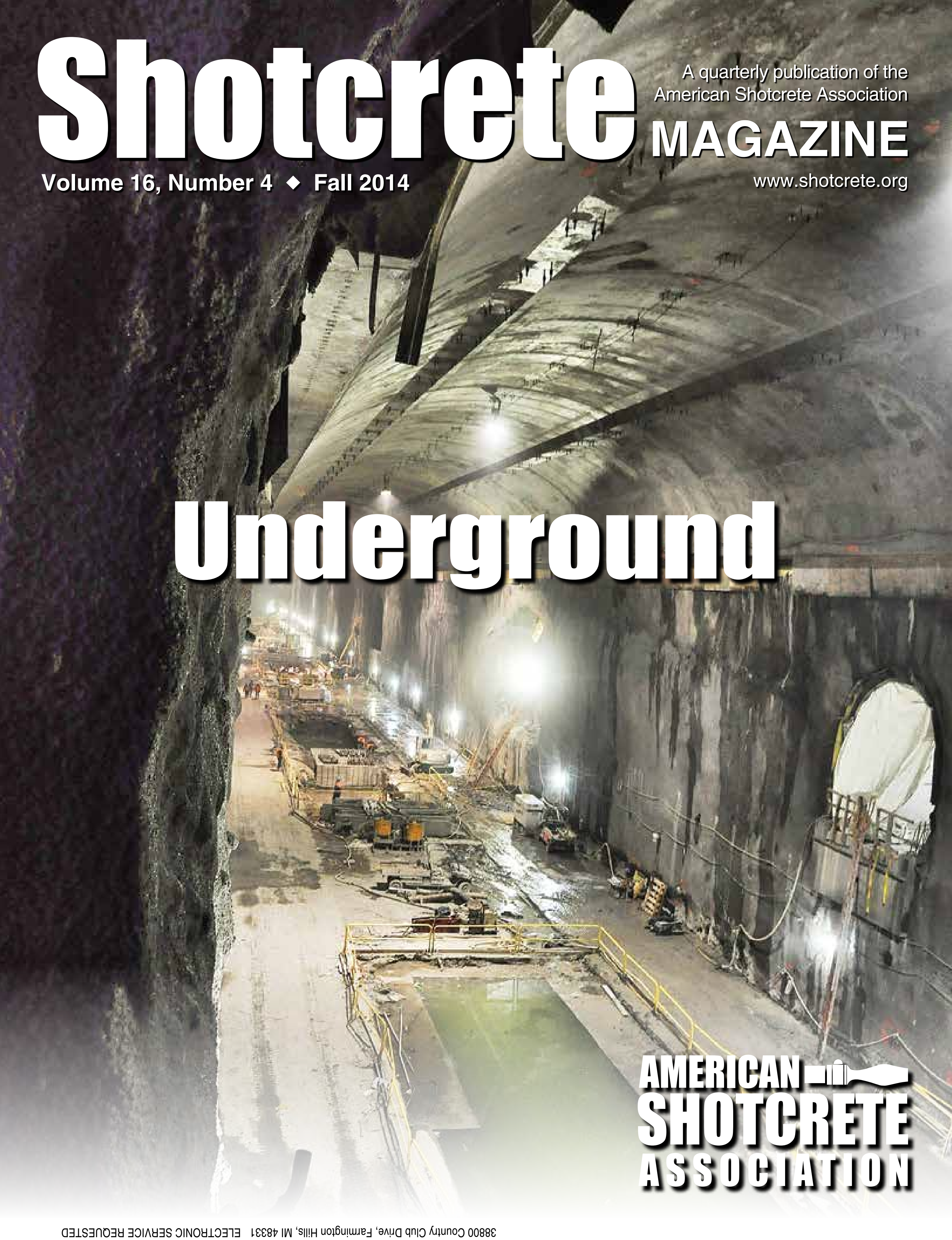
Shotcrete

A quarterly publication of the American Shotcrete Association

MAGAZINE

Volume 16, Number 4 ◆ Fall 2014

www.shotcrete.org



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AMERICAN SHOTCRETE ASSOCIATION

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

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Website: **www.shotcrete.org**

Shotcrete MAGAZINE

Volume 16, Number 4
Fall 2014

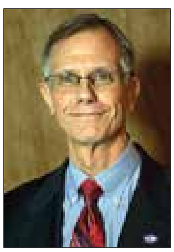
Features

Departments

On the cover: NYC Second Avenue Tunnels
Photo Courtesy of Jeff Boucher, Drakeley Industries

Google has Maps, Apple has Maps, and now ASA has a MAP!

By Charles S. Hanskat



These are exciting times for ASA. If you look back at where we started in 1998, to where we are today, you see we've grown and developed into a credible, respected organization that is spreading the word about shotcrete throughout the construction marketplace. Our growth and direction over the last 16 years has been a result of the tireless dedication of our past presidents, officers, committee chairs, members, and staff to fulfill the need for shotcrete education and acceptance.

However, looking forward to envision where we want ASA to be in 3, 5, or 10 years, there hasn't been a documented plan. We didn't have a road map to help guide us from year to year. Thus, earlier this year we started the process for developing a strategic plan. We formed a task group with experienced members—Past Presidents, officers, younger members, Board members, and staff who represented nearly all the "practice areas" in ASA (contractors, material suppliers, equipment manufacturers, engineers, and staff).

To help us efficiently and effectively develop the plan, we brought in a recognized facilitator, Jon Hockman, from Washington, DC. The group met in our headquarters office in Farmington Hills, MI, over a weekend in early August. We started Saturday afternoon, and wrapped up about 24 hours later on Sunday afternoon.

The process was eye-opening and frankly exciting. Everyone actively participated as we sat around a large conference table the first day. During the initial brainstorming, we had ideas, thoughts, programs, and concepts flying around the room. With Hockman's help we focused the raw thoughts into manageable goals and objectives that support the mission and vision of ASA, which we also updated. As we wrapped up on Sunday afternoon, everyone was enthusiastic and somewhat amazed by what we put together.

We updated our vision statement—"Structures built or repaired with the shotcrete process are accepted as equal or superior to cast concrete"—and then created a mission statement to support that vision: "ASA provides training, qualification, certification, education, networks, and leadership to increase the acceptance, quality, and safe practices of the shotcrete process."

Moving down through the plan, the mission is accomplished by four key strategic priorities:

1. Professional development
2. Outreach
3. Credibility
4. Organization strength

And for each of these strategic priorities, we developed goals and objectives to achieve each one. The plan was tweaked a bit by the group in the weeks after our weekend retreat in the suburbs of Detroit, and then presented to the ASA Board in a web conference in September. The Board was very receptive and, after much discussion, approved the strategic plan at the end of the meeting.

So now we have a Strategic Plan—a road map detailing where we want to be within 3 to 5 years. Each of the goals and objectives will be reviewed with our committees at the Fall 2014 ASA meetings in Washington, DC. Each committee will then decide what objectives fall under their scope, and start to put together a set of tasks to accomplish those objectives. A plan on the shelf does nothing—we have to be sure the gears are set in motion, and keep moving.

The approved Strategic Plan follows this column. Please review it, and if you have any questions, please feel free to contact me or any of the task group members. The task group members were: Michael Cotter, Marcus von der Hofen, Bill Drakeley, Oscar Duckworth, Patrick Bridger, Cathy Burkert, Ryan Poole, Dennis Bittner, Tom Norman, Alice McComas, and Mark Campo. My sincere thanks to all the task group members for taking a beautiful summer weekend away from family to help ASA develop the Strategic Plan.

The Strategic Plan must not be a static document. We will certainly refer to it as we progress, but we must also consider how changes in the marketplace, our membership, or our activities may need to change the plan. It should be a living, evolving document—one that helps everyone associated with ASA see what we want to accomplish, and how we will do it. I look forward to having your active support to raise ASA to the next level and bring the acceptance of shotcrete to an equal or superior footing with cast concrete.

Here is the ASA Strategic Plan, and it can also be found on our website: **www.shotcrete.org/media/pdf/ASA_Strategic_Plan_2014.pdf**.

AMERICAN SHOTCRETE ASSOCIATION

Strategic Plan

Our Impact | ASA's Vision

Structures built or repaired with the shotcrete process are accepted as equal or superior to cast concrete.

Our Drivers | ASA's Strategic Priorities

Professional Development

Outreach

Credibility

Organization Strength

Our Business | ASA's Mission

ASA provides training, qualification, certification, education, networks, and leadership to increase the acceptance, quality, and safe practices of the shotcrete process.

Our Success | Key Performance Indicators

- Member Satisfaction
- Financial Health
- Membership Growth

Professional Development

Strategic Driver	Goals	Objectives
ASA will develop and deliver programs, products, and services that provide knowledge, skills, and validate credibility.	Enhance resources for students	Develop a training and technical support relationship with three universities with strong concrete research programs
	Enhance resources for craftsman	Develop a mobile/web app to log shotcreting hours as a new nozzleman benefit and enroll 100 nozzlemen in the first year
		Develop a safety presentation to accompany safety guide and present at WOC and two other times/year
	Enhance resources for contractors	Develop two short-courses for education of employees of ASA member companies within two years (one targeted towards education of shotcrete crews, another towards education of superintendents and project managers) to enhance safety and quality
	Enhance support for specifiers and designers	Develop an AIA continuing education session for engineers/specifiers/architects and conduct three sessions with 20 participants
	Enhance resources for inspectors	Acceptance of inspector training program in 2 years
		Develop a test for certification of inspector credentials in 1 year
		Compile a list of ASA educated inspectors within 3 years

Outreach

Strategic Driver	Goals	Objectives
ASA will positively influence the shotcrete industry through mutually beneficial alliances.	Maximize member exposure	Hold two education programs at WOC and two at other venues
	Build and leverage relationships in higher education	Cultivate relationship through information programs to university-level engineering, architecture, and construction management students and professors
		Develop a module for members to present to undergraduate-level students. Make three to five presentations at universities each year
		Develop 1-hour course module (lecture notes, homework, testing, resources) for university professors to cover shotcrete within 3 years
		Further develop or retain scholarship applicants with shotcrete presentation at their learning institution
	Strengthen connections with specifiers, DOTs, and owners (railroads, facility managers, etc.)	Get shotcrete specified in state/DOT design manuals —one a year
		Cultivate relationships through informational programs through six DOT, specifiers, or owners each year
	Leverage relationship with concrete-related groups	Develop alliances with the ACPA, AASHTO, NRC, NTPEP, Sprayed Concrete Association (UK), EFNARC

Credibility

Strategic Driver	Goals	Objectives
ASA will be a well-respected organization representing an industry that is understood, credible, and used.	Strengthen role of shotcrete in ACI, AASHTO, and other codes and standards used in concrete design and construction	Shotcrete in next version of ACI 318
		Shotcrete in next version of ACI 301
		Investigate involvement with ACI 562 and AASHTO within 6 months (NTEPP)
	Enhance ethics, quality, and code of conduct across the industry	Develop and approve a Contractor Qualification program within 1 year for implementation in year 2
		15 contractors processed through the Contractor Qualification program in 3 years
	Support R&D in shotcrete and active distribution of shotcrete knowledge	Website has updated shotcrete bibliography in 2 years
		Complete and publish one research project within 3 years
		Identify and prioritize three research needs for shotcrete
		Identify funding sources for research within 6 months of developing short list of three research needs

Organization Strength

Strategic Driver	Goals	Objectives
ASA will have the resources and structures to fully support its strategic priorities.	Maximize member participation	12 new active committee members (four per year)
	Grow membership	Greater than or equal to 10% member growth per year
		Retain 85% of corporate members from certification activity every year
	Maximize net income to fund strategic priorities	Allocate funds to increase staff for support of new programs
	Increase professional staff support (such as technical director)	Employ full-time technical director within 3 years—or as soon as funding is identified
	Partner with ACI and groups for additional resources	Get shotcrete more broadly recognized in closely affiliated concrete groups like ACI, ICRI, and ASCC. Make one presentation/year at these group's annual meetings, webinar or appropriate committee meetings
		Investigate potential funding and support for research and programs from partner groups
	Strengthen ASA presence across all of the Americas	Target and recruit one member per year from Latin America
		Present ASA education session at Hanley Wood India
	Enhance communications—internal and external	Executive committee actions reported to the Board of Direction within 2 weeks of meetings.
		Investigate enhancement of ASA e-mail "newsletter" and website communication within 1 year

ASA Pool & Recreational Shotcrete Committee

By William T. Drakeley

The continued goal of the Pool & Recreational Shotcrete Committee is to provide basic education to entrants to the pool industry, as well as to promote continued education related to pool shotcrete applications with increasingly high standards for industry veterans. This mission is aligned with the founding purpose of the ASA as a whole.

I have had the opportunity to travel the country, teaching seminars and coaching shotcrete contractors. I have been amazed at the warm reception that the pool industry has shown to ASA as a beneficial resource of technically sound, accessible information. On the whole, small- to medium-sized contractors are demonstrating a desire to improve their product. Nevertheless, there are some larger contractors who are reticent to change their practices, regardless of potential conflict with proper installation standards. It seems that the operating premise of "quantity over quality" still prevails in some high-volume shooters, particularly with regard to cement-aggregate ratios, water-cementitious material ratios, rebound control, and minimum acceptable strength values (4000 psi [28 MPa]).

Until all members of the pool shotcrete industry adhere to proper procedures, the pool industry will not be clear of the black eye that is its damaged reputation due to substandard construction practices. We as pool contractors must demand higher standards of our colleagues—the same standards that our clients demand of us. I am happy to report that support for the standard-setting function of ASA remains high, and that its membership regularly requests updated guidelines for the newest techniques. The Pool & Recreational Shotcrete Committee is currently developing two new position papers dealing with watertight pool shotcrete and non-cold-joint applications, respectively. I look forward to sharing them with you as they become available.

ASA Pool & Recreational Shotcrete Committee

William T. Drakeley, Chair | Drakeley Industries

Joey Bell | Active Minerals International
Jonathan Dongell | Pebble Technologies
Oscar Duckworth | Valley Concrete Services
Mason Guarino | South Shore Gunite Pools & Spas Inc.
Marc Jolin | Laval University
Ron Lacher | Pool Engineering Inc.
Chris Marston | Airplaco Equipment Company
Tom Norman | Airplaco Equipment Company
Raymond Schallom III | RCS Consulting & Construction Co Inc.
James Scott | Group Works LLC
Marcus H. von der Hofen | Coastal Gunite
Lihe (John) Zhang | LZhang Consulting & Testing Ltd.

Ironically, repairing one of the busiest tunnels in Steel City required our shotcrete.

When Pittsburgh's 80-year-old Liberty Tunnels needed structural repairs, QUIKRETE® Shotcrete MS got the job done. Crews were able to complete their work within tight time constraints using the dry process with a pre-dampener. In fact, our shotcrete products were part of the American Shotcrete Association's "Outstanding Underground Project" for 2009 and 2010.

Snap this tag for Shotcrete MS product specs.*
Or visit QUIKRETE.com/Shotcrete

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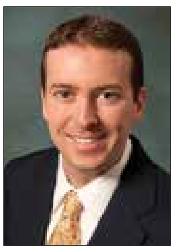
ASA at World of Concrete 2015

By Mark A. Campo, ASA Executive Director



World of Concrete (WOC) is considered by many to be the top show in the industry, and the 2015 show is expected to be the largest in over 6 years with over 600,000 ft^2 (55,740 m^2) of indoor and outdoor exhibit space and over 1100 exhibitors. The show also presents a critical outreach and educational opportunity for ASA. The diverse collection of attendees, ranging from equipment and material suppliers to contractors, engineers, and specifiers, creates an outstanding forum to efficiently communicate the numerous advantages of placing concrete via the shotcrete process.

ASA's presence as a cosponsor of this show has grown steadily and the 2015 show will be no exception. Please visit ASA's official WOC 2015 web page, **www.shotcrete.org/WOC**—a one-stop source for all ASA activities at WOC.

Following is a summary of all the activities ASA has planned at WOC 2015.

ASA Board of Direction and Annual Membership Meetings

ASA will hold its committee meetings on **Monday, February 2, 2015** (the day before the exhibit hall opens). Meetings will be held in the South Convention Hall of the Las Vegas Convention Center, and are free and open to anyone with an interest in shotcrete. (Room locations are not available at the time of printing. Please check ASA's calendar for the latest updates on times and locations: **www.shotcrete.org/pages/news-events/calendar.htm**.)

The ASA Board of Direction meeting will convene at 9:00 a.m. Following that, the **ASA Annual Membership Meeting is scheduled at 11:00 a.m.** This annual meeting will feature the announcement of ASA's newly elected Board members and Officers, in addition to highlighting the key initiatives being undertaken by the association this year—the most significant of which is a recently released ASA Strategic Plan, with a host of newly affirmed goals and objectives that will elevate ASA and the shotcrete industry to new heights.

ASA's other standing committees—Education, Pool & Recreational Shotcrete, Marketing, Membership, Publications, and Safety—each meet twice a year in the spring and fall. All ASA committees will next meet in Kansas City, MO, on Saturday, April 11, 2015.

Registration

If you are involved in the shotcrete industry and think you may attend WOC 2015, please register for the show using ASA's source code: **A17**. In doing so, you will receive a reduced rate of $20 (restrictions apply) exhibit-only pass *and* discounts on registration for educational sessions, while helping to support ASA at the same time. ASA has been an official cosponsor of WOC for 12 years; each registration made using ASA's **A17** source code results in a rebate to ASA. This is an easy but important way for you to help generate financial support of ASA, enabling its continued mission to market and educate on the benefits of the shotcrete process and grow the industry. The easiest way to register is to use our automatic link at **www.shotcrete.org/WOC**.

Remember that **early-bird registration** for ASA's educational programs mentioned below **ends December 15, 2014**.

ASA Shotcrete Nozzleman Education Session

Scheduled for **Tuesday, February 3, 2015, from 9:00 a.m. to 4:00 p.m.**, this session is designed for shotcrete nozzlemen, individuals involved with inspection of shotcrete, and anyone interested in learning about the principles and practices that must be known and understood for a nozzleman to satisfy his role in the quality application of the shotcrete process.

ASA nozzleman education sessions present an overview on placement technique, finishing, curing, testing, equipment, and safety as it relates to the nozzleman and the shotcrete process. This session will also help prepare individuals for participation in the ACI Nozzleman Certification program. ACI-required work experience, written exam, performance exam, and other program criteria will be discussed.

The CP-60(09) Shotcrete Nozzleman Craftsman Workbook is included with the session registration fee.

Please note the following important items about this session:

- **Attendance at this session will not result in certification as an ACI Shotcrete Nozzleman**.
- This session will satisfy the education session requirement for a nozzlemen wishing to pursue certification as an ACI Shotcrete Nozzleman through ASA.
- Attendees wishing to pursue ACI Certification will need to arrange for a certification session with ASA separately from this session.
- Attendees will qualify for and receive a complimentary 1-year ASA Nozzleman Membership.

Sign up early to take advantage of the $295.00 event registration fee on or before **December 15, 2014**; after that date, the fee rises to $345.00 (Registration Code: **ASATU**).

ASA Educational Seminar—Advanced Shotcrete for Infrastructure, Rehab, and Recreational Construction

Each year, ASA conducts one or more seminars as part of the WOC education program. This year's seminar, titled "Advanced Shotcrete for Infrastructure, Rehab, and Recreational Construction," will be presented by ASA Directors Bill Drakeley and Lihe (John) Zhang. The seminar will take place from **1:30 to 3:00 p.m. on Wednesday, February 4, 2015** (Registration Code: **WE151**).

This seminar will give the owner, design engineer, project specifier, field inspector, specialty subcontractor, and general contractor an overview on how shotcrete can be efficiently and cost-effectively used for structural repair, rehabilitation, and repurposing of concrete buildings and infrastructure. A basic overview of the shotcrete process and design, specifying, and detailing considerations for design of shotcrete repairs will be discussed. Field considerations including reduced formwork needs and scheduling advantages will also be covered, as well as achieving quality of shotcrete, addressing field inspection, specific placement techniques, nozzleman certifications, and contractor qualifications. Final discussions will include sustainability benefits of shotcrete and appropriate references and resources on use of shotcrete for structural concrete repair.

Having completed this program, you should be able to:

1. Identify design, specifying, and detailing considerations when using shotcrete for repair of structural sections;
2. Delineate the field advantages of shotcrete placement for structural concrete repairs;
3. Know the placement techniques, inspection, and contractor qualifications critical to producing quality shotcrete;
4. Compare sustainability of shotcrete to cast-in-place concrete; and
5. Examine references and resources about shotcrete for structural concrete repair.

Attendees will receive 1.5 continuing education hours from this seminar. Don't miss this outstanding opportunity to learn from two leading ASA experts in the shotcrete industry. Events fill up fast, so act soon!

ASA Shotcrete Inspector Education Session

With the strong growth of shotcrete construction, the concrete construction industry needs on-site inspectors who are knowledgeable about shotcrete materials, application, and quality. Although an inspector may be thoroughly experienced in the inspection of cast-in-place concrete construction, shotcrete has fundamentally different equipment, material selection, crew responsibilities, application techniques, testing, curing, and protection that need to be considered for producing high-quality and durable shotcrete.

This program, scheduled for **Thursday, February 5, 2015, from 9:00 a.m. to 4:00 p.m.**, will cover more than 40 critical elements of shotcrete applications that on-site inspectors must know to properly evaluate and sign-off on acceptance documents for shotcrete. These include an overview on material selections, equipment, placement techniques, finishing, curing, protection, testing, and safety as it relates to the building official or inspector.

ASA Inspector Training documentation, as well as copies of ACI 506.2-13, "Specification for Shotcrete"; ACI 506R-05, "Guide to Shotcrete"; and *Shotcrete: A Compilation of Papers* by Rusty Morgan (over $200 nonmember value), are included with the course registration fee. Please also note:

- Attendance at this course will not result in a certification; this course is intended to provide shotcrete-specific education, which may be a prerequisite for local/national certifications.
- Attendees will receive a certificate of completion from ASA.
- Lunch is not provided with this course. A 1-hour break is scheduled for lunch.

Sign up on or before **December 15, 2014**, to take advantage of the early-bird $395.00 registration fee; after that date, the fee rises to $475.00 (Registration Code: **ASATH**).

ASA's 10th Annual Outstanding Shotcrete Project Awards Banquet

This year's awards banquet will be held on **Tuesday, February 3, 2015**, at the New York, New York Hotel and Casino. I urge you to join us at this important event to meet, connect, and network with leaders in the shotcrete industry. Registration and cocktails with hors d'oeuvres begin at 6:30 p.m. Dinner is served at 7:30 p.m., followed immediately by the awards ceremony. A networking reception with a cash bar will continue afterwards. See page 13 for registration information. Early-bird registration is available until January 15, 2015.

Awards Sponsorship Opportunities: Sponsoring the ASA Outstanding Project Awards Program is an investment in highlighting and recognizing the exceptional versatility and quality of the shotcrete process to the construction world. Award sponsors receive excellent exposure through this celebrated program. Please consider your involvement this year by sponsoring at one of the following levels:

- "Big Shooter"—$5000
- Gold—$2500
- Silver—$1000
- Bronze—$500

More information is available at **www.shotcrete.org/media/pdf/BanquetSponsorForm.pdf**.

ASA Exhibit Booth: #S10839

ASA's booth remains in its high-profile location along the main aisle in South Hall this year. A great place for resources and networking within the shotcrete industry, you can chat with ASA directors, review and pick up publications, meet with your colleagues using our meeting table and chairs, or just say hello!

And don't forget to **register today using ASA's source code, A17**, for discounted exhibit-only registration to World of Concrete for as low as $20 (restrictions apply).

Tenth Annual Outstanding Shotcrete Project Awards Banquet

New York-New York Hotel and Casino
Staten Island Ballroom
Tuesday, February 3, 2015

6:30-7:30 p.m. Registration, networking, cocktails, and hors d’oeuvres
7:30-11:00 p.m. Plated dinner and awards ceremony
Further networking and cash bar available after the awards ceremony

Tenth Annual Outstanding Shotcrete Project Awards Banquet

AMERICAN SHOTCRETE ASSOCIATION

Registration Form

Join us in celebrating another year of membership success and in recognizing our project award recipients. Submit one form per attendee by January 15, 2015.
We look forward to seeing you in Las Vegas!

Banquet Information:

Location: New York-New York Hotel and Casino, Las Vegas
Staten Island Ballroom

Date: Tuesday, February 3, 2015

6:30-7:30 p.m.	Registration, networking, cocktails, and hors d'oeuvres
7:30-11:00 p.m.	Plated dinner and awards ceremony, followed by cash bar networking reception.

Attendee Information:

Name ______________________ Company ______________________

Address ____

City ____________ State ______ Zip ______ Country ____________

Phone ______________________ Fax ______________________

E-mail ____

❑ Early-bird registration due date: January 15, 2015 ($95-pp)

❑ Preregistration: January 16 - February 2, 2015 ($150-pp)

Preregistration before 2/2/2015 is encouraged, as only a limited number of seats will be available at the door. (February 3, 2015: $175-pp)

Online registration is now available! Visit **www.shotcrete.org/BanquetReg**.

❑ Vegetarian or other special dietary needs ______________________

Payment Information:

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❑ "Big Shooter"—$5000.00 ❑ Gold—$2500.00

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The following article originally appeared in Deep Mining 2014, published by the Australian Centre for Geomechanics, www.acg.uwa.edu.au.

Ultra Rapid Strength Development in Dry-Mix Shotcrete for Ultra Rapid Support in Challenging Mining Conditions

By Jean-Daniel Lemay, Marc Jolin, and Richard Gagné

Recent developments in the field of cementing materials have brought forward many non-traditional binder systems. Engineers involved in the fields of emergency repairs and rapid ground support have been on the lookout for materials that allow rapid production, placement, and, most of all, very rapid strength development kinetics. One binder system that fits the description is composed of ordinary portland cement (OPC), calcium aluminate cement (CAC), and calcium sulfate (CS). However, this type of binder also sometimes exhibits difficult workability that severely limits its use in regular cast in-place concrete. This limitation is overcome when using dry-mix shotcrete as a placement method. Since the contact between water and cement occurs in the nozzle immediately before placement, workability problems are avoided.

As a part of a graduate project at Laval University, 49 different mixtures, including simple, binary, and (mainly) ternary blends, were tested. Two major parameters were studied, the development of compressive strength and the volumetric stability. The numerous binder compositions tested allowed the selection of a stable optimized formulation in regard to early compressive strength and volumetric stability. Finally, the selected formulation was successfully tested with industrial dry-mix shotcrete equipment to verify the large-scale placement feasibility of such a product.

Introduction

Transport and placement methods for concrete have evolved tremendously throughout history. Although cast-in place concrete is still the most common placement method, other processes have been developed; let us simply think of the first concrete pump, self-leveling concrete, or roller compacter concretes. There is also another concrete placement process developed at the beginning of the last century that has gained global acceptance. First presented to the construction industry in 1910 by Carl Akeley (American Concrete Institute [ACI] 2005), shotcrete is now present everywhere, particularly in the mining and tunneling businesses.

Shotcrete (also known as sprayed concrete in many parts of the world) is a placement method for concrete. Shotcrete is defined as a mortar or concrete pneumatically projected at high velocity onto a surface (ACI 2005). The high velocity is essential to the process as it ensures an adequate compaction or consolidation and allows the material to stick to the sprayed surface. Without the proper compaction, quality shotcrete cannot be produced (ACI 2009).

As with all placement methods, different advantages of shotcrete make it more appropriate in certain situations. With its capacity to stick to vertical and overhead surfaces, shotcrete need only minimum, if any, formworks. To take full advantage of this specificity, shotcrete is best used in ground supports (tunnel, mine, slope stabilization, etc.), overhead civil work reparation (bridge deck and parking lower surface, etc.), and where complex formworks make cast-in place concrete very expensive (arc type bridge, circular column repairs, etc.).

Shotcrete can be produced using two different processes, the wet-mix and the dry-mix. The major differences between these processes are the conveying method of the material through the hose and the location where the water is added to the mixture.

Wet-Mix Shotcrete

In the wet-mix process, all the ingredients are mixed together before being pumped through the

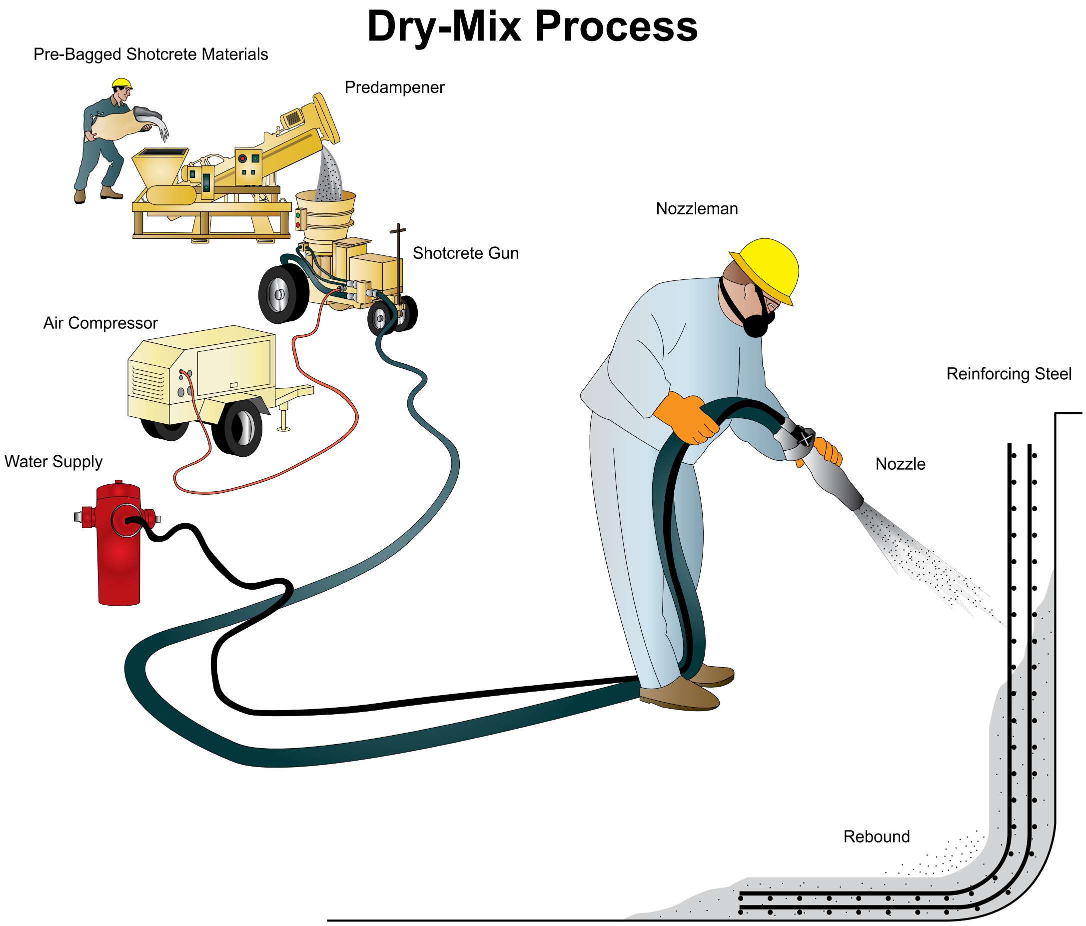

Fig. 1: Typical setup for dry-mix shotcrete operations

Table 1: Difference between dry-mix and wet-mix process

Dry-mix process	**Wet-mix process**
Pros	
Instantaneous adjustment of shooting consistency	Known *w/cm*
Delivery hose lighter to move	Rebound and dust are lower
Start-stop operations simple	High volume output
Cons	
Higher rebound	High volume output sometimes difficult to manage
Low volume output	Use (and dosage) of accelerator on site

hose. Air is added at the nozzle, through an air-ring, to propel the material at high velocity onto the surface ensuring sufficient compaction. As all components are mixed together prior to pumping, wet-mix concrete is usually delivered on site by a standard ready-mix truck and is fed directly into the pump.

With the exception of the set-accelerator, all admixtures are blended before pumping. When needed, the set-accelerator is added at the nozzle through a separate valve by using a special admixture pump. Normal dosage of accelerator usually ranges from 2.5 to 6%, but a dosage of >10% of binder content is sometimes used (Prudêncio Jr. 1998). Accelerator dosage has to be carefully planned as it reduces long-term resistance and durability of concrete (Neville 2008).

Dry-Mix Shotcrete

Dry-mix shotcrete is fundamentally different from its wet-mix counterpart. In this process, all the solid materials (gravel, sand, cement, additives, fibers, admixtures) are transported through the hose using compressed air. Water is added through a water ring at the nozzle or shortly before depending on the type of nozzle used. No matter the type of equipment used, the water-binder contact comes only a fraction of a second before placement. This particularity enables this process to bypass workability issues usually associated with the mixing and pumping of regular concrete. Figure 1 shows a schematic of a typical dry-mix shotcrete setup.

Since materials are introduced in the dry state in the hose, production of dry-mix shotcrete usually takes advantage of pre-bagged material. This enables easier quality control of the material as the production of such bags is done in a controlled environment.

Comparison of Both Processes

Each process has its own advantages and disadvantages. Wet-mix shotcrete is usually used only when high volumes of shotcrete are needed due to the important mobilization needs. On the other hand, while the dry-mix process cannot reach the production rates of the wet-mix process, its mobilization costs, preparation time, and flexibility are key factors in its selection.

Table 1 presents the major differences between both processes.

Development of New Shotcrete

The development of a new and alternative binder to Portland cement has opened the field of cementitious binders to a whole new variety of binder. One of those binders exhibiting very promising properties is a binder composed of OPC, CAC, and CS (Lamberet 2005). This type of mixture shows very rapid hardening behavior but is unfortunately often accompanied with important workability issues. With a pot life of less than 10 minutes, regular cast-in place application of this type of concrete is impossible without the use of numerous chemical admixtures to control set and fluidity. A means to avoid this type of problem was sought and this is where dry-mix shotcrete becomes a very interesting process since water is added only a fraction of a second before impact onto the receiving surface, avoiding workability issues. The validity of such a hypothesis was part of a research project at Laval University (Lemay 2013).

Research Program

The research program was divided in two phases. The first part focused on the mixture composition and the second on an actual life-size equipment testing.

Phase 1

Ternary binder made of OPC, CAC, and CS can present expansion if the mixture design is not properly done. The expansion can be such as to ruin the concrete (or shotcrete) and so, must be correctly assessed.

Based on work previously conducted by Lamberet (2005), numerous mixture formulations were tested. The stability was evaluated using standard 2 in. (50 mm) cubes incorporating only fine aggregate (sand). Each mixture had the same proportions and the same water-cementitious material ratio (*w*/*cm*). To ensure sufficient workability for casting, a polycarboxylate high-range water-reducer-super—plastisizer was used. The admixture dosage varied based on the formulation as the efficiency was influenced by the major component of the binder (OPC or CAC). Table 2 presents the mixture design proportions (by weight) used in Phase 1.

The difference between each mixture was the proportion of OPC, CAC, and CS of the paste. All cubes were cured in a 100% relative humidity room at 82.4 ± 1.8°F (21 ± 1°C). Forms were removed as soon as possible and depending of the setting of the mixture could be as soon as 2 hours.

Phase 2

The main objective of the project consisted in realizing a conventional dry-mix shooting session of a special mixture based on a ternary binder using standard dry-mix equipment and techniques (ACI 2005, 2009). To ensure consistent shotcreting and adequate quality control, the shotcreting took place at Laval University's shotcrete laboratory. The laboratory is equipped with full-scale shotcreting equipment in an indoor environment that is temperature controlled. The shotcrete was sprayed using a rotating barrel ALIVA 246 with a 1.5 in. (38.1 mm) interior diameter hose with the water ring placed 10 ft (3 m) upstream from the outlet of the nozzle—also known as the hydromix nozzle (Fig. 2).

The mixture was shot indoors at an average temperature of 70°F (21°C). The shotcrete laboratory's equipment includes an electronic air flow meter, a water flow meter, and a set of electronic scales; the data acquisition system records the airflow, the water flow, and the material used during the spraying operations (Fig. 3). The targeted airflow is 180 ft^3/min (4.25 m^3/min) at a working air pressure of 100 psi (700 kPa). The water flow was adjusted (by the operator holding the nozzle) to what is referred to in the industry as the wettest stable consistency. The evolution of the water and material flows are used as a quality control point. Irregular or non-uniform flows lead to the rejection of a mixture.

Prior to the shotcreting operation, 1200 lb (780 kg) of dry shotcrete material was pre-weighted and pre-blended to allow for the production of the various panels and samples needed for testing. Table 3 shows the dry proportion of the pre-blended material.

Table 2: Mixture design for Phase 1 mixture

Water, %	Paste, %	Aggregate, %
7.7	17.5	74.4

To correctly assess the strength development of the ternary mixture, compressive strength tests were conducted. Early-age compressive strength tests (up to 3 hours) were conducted using beam specimens. These beam specimens are sprayed in steel mold to realize end beam test (Heere and Morgan 2002), which is a common test in the mining industry. Figure 4 shows the setup used to perform the test and an actual specimen tested.

To evaluate compressive strength after 3 hours, 3 in. (75 mm) diameter cores were extracted from test panels (ASTM International 2003, 2005). Figure 5 shows the different test panels ready for shotcreting in the rebound chamber in the shotcrete laboratory.

Results

Phase 1—Results

To obtain an accurate representation of the expansion pattern of these types of ternary binder, over 49 different mixtures were tested. The fast-setting nature of the OPC-CAC-CS binder ended up requiring the assistance of three persons to cast the cubes. Doing otherwise resulted in the setting of the mixture prior to proper placement. Initial setting of less than 5 minutes has been observed on some mixtures. Figure 6 presents all the mixtures tested in Phase 1. Figure 7 presents the wide range of expansion observed for the unstable mixtures.

The line leading to expansion is not a straight line because of the variability in the OPC, CAC, and CS oxide in the binders. Because of this difference and the very sensitive nature of the expansion, a straight and clear expansion limit cannot be identified. This means that with any composition change in any of the three components of the binder, this limit must be investigated again. Doing otherwise may lead to catastrophic expansion of the mixture.

It should be noted that the limit observed is very similar to what was observed by Lamberet (Lamberet 2005) with a minor difference in the CS content leading to expansion on the CAC side of the line. This is most likely due to the difference between the material used in Europe and Canada. For instance, a minor change in sulphate contents (SO_3) can have an important change in the mixture stability.

Based on the results from Phase 1, a non-expansive mixture was chosen for the shotcreting operations. The results and discussion on this selection can be found in previous work (Lemay et al. 2014).

Phase 2—Placement and Adhesion

The first goal of this shotcreting session was to establish whether the new type of binder allows for proper shooting and placement of dry-mix shotcrete. Using the standard equipment described above, the shotcreting was a success. Indeed, the use of the hydromix nozzle was efficient in reducing dust emission and no plugging was observed; dust and rebound were similar to those obtained with traditional dry-mix shotcrete mixture design. Later coring of the test panels confirms the homogeneity of the in-place material.

Overall, the material shot very well and allowed placement on vertical surfaces without the need of accelerator; the in-place mixture showed sufficient cohesion and adhesion to stay in place with more than 5 in. (125 mm) thickness while presenting rebound losses of approximately 20%.

Fig. 2: (a) Spraying gun; and (b) hydromix nozzle

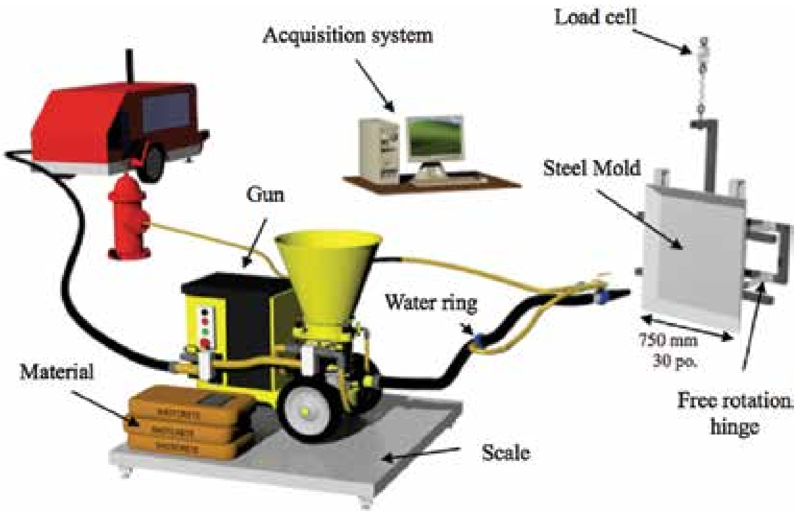

Fig. 3: Schematic of the electronic acquisition system

Table 3: Dry proportion of sprayed mixture

Ternary binder, %	Aggregate, %	
	Sand	Rock
19.0	52.7	28.3

Fig. 4: End beam test apparatus

Fig. 5: Rebound chamber before spraying

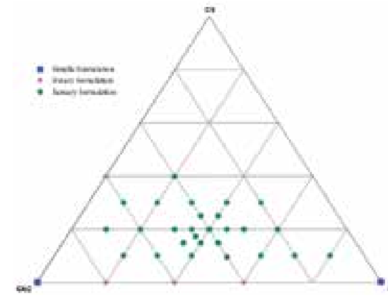

Fig. 6: All mixtures tested in this study

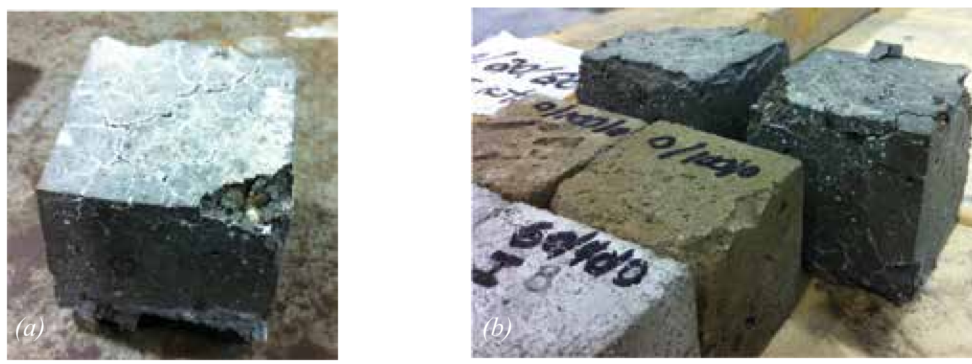

Fig. 7: (a) Expansion of a mixture close to the expansion line; and (b) expansive mixture compare to a stable mixture

Table 4: Average compressive strength

Specimens	Compressive strength, MPa						
	1 h	2 h	3 h	6 h	1 d	7 d	28 d
Prisms	12.9	24.9	29.6	—	—	—	—
Cores	—	—	35.6	47.6	54.6	51.9	52.1

Note: 1 MPa = 145 psi.

Phase 2—Compressive Strength

The spraying was successful using standard dry-mix shotcrete equipment. Particularly, the use of a hydromix nozzle where water is introduced 10 ft (3 m) prior to its delivery through the nozzle allowed the production of homogeneous good quality shotcrete with no clogging in the equipment. Table 3 presents the average compressive strength obtained using the end beam test (Fig. 4) and the average compressive strength using three cores taken from panels.

The results presented in Table 4 are actually quite impressive and are deemed a success for the mining and tunneling industry; indeed, typical early-age and compressive strength obtained with ordinary Portland cements based mixture design and set accelerators are usually around 435 to 580 psi (3 to 4 MPa). Compressive strengths over 4350 psi (30 MPa) at 3 hours with 28-day compressive strengths of some 7250 psi (50 MPa) are extremely promising. On the other hand, the 1-hour results also show very interesting potential for emergency response. Structural damages caused by fire in tunnels or by natural disasters (e.g. flooding or earthquakes) on essential structures could very rapidly be alleviated using such a mix design in combination with the dry-mix shotcrete application method. In fact, although not measured because of its rapid onset, the setting time of the mixture used is very short (<10 minutes) which translates most probably to a few megapascals of compressive strength with minutes of its placement.

Obviously, the use of dry-mix shotcrete represents an extremely well-adapted method for placing such potent mixtures. Indeed, the fact that all of the dry materials are conveyed with air through the hose to the nozzle where water is added gives a very short contact time between the water and the cementing materials before it is sprayed onto the surface. By using pre-blended bulk bags that can be stored for long periods of time, it becomes easy to have concrete material ready in case of emergency. Combined with the very simple mobilization of dry-mix shotcrete and absence of a need for formwork, a fast and reliable system could be obtained.

Conclusion

The objective of this research project was to produce a dry-mix shotcrete material offering a very rapid strength development. This was successfully achieved using standard shotcreting equipment.

While normal non-accelerated shotcrete usually needs a couple of hours before showing any compressive strength, it was possible to walk on the shotcrete developed after 10 minutes. The very rapid hardening provides extremely high early compressive strength (1740 psi [12 MPa] at 1 hour), showing very interesting potential for emergency response. Structural damages caused by fire in tunnels or by natural disasters on essential structures could be very rapidly alleviated using such a mixture design in combination with the dry-mix shotcrete application method. Along with pre-blended bulk bags and combined with the ease of mobilization of dry-mix shotcrete equipment, a fast and reliable system could be obtained for rapid structural emergency response.

The next step toward the acceptance of this new kind of binder is field testing. While showing a traditional comportment in the laboratory, extensive testing on the field must be done before it is used on a large scale.

Acknowledgments

The authors would like to thank the Centre de Recherche sur les Infrastructures en Béton (CRIB) for the funding of this research project.

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Variability of Compressive Strength of Shotcrete in a Tunnel-Lining Project

By Lihe (John) Zhang

Recently, questions have been asked by the International Tunnelling and Underground Space Association (ITA) about what variability can be expected for compressive strength for shotcrete (sprayed concrete) in ground support projects. The compressive strength of concrete and shotcrete is mainly controlled by mixture design parameters, including the water-cementitious material ratio (*w/cm*). With shotcrete, other factors, including the skill set of the nozzleman applying the shotcrete, can also affect compressive strength. The shotcrete method used—wet-versus dry-mix and accelerator addition at the nozzle—may also affect compressive strength and variability.

During recent shotcrete ground support projects, the author conducted routine quality control (QC) testing for compressive strength of shotcrete. Data from these projects showed that the compressive strength is dependent on the application method used. For one tunnel project, over 6500 yd^3 (5000 m^3) of accelerated wet-mix shotcrete was applied and over 700 sets of cores (two cores for each set) were tested for compressive strength at 7 and 28 days of age. This paper provides a statistical analysis of the shotcrete compressive strength test data from a civil tunnel project in western Canada and shows that the variability in compressive strength is influenced by a number of factors.

Introduction

During the construction of a tunnel project in western Canada, a total of over 6500 yd^3 (5000 m^3) of shotcrete was applied as the final lining. The tunnel was lined with shotcrete reinforced with one or more types of reinforcement, including rock anchor bolts, steel mesh, steel sets, or ring beams, depending on the ground conditions. Wet-mix shotcrete with accelerator added at the nozzle was used for the project. The project design required shotcrete to be applied to an average thickness of 4 in. (100 mm), with a minimum 2 in. (50 mm) cover over steel sets or ring beams. Performance requirements for the wet-mix shotcrete were as follows.

Specifications

- Compressive strength: 1450 psi (10 MPa) at 3 days, 2900 psi (20 MPa) at 7 days, 5000 psi (35 MPa) at 28 days tested to ASTM C1604/C1604M;
- Boiled absorption: <8% tested to ASTM C642; and
- Volume of permeable voids: <17% tested to ASTM C642.

To meet the performance requirements, a wet-mix shotcrete with silica fume was designed, as shown in Table 1.

This mixture design used 10% silica fume by mass of cement to achieve the durability requirement. A hydration-controlling admixture was used to extend the plastic life of the shotcrete for up to 8 hours. To apply overhead shotcrete with minimal fallout, an alkali-free accelerator was added at the nozzle at dosages of 6% by mass of cement. The higher dosages of accelerator were used in wet ground conditions and where thicker shotcrete encapsulations were required.

Shotcrete Quality Control Testing

The project required hand nozzling and all of the nozzlemen were American Concrete Institute (ACI) Certified Nozzlemen. Two levels of qualifications were required: Level I—each nozzleman was required to shoot a vertical test panel and an overhead test panel, and cores were extracted from each panel and tested for compressive strength, boiled absorption, and volume of permeable voids as required by the project specification; Level II—each nozzleman was qualified specifically to the underground reinforcement shooting, underground ring beams, steel girders, and wire mesh reinforcement.

During the construction stage, one QC testing panel was shot for each nozzleman for each day when shotcrete was applied. Four cores with diameters of 2.75 in. (70 mm) were extracted for

Table 1: Wet-mix shotcrete mixture proportions

Material	Mass per 1.3 yd³ (1 m³), SSD aggregate
Cement type GU	900 lb (410 kg)
Silica fume	88 lb (40 kg)
Coarse aggregate (0.2 to 0.4 in. [5 to 10 mm], SSD)	1180 lb (535 kg)
Fine aggregate (SSD)	2480 lb (1125 kg)
Water	49 gal. (185 L)
Water-reducing admixture	0.142 gal. (0.538 L)
Hydration-controlling admixture	0.227 gal. (0.860 L)
Air content: at pump	3 to 6%
As shot, ±1.5	3.5%
Total	5072 lb (2301 kg)

every test panel. Two cores were tested for compressive strength at 7 days and two cores were tested at 28 days. Shotcrete construction included Stage I, when shotcrete was applied primarily on the upper walls and overhead parts of the tunnel, and Stage II, when shotcrete was applied primarily in the lower half of the tunnel. A total of over 1000 cores were extracted from QC test panels and tested during the whole construction stage of the project.

7-day Compressive Strength

A total of 566 cores were tested for 7-day compressive strength in Stage I of the project and 482 cores in Stage II. Test results are graphically shown in Fig. 1 and 2 for Stage I and Stage II, respectively.

Figures 1 and 2 show that the 7-day compressive strength for shotcrete cores extracted from the test panels ranged from 1450 to 7300 psi (10 to 50 MPa) with the majority of results meeting the specified minimum (7-day requirement of 2900 psi [20 MPa]). For Stage I shotcrete, the average compressive strength was 4400 psi (30.5 MPa) and there were 22 cores out of 556—that is, 22/566 = 3.9%—where the 7-day strength did not meet the specified 2900 psi (20 MPa) compressive strength requirement. For Stage II shotcrete, the average 7-day compressive strength was 4200 psi (28.7 MPa) and there were 30 cores out of 482—that is, 30/482 = 6.2%—where the 7-day strength did not meet the specified compressive strength requirement.

The standard deviation (SD) for shotcrete core 7-day compressive strength from both Stage I and Stage II shotcrete was less than 1300 psi (9 MPa), with 95% of them being less than 730 psi (5 MPa). The coefficient of variation (COV) for 7-day compressive strength was 21% for Stage I shotcrete and 20% for Stage II shotcrete. It should be noted that 95% (540/566) of the core strengths in Stage I had a COV of less than 15%, while 95% (460/482) of the core strengths in Stage II had a COV of less than 20%. This shows that the

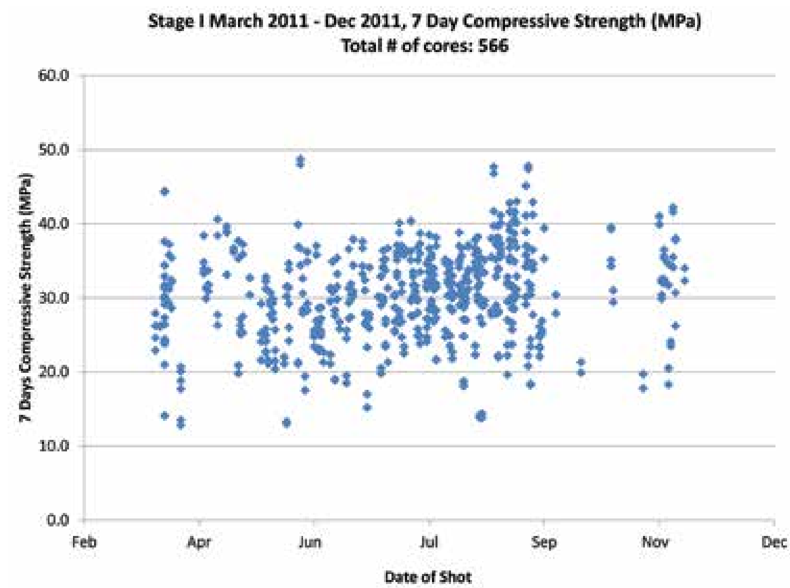

Fig. 1: 7-day compressive strength for shotcrete cores from test panels, March to December (Note: 1 MPa = 145 psi)

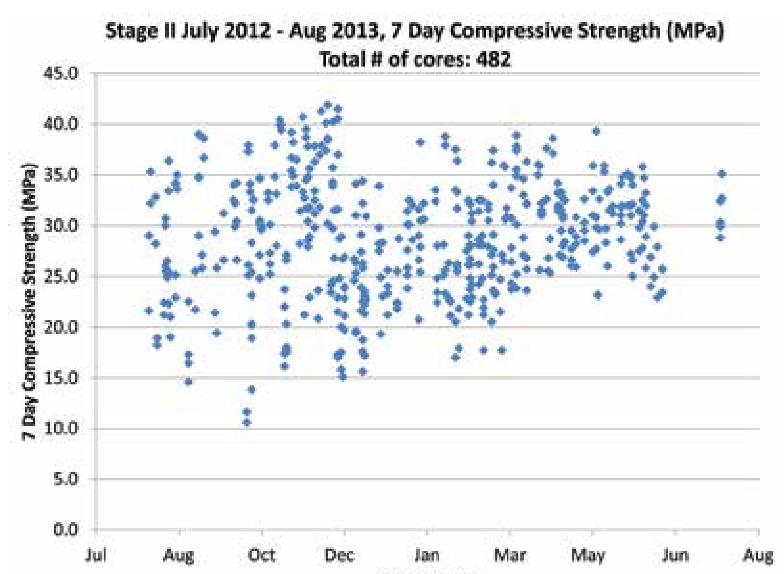

Fig. 2: 7-day compressive strength for shotcrete cores from test panels, July to August (Note: 1 MPa = 145 psi)

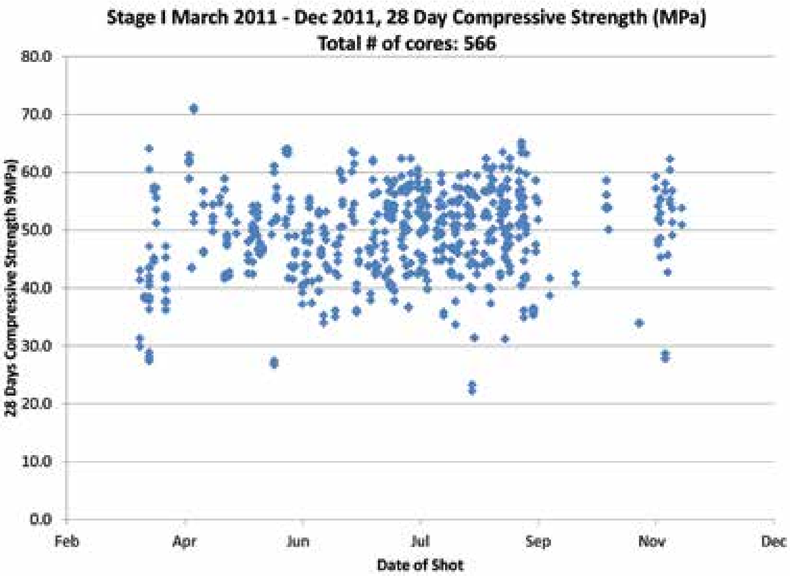

Fig. 3: 28-day compressive strength for shotcrete cores from test panels, March to December (Note: 1 MPa = 145 psi)

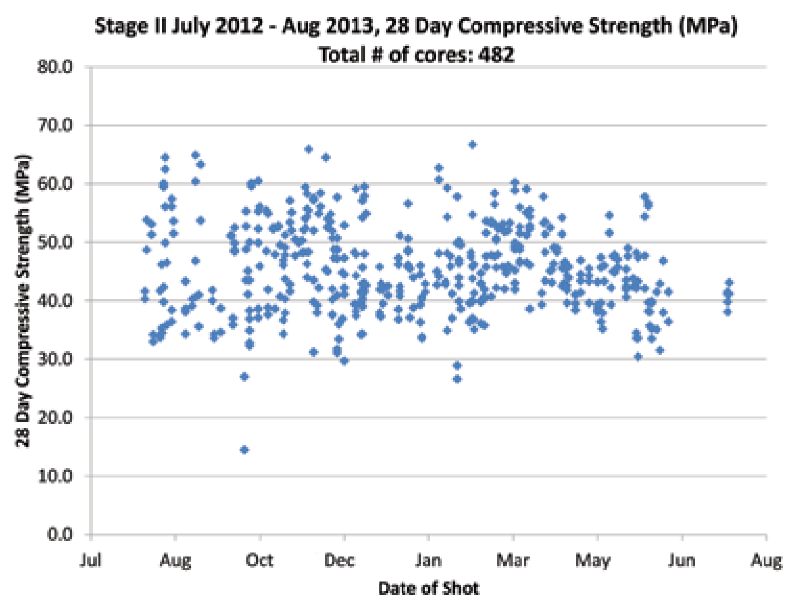

Fig. 4: 28-day compressive strength for shotcrete cores from test panels, July to August (Note: 1 MPa = 145 psi)

strength variation of Stage II shotcrete cores is higher than in the Stage I shotcrete cores.

28-day Compressive Strength

Figure 3 shows the compressive strength development at 28 days for Stage I shotcrete. It ranged from 4400 to 10,300 psi (30 to 71 MPa) with an average compressive strength of 7140 psi (49.2 MPa). For Stage I shotcrete, there were 15 cores that have strengths lower than the specified 5000 psi (35 MPa), which means that 97% (551/566) of the shotcrete cores met the specified compressive strength of 5000 psi (35 MPa) at 28 days.

For Stage II shotcrete, except for one core which had a compressive strength of 2000 psi (14 MPa), the 28-day compressive strengths ranged from 3900 to 9700 psi (27 to 67 MPa) with an average compressive strength of 6600 psi (45.4 MPa). Figure 4 shows there were 16 cores with strengths lower than the specified minimum 5000 psi (35 MPa). This means that 97% (464/482) of the shotcrete cores met the specified compressive strength of 5000 psi (35 MPa) at 28 days.

The SD and COV of the 28-day compressive strength for Stage I and Stage II were calculated and are summarized in Table 2. The SD of 28-day compressive strength for Stage I shotcrete is 1100 psi (7.8 MPa) and the COV is 16%. Except for three cores that show higher SD and COV, the SD for Stage I shotcrete 28 days core strength is less than 870 psi (6 MPa). This shows that 99.5% (553/556) of the Stage I shotcrete cores had a SD of less than 870 psi (6 MPa) and a COV of less than 15% at 28 days.

The SD of 28-day compressive strength for Stage II shotcrete is 1100 psi (7.5 MPa) and the COV is 17%. Except for four cores, the SD for Stage II shotcrete core strength is lower than 1450 psi (10 MPa). This means that 99.4% (479/482) of the Stage II shotcrete cores had a SD of less than 1450 psi (10 MPa) and a COV of less

Table 2: Summary of average strengths, standard deviation, and coefficient of variation at 7 and 28 days

Variation	Stage I shotcrete compressive strength		Stage II shotcrete compressive strength	
	7 days	28 days	7 days	28 days
Specified, psi (MPa)	2900 (20)	5000 (35)	2900 (20)	5000 (35)
Average, psi (MPa)	4420 (30.5)	7140 (49.2)	4160 (28.7)	6580 (45.4)
SD, psi (MPa)	910 (6.3)	1130 (7.8)	840 (5.8)	1090 (7.5)
COV, %	21	16	20	17
CSA required average strength, psi (MPa)	4580 (31.6)	7280 (50.2)	4410 (30.4)	7180(49.5)

than 28%. This shows that the 28-day compressive strength for Stage II shotcrete cores is higher than that in Stage I shotcrete.

Compressive strength at 28 days versus 7 days

Generally, concrete develops about 70 to 75% of its 28-day compressive strength at 7 days. For shotcrete cores, similar compressive strength development is expected, provided the cores are cured properly. Figures 5 and 6 show the increases of the compressive strength from 7 days to 28 days. The compressive strength ratio is defined as the ratio of compressive strength at 28 days versus the compressive strength at 7 days. The ratio ranges from 1.5 to 2.5 for both Stage I and Stage II shotcrete. This variability could be attributed to the following reasons:

1. **Curing of the testing panels:** The shotcrete QC test panels were typically shot in the tunnel, and left there for 2 days before being transported to the surface and then to the testing laboratory. The moisture content in the tunnel was generally above 80%, and was considered to provide natural curing as defined in ACI 506.5R-09, "Guide for Specifying Underground Shotcrete." But the temperature in the tunnel was generally in the 40 to 50°F (5 to 10°C) range. In addition, Sets 541 and 542 had greater increases in compressive strength from 7 to 28 days due to the fact that the cores were left on site without proper curing (the weather was cold during February when cores were extracted), and were only delivered to the lab at 7 days of age. Therefore, these cooler temperatures caused a slower rate of strength development in the 7-day test results, compared to cores with standard laboratory curing at 73°F (23°C) from 2 days of age.
2. **Handling the QC test panels:** Due to the challenges in shotcrete QC panel handling, some panels, when moved to the surface, were found to have been left outside for a few days without proper curing before cores were extracted for testing. In a few cases, the shotcrete cores were extracted at 7 days and then sent to the laboratory for testing without even being stored in the laboratory curing tank.
3. **Addition of accelerator:** An alkali-free accelerator was added to the shotcrete. The dosage of the accelerator was found to not be consistent during shotcrete production. This was largely due to the challenges of properly operating the accelerator dosing pump in the underground environment. The author worked with the contractor to accurately calibrate the accelerator dosing pump, establish operational procedures, and train the shotcrete crew.[3] However, it was found that the accelerator dosing pump was not always operated properly. Excessive accelerator addition occurred at times and was found to be detrimental to the 7- and 28-day compressive strength.[4] This influenced the variability of compressive strength test results.
4. **Nozzlemen shooting technique:** Shotcrete is a method of placing concrete, and the quality of the shotcrete is dependent on the nozzleman's skills. Hand nozzling requires proficient operation of the nozzle, prompt adjustment of

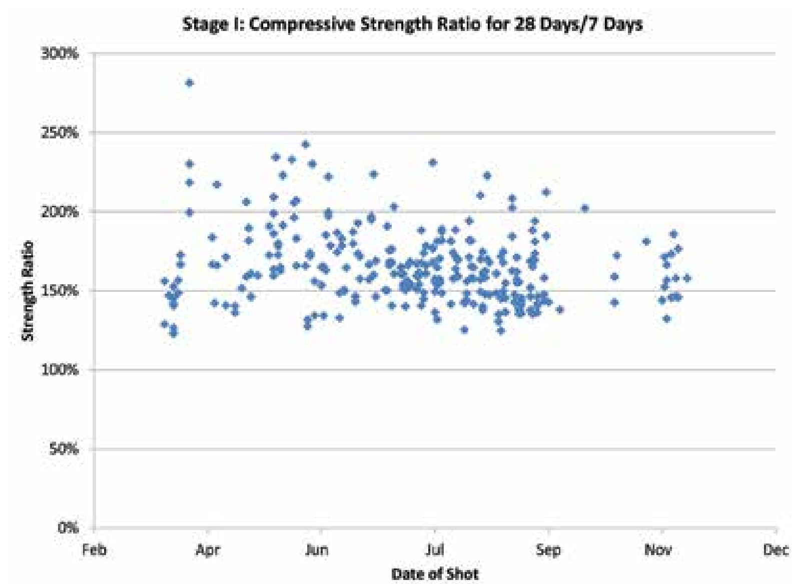

Fig. 5: Compressive strength of concrete at 28 days versus 7 days for Stage I shotcrete

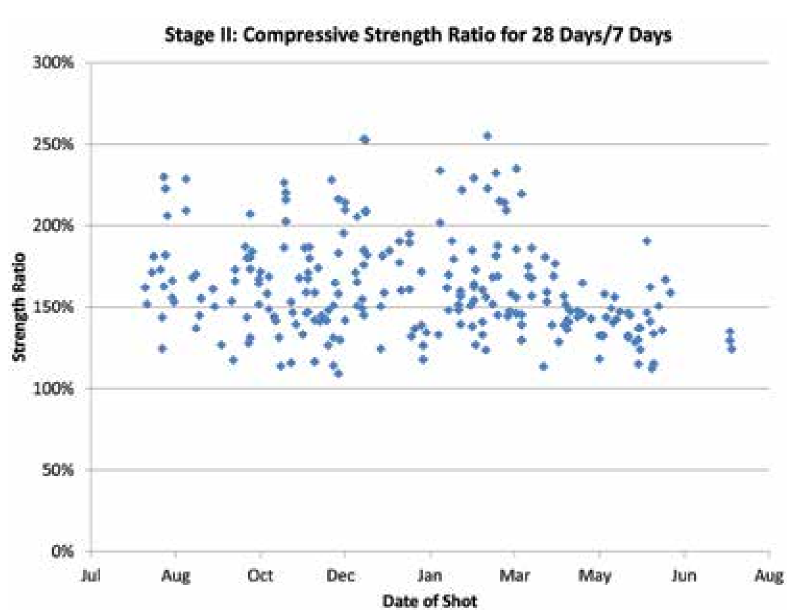

Fig. 6: Compressive strength of concrete at 28 days versus 7 days for Stage II shotcrete

the accelerator dosage to meet the ground condition requirements, and instant communication with other crew members, including the pump operator, to operate safely. During shotcrete construction, two items which influenced compressive strength were observed and found to be related to the nozzleman's shooting technique. First, a variation in strength between two cores extracted from the same test panel was shot by one nozzleman. One set (Set 282) had a core with 28-day compressive strength of 7140 psi (49.2 MPa), and the strength of the other core was only 3550 psi (24.5 MPa). Another set (Set 323) had one core with a compressive strength of 4680 psi (32.3 MPa) and the other core had a compressive strength of 7250 psi (50.0 MPa). Second, core strength variations were found between different nozzlemen. During QC testing, it was found that the shotcrete core strength from one particular nozzleman was typically 725 to 1450 psi (5 to 10 MPa) lower than the other nozzlemen. Shotcrete cores were examined prior to and after testing and it was found that there was typically a layer of overspray in the middle of the cores (Fig. 7). This nozzleman was then trained by the author to properly operate the nozzle and improve nozzling skills.

Fig. 7: Low-strength shotcrete cores from one nozzleman, with overspray in the middle

Variability of Shotcrete Core Compressive Strength

1. Table 2 summarizes the SD and COV for 7- and 28-day compressive strength for both Stage I and Stage II shotcrete. It shows that the COV for 7-day strength is 20 to 21%, and 15 to 17% for 28-day strength. This shows that the 7-day strength tends to have higher variation than the 28-day strength. The reasons have been discussed in the previous sections. Those include curing, panel handling, and core extraction.
2. The Canadian Standard Association (CSA) A23.1/23.2-2009[4] requirements for cores drilled from a concrete structure are: "… for standard-cured concrete specimens, the strength can be accepted if concrete has an average strength of (1) 1.4 times the SD above the specified strength when the SD is not more than 3.5 MPa (500 psi); and (2) 2.4 times the SD minus 3.5 MPa (2.4 x SD – 3.5 MPa) above the specified strength when the SD is more than 3.5 MPa (500 psi). The SD should be based on at least 30 consecutive strength tests, representing concrete made from a single mix design." The CSA-required strength is calculated and listed in Table 2. It appears that the actual average strength for 7 days and 28 days for Stage I and Stage II are slightly lower than the CSA-required average strength. This is due to the fact that several compressive strength tests did not meet the specified compressive strength of 2900 psi (20 MPa) at 7 days and 5000 psi (35 MPa) at 28 days.

Based on the testing data from this project, it appears that the COV of shotcrete core strength should be less than 20%. The least variation can be achieved by proper mixture design, rigorous quality control, proper curing and handling of test panels and shotcrete core samples, proper shooting skills, and most importantly, rigorous implementation of a QC testing program to test compressive strength for daily shotcrete production.

Low Compressive Strength

When shotcrete cores show low compressive strength results, the owner will question the quality of the shotcrete being applied, and the contractor will then be required to pay attention to shotcrete production, transportation, and application, as well as the handling and curing of the shotcrete test panels. One example is a test result from January and February. Shotcrete core strength results (Sets 500 to 600) showed that the strengths at 7 days were lower than 2900 psi (20 MPa), and then increased greatly to about 5800 psi (40 MPa) at 28 days; later on, March shotcrete core strength test results (Sets 600 to 630) showed that the strength increased by about 4350 psi (30 MPa) from 7 to 28 days.

The low test results from Sets 500 to 600 (January and February) was attributed to the test panels being kept in the tunnel for a few days due to logistic challenges, and then were moved to above ground and left uncured. Considering the cold weather conditions in the tunnel site, which were normally 32 to 50°F (0 to 10°C) during that time, the strength gain at early age under low temperature conditions was not sufficient. Most of these sets were delivered to the QC lab at about 6 or 7 days, and then put into the curing tank for standard moist curing. The 7-day compressive strength was thus tested when cores had not been properly cured. Consequently, the 28-day strength increased dramatically, and even doubled or tripled compared to 7-day compressive strength, as shown in Fig. 5 and 6.

Once core compressive strength was found to be lower than the specified strength, the shotcrete was ruled to be nonconforming. Contractors were then required to extract in-place cores from the tunnel and test these in-place cores for compressive strength. Test results for in-place cores override the strength of cores from the test panels and these cores were referred to as quality assurance (QA) cores. Normally, three shotcrete cores were extracted from one area and tested for compressive strength. Compressive strengths from QA cores ranged from 5440 to 8380 psi (37.5 to 57.8 MPa). Although the testing age exceeded 28 days, the strength met the 5000 psi (35 MPa) requirements and therefore, the project owner accepted the shotcrete represented by them.

Summary

Underground shotcrete QC core strength is dependent on the mixture design, nozzleman skills, equipment, curing conditions, and test panel handling.

Variation in compressive strength of shotcrete cores at 28 days was found to be less than that found at 7 days.

When accelerator was used, the variation of the core strength tended to increase.

With a proper QC program, a minimum of 96% of the shotcrete cores tested met the specified minimum compressive strength of 2900 psi (20 MPa) at 7 days and a minimum of 96% of the shotcrete cores met the specified compressive strength of 5000 psi (35 MPa) at 28 days.

Tunnel shotcrete cores show an SD of 870 to 1160 psi (6 to 8 MPa) for compressive strength, and COV of 16 to 21%. The variation can be minimized by proper mixture design, rigorous quality control, proper curing and handling of test panels and shotcrete core samples, proper shooting skills, and most importantly, implementation of a rigorous QC testing program to test compressive strength for daily shotcrete production.

Shotcrete cores from test panels with strengths lower than the specified compressive strength were rejected as nonconforming. In such cases, in-place cores can be extracted from the tunnel lining and tested for compressive strength, with these results overriding test panel results.

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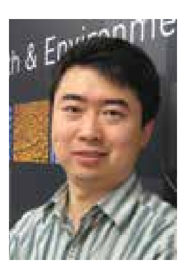

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Providing Sulfate Resistance in Severe Exposure Conditions

By Mark R. Lukkarila

Naturally occurring sulfates are common in soils within certain regions of the United States and Canada, especially the western United States and prairie provinces of Canada. The severity of the damage caused by sulfate attack is dependent on the exposure conditions; concrete mixture proportions (water-cementitious material ratio is very important); and quantity of sulfates in the soil, rock, or water. Shotcrete is often in contact with the ground (for example, slope stabilization) or rock formations in mining and tunneling applications. When sulfates are in the soils, water, or rock with which shotcrete will be in contact, it is important to know at what level of sulfate is present. Once the level of sulfate is known, a strategy to mitigate sulfate attack must be developed. Without mitigation, sulfate attack will deteriorate shotcrete over time and may ultimately result in failure.

The primary mechanisms involved with sulfate attack are the formation of ettringite ($CaO \cdot Al_2O_3 \cdot 3CaSO_4 \cdot 32H_2O$) and the formation of gypsum ($CaSO_4 \cdot 2H_2O$). The formation of ettringite can lead to expansion and the formation of gypsum can lead to softening of the concrete paste and loss of strength.

In specifications, the ASTM C150 cement type that is specified depends on the severity of the sulfate exposure. Soils are classified as Exposure Classes S0, S1, S2, or S3. Exposure Class S0 is the least severe and there are no limitations on cement type. Exposure Class S3 is the most severe. Many specifications still require the use of Type V portland cement or Type V combined with a supplementary cementitious material (SCM) for concrete in the most severe sulfate environments (S3). Prior to 2008, Type V portland cement combined with a pozzolan was the only option in ACI 318, "Building Code Requirements for Structural Concrete and Commentary,"[1] for Exposure Class S3.

Type V portland cement will always be an excellent option for mitigating sulfate exposure. There are instances, however, when concrete suppliers have limited silo space or Type V portland cement is not readily available. Ready mix suppliers that use Type I or Type II portland cement for the bulk of their work would need to replace the Type I or Type II in one of their silos with a Type V for their concrete mixtures if they do not have the silo capacity to accommodate an extra cement.

In 2008, ACI 318 was revised to allow alternatives to specifying or using Type V portland cement when Exposure Class S3 conditions are encountered on a project. This involves using blended hydraulic cement or a Type II, Type III, or Type V portland cement in combination with an effective SCM to mitigate sulfate attack.

The provisions in ACI 318-11 list the types of cementitious materials allowed for the different exposure classes. For the most severe class (S3), Table 4.4.1 lists ASTM C150 Type V plus a pozzolan or slag, ASTM C595 Type IP (high sulfate resistance) or Type IS (HS) plus a pozzolan or slag, or an ASTM C1157 HS blended cement plus pozzolan or slag. However, Table 4.5.1 allows for alternative combinations of cementitious materials in lieu of Type V for sulfate exposures in Section 4.5 (Fig. 1). A suitable alternative to Type V combined with an SCM for Exposure Class S3 is determined by performing an ASTM C1012/C1012M test for a period of 18 months. If the expansion after 18 months is less than 0.1%, the cementitious system is considered a suitable alternative to Type V with a pozzolan for Exposure Class S3.

The use of pozzolans in the concrete mixture as a partial replacement of portland cement has several benefits. One of the most important is the reduction in permeability of the hydrated cementitious paste. Sulfates can attack concrete through physical and chemical mechanisms. The ability of hardened concrete to resist the ingress of aggressive solutions such as sulfates will greatly increase the service life of the concrete in severe environments. Pozzolans react with calcium hydroxide, a product of cement hydration, and form calcium silicate hydrate. The calcium silicate hydrate produced during the reaction between the pozzolan and calcium hydroxide continues to fill pore space in the hydrated cement paste over time. This greatly reduces the permeability of the concrete.

The partial replacement of Type II portland cement with a pozzolan also reduces the C_3A

4.5 — Alternative cementitious materials for sulfate exposure

4.5.1 — Alternative combinations of cementitious materials to those listed in Table 4.3.1 shall be permitted when tested for sulfate resistance and meeting the criteria in Table 4.5.1.

TABLE 4.5.1 — REQUIREMENTS FOR ESTABLISHING SUITABILITY OF CEMENTITIOUS MATERIALS COMBINATIONS EXPOSED TO WATER-SOLUBLE SULFATE

Exposure Class	Maximum expansion when tested using ASTM C1012		
	At 6 months	At 12 months	At 18 months
S1	0.10 percent		
S2	0.05 percent	0.10 percent*	
S3			0.10 percent

*The 12-month expansion limit applies only when the measured expansion exceeds the 6-month maximum expansion limit.

R4.5 — Alternative cementitious materials for sulfate exposure

R4.5.1 — In the 2008 version of the Code, ASTM C1012 is permitted to be used to evaluate the sulfate resistance of concrete mixtures using alternative combinations of cementitious materials to those listed in Table 4.3.1 for all classes of sulfate exposure. More detailed guidance on qualification of such mixtures using ASTM C1012 is given in ACI 201.2R.[4.6] The expansion criteria in Table 4.5.1, for testing according to ASTM C1012, are the same as those in ASTM C595 for moderate sulfate resistance (Optional Designation MS) in Exposure Class S1 and for high sulfate resistance (Optional Designation HS) in Exposure Class S2, and the same as in ASTM C1157 for Type MS in Exposure Class S1 and Type HS in Exposure Class S2.

Fig. 1: ACI 318-11 requirements for alternative cementitious materials for sulfate exposure[1]

content of the cementitious component of the concrete mixture. This is important because C_3A is known to be a contributing factor to sulfate attack. It is important to note that most specifications do not allow the use of Class C fly ash. The reason for this is that Class C fly ash contains a significant quantity of C_3A.

The importance of a strategy for mitigating sulfate exposure cannot be overstated. Contact a consultant or your shotcrete material supplier to determine what materials and shotcrete mixture proportions would be appropriate for the anticipated exposure conditions.

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EFNARC Nozzleman Certification Scheme

By Dan Millette

EFNARC was an acronym for "European Federation of National Associations Representing producers and applicators of specialist building products for Concrete," which was founded by the European concrete industry in 1989. Over the years, the name of the organization has changed to "Experts for Specialised Construction and Concrete Systems," but the acronym remains EFNARC. In cooperation with the International Tunneling and Underground Space Association (ITA), it was decided that there needed to be a standard for robotically sprayed concrete.

As is now occurring in North America, Europeans were early to convert from dry-mix shotcreting to the wet-mix process, especially in underground applications. In North America, the American Concrete Institute (ACI) began to offer shotcrete nozzleman certification programs for both dry-mix and wet-mix. But this certification program only deals with handheld nozzle application and is somewhat lacking in shooting methods for underground applications. The ACI program also does not deal with any type of mechanical or robotic arms or spraying equipment, which is becoming the standard in tunneling and mining operations.

Consequently, EFNARC and the ITA launched the Nozzleman Certification Scheme in 2009 to remedy these shortcomings in underground applications. Unlike the ACI program, the EFNARC program only deals with wet-mix shotcrete or "sprayed concrete" as it is termed in Europe, and rightfully so, as concrete is exactly what is being sprayed.

Program Differences

The EFNARC scheme does not even discuss dry-mix and they have no distinction between vertical and overhead certifications as the ACI program does; if you are shooting underground, then it is simply assumed that you will be shooting vertical and overhead. Other than the omission of the dry-mix, the education portion or the course for the EFNARC program is a little heavier on certain aspects than the ACI program. EFNARC has more emphasis on the materials that go into a mixture, including aggregate, cements, pozzolans, and chemicals, and their effects when shooting.

The course also spends some time discussing nozzle accelerators. One other item where there is significant focus is in the handling of plugged lines because this is a significant safety issue. There is also a section on concrete testing. Then, of course, there are the sections of the education portion that cover the equipment used to spray as well as procedures for unloading the mixers. One other major difference is that the ACI certification is valid for 5 years while the EFNARC certification is only valid for 3 years.

Examiner Selection

EFNARC examiners must fill in an application form and submit a résumé. EFNARC states that "an Examiner shall have a wide experience of underground construction and sprayed concrete applications." The application form also asks the examiner in what region he expects to do certifications and in what language(s). The region can be as specific as a single portion of a country or as large as the entire world. Once accepted, the examiner must travel to the Hagerbach test facility in Switzerland for a 3-day course that consists of both classroom application assessment and an examination and interview.

After completing and passing the examinations, an examiner is then issued a certificate and his/her contact information is posted on the EFNARC website.

Course Materials

A 157-page study guide is given to examiners at the initial certification and all course materials used by the examiner must be in accordance with this master document. The examiner is permitted to use slides as they appear or modify them slightly to accommodate regional differences. As an example, I have decided that I want to do the examinations in English (U.S. and metric), French, and Spanish, so I have put together four different presentations to accommodate all of these applications.

The examiner also receives the exam questions and the Practical Assessment Form in English and is free to also translate them into the languages of his choice.

Although the EFNARC Nozzleman Certification Scheme is intended to be a certification program only, the examiner is free to offer educa-

tion and training separately or in conjunction with the certification and has access to the EFNARC course materials to do so. I have done several education-only sessions for mining companies and have been told that this has been instrumental in having them notice a significant improvement in their shotcrete applications.

Conducting Certifications

Certifications begin by either an individual or a company contacting the examiner directly. The certification session is a contract directly between the examiner and the examinee(s). Unlike the ACI program, there are no limits as to who the examiner contracts with—EFNARC trusts the examiner to be ethical and professional in his assessments.

The examinee must complete an application form stating his experience in underground application of sprayed concrete. When the class has been organized, the course material is reviewed by the examiner and then the candidates need to write an exam. This exam can also be administered orally and it is up to the examiner which method is preferable for each examinee. A list of 40 exam questions are given to the examiner upon completion of his certification and he must choose 25 of these for the nozzleman exam. But there must be a specific number of questions from each category, as outlined in the examiner documents. Even though the exam only contains 25 multiple-choice questions, in some cases there are five correct answers in one question and all five must be chosen for full marks so it is not simply a 25-answer exam.

Another portion of the certification examination requires that the nozzleman be assessed in his work. This is where an examiner can immediately discern whether or not a nozzleman has the required experience and can stop the certification process at any time. Each nozzleman applicant is expected to shoot 4 to 5 yd^3 (3 to 4 m^3) of concrete during his practical assessment and he must do this in a tunnel-like structure with both vertical and overhead components, as in a real situation. All of the certifications with which I have been involved took place in either a mine or tunnel where the applicant(s) worked. During this assessment, the other applicants are not permitted to be at the assessment location. The applicant must first do a check of his equipment, move it into place, and set it up properly. He must then get the concrete delivered to the machine and spray both the ribs and the crown of the tunnel in the correct manner. He must then clean the machine and put it away for the day as he would at the end of his shift. Throughout this entire process, the examiner is marking items on the Practical Assessment Form and will tally up the marks at the end of the session. The examiner must also photograph the applicant in various stages of this assessment.

Whether or not an applicant passes the exam and practical assessment, all of the exams, practical assessment forms, and photographs are sent to the EFNARC secretary, who currently is a resident of England, along with a recommendation from the examiner. The examiner has the recommendation form as a tool to weed out marginal performers. If for some reason an applicant passes the written exam and the practical assessment but there is clearly evidence that he is lacking experience, the examiner can recommend that the applicant not be granted certification. It is then up to EFNARC to make the final decision.

Once a nozzleman has been certified, he must then maintain a record of work, with validation from his employer, until his recertification is due. At this time, with sufficient experience, he only needs to undergo his practical assessment again.

A Worldwide Program

The EFNARC Nozzleman Certification Scheme is only 5 years old but is gaining acceptance worldwide. Because it is structured for the underground industries, it is quickly becoming recognized as a valuable tool for ensuring quality applications of shotcrete using robotic arms. There are now certified EFNARC nozzlemen throughout Europe; in most of Latin America, including Mexico; Australia; and some in Asia. North America has been a little slower to adopt this program but it is now starting to catch on in the mining environment.

Contractors and owners now have a choice of certification options for handheld nozzle certifications through ACI or the robotic certifications through EFNARC. I believe that by its 10th year of operation, the EFNARC Nozzleman Certification Scheme will have equivalent recognition as the ACI program has now.

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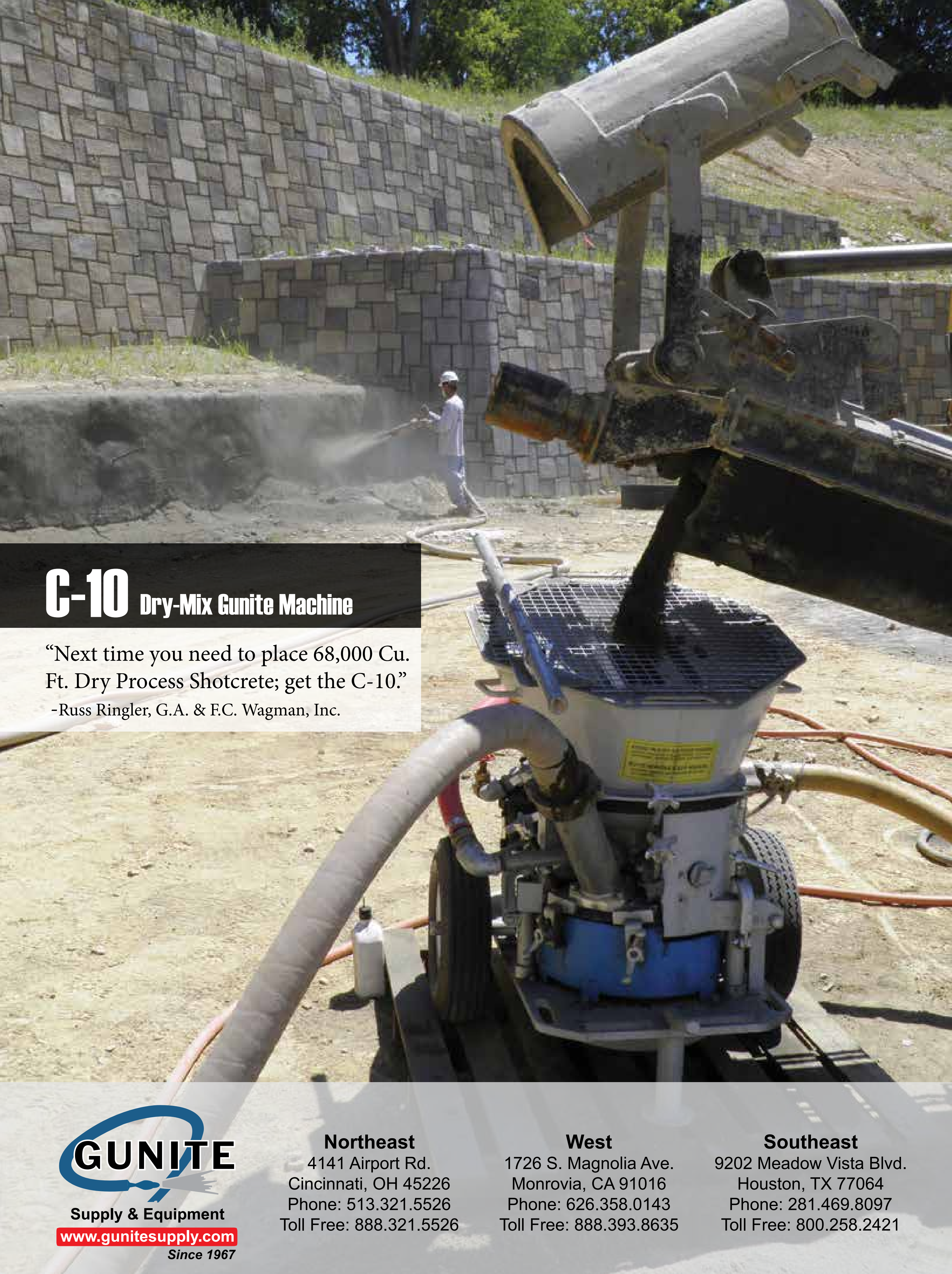
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Considerations for Underground Training

By William T. Drakeley Jr.

The growing demand for increasingly complex and adaptable urban infrastructure has caused developers to turn an eye to shotcrete as the most economically viable, technically flexible, and structurally sound construction method.

Shotcrete—or sprayed concrete—is the natural option for the underground tunnel or mining environment. It intrinsically allows for the stabilization of existing structures and accommodates tight construction schedules through quick application without the need for forming. Furthermore, shotcrete can be applied to variable-grade substrates such as ore, existing rock, or ledge without requiring extensive demolition because as a material, it binds quickly and bears its own weight.

Shotcrete has increased in popularity as the preferred method of stabilizing blasted rock and covering exposed earth in underground construction. Because tunnel construction is a multi-phase process wherein excavation may take place in stages depending on the load-bearing capacities and stability of the substrate, shotcrete ideally allows for flexibility in the concrete application without compromising strength.

Relative ease of application notwithstanding, underground shotcrete requires a precise set of skills that are responsive to the underground setting. Incorrectly placed materials can lead to disaster, especially in high-risk environments such as tunnels or mines.

For those familiar with the aboveground shotcrete process, shotcrete in the underground environment will sound virtually the same. For instance, following production of the shotcrete material, the material is transported to the site and conveyed to the equipment. The material is then sprayed at high velocity onto the receiving surface. Given the force of compaction and the immediate commencement of the hydration process, material may also be placed vertically and overhead. The shooting direction should be at a right angle to the receiving surface, whether placed manually or robotically.

However, in the tunnel environment, it is the substrate—the existing rock or ground conditions—that should be viewed as the primary construction material. Shotcrete is a key support component. Crews must have the ability to perceive the reinforcement needs of individual sections of rock, following joints and fractures in the substrate and placing the material accordingly.

Key ingredients that are a must for any applicator, subcontractor, or company in the underground shotcrete world include complete familiarity with the following:

1. Underground excavation;
2. Geologic conditions of ground or rock formations;
3. All aspects of the shotcrete process as it relates to underground support systems; and
4. Installation techniques, geologic reinforcement, and all alignment controls (such as rock bolts, lattice girders, welded wire, ground wire, pencil rods, and mining straps).

With many tunnels or underground infrastructure projects, determining the weight-bearing properties and stability of the rock or ground will determine shotcrete techniques (Fig. 1). Shotcrete installation comprises a key support component to the substrate, following the process of identification. A typical shotcrete crew needs to understand this basic premise. Shotcrete applicators need to know how a site is excavated, what the different phases of tunnel rock removal are, and at what time drift wall support is needed.

Jürg Schlumpf and Jürgen Höfler, in their handbook *Shotcrete in Tunnel Construction*,[1] identify six factors that are of prime importance to the mixture requirements for both dry- and wet-mix shotcrete processes relating to the workability and durability of the mixture: high early strength, the correct set concrete characteristics, user-friendly workability (long open times), good pumpability (dense flow delivery), good sprayability (pliability), and minimum rebound.

Regarding placement, crews must be able to identify the factors that will determine the amount of material that can be placed in a single sitting. These include the adhesive strength of the concrete, the characteristics of the receiving surface, and the direction of placement. For instance, when shooting a ground or floor surface, the depth of placed material can be as thick as desired, as long as rebound and overspray are removed. When shooting walls, it is preferable to build thickness through a number of thinner applications or through the systematic layering of the full thickness from the lower elevation to the higher elevation (benching), while still removing rebound. By contrast, when shooting overhead, thinner applications are preferable to allow for less rebound and maximum adhesion and reducing the potential for dropouts. Alignment control is another key factor in producing a precise application. Devices to establish line and grade include ground wires (piano wire), pencil rods for curved profiles, lattice girders, depth gauges, rock bolt extensions, and guide strips/formwork.

Qualification to shoot in an underground environment is based on both individual and group crew training for underground environment. Not every crew will qualify for every job. For instance, ACI certification does not, by virtue of content covered, constitute qualification for underground shotcrete construction. To be considered competent in the underground environment, a nozzleman must be familiar with all the following: the process of underground excavation and underground support; the condition of ground/rock surfaces (that is, hard rock, frozen ground, soft ground conditions, and sacrificial layering); and the aspects of the shotcrete process as it relates to the ground support system.

Many shotcrete crews seeking to enter the underground shotcrete market adopt a "learn-on-the-job" mentality. Not only does this present significant safety concerns but it also can lead to longer project timelines, greater costs, and quality differentials between early-project shotcrete and late-project shotcrete. A proper training program will call out methods of advanced placement. Make no mistake, shooting in the underground environment constitutes advanced shotcrete placement. Each job should have its own training and qualification program specifically designed for its substrate characteristics. This type of pinpoint training with regard to quality control and quality assurance allows the owner and/or general contractor to be confident in the applicator, and more generally, in the shotcrete process. Many of us would be surprised to find out that most underground shotcrete applicators and those trying to enter that market have little experience with the actual environment or can successfully identify advancement protocol in a simple crown, bench, or base of a tunnel cross section (Fig. 2).

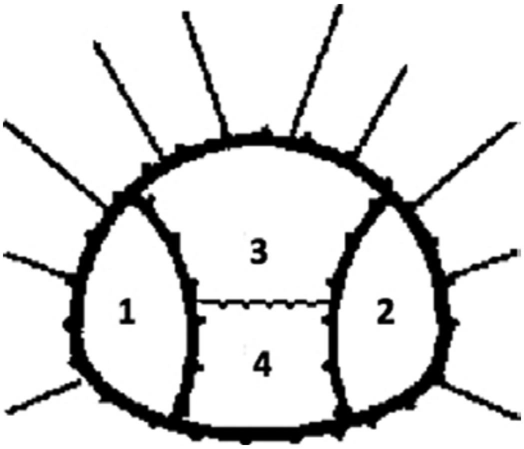

Fig. 1: Drift wall advance: Preceding drift walls (1 and 2), followed by excavation of the crown (3) then the bench and invert (4), including safe support in each case[1]

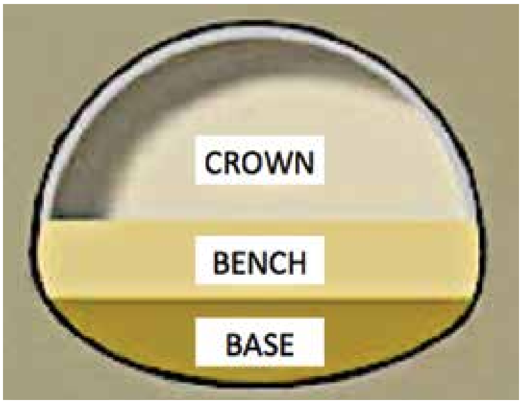

Fig. 2: Methods of advance[1]

Fig. 3: Preliminary training and shotcrete scope review with team members

The underground environment is vast and greatly varied. For this reason, current ACI nozzleman certification does not make one automatically capable of properly executing a complex job. The ACI certification covers the basic facets of shotcrete production and application, and is not intended to fully encompass the complex aspects of most underground or heavy structural work. Our current nozzleman training is limited and is not designed as "one size fits all." Many specifiers, engineers, and even shotcrete contractors are confused on this point. The New Austrian Tunneling Method (NATM) currently states that training programs should be developed specific to job parameters. Appropriate application methods, as identified in a quality control and quality assurance submission, would include nozzleman qualification pre-mockup testing and specific pumping and shooting techniques needed to place material on and around blasted rock, unstable soils, lattice girder, or ring steel. These components can be adapted and qualified prior to actual job commencement.

In addition to job-tailored training, crews should be supported by around-the-clock trainers and quality monitors—at least in the early phases of the job—to help crews to make the transition from an aboveground shotcrete skill set (and mind set) to an underground one. The ultimate quality of the project—and the safety of all those involved—depends on it (Fig. 3).

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William T. Drakeley Jr. *is President of Drakeley Industries and W. Drakeley Swimming Pool Company. Drakeley Industries is a shotcrete consulting firm that is dedicated to the training and implementation of the shotcrete process in regards to building water-retaining structures, ground support, and underground shotcrete application. Drakeley Pool Company is a design-build construction and service firm specializing in in-ground, high-end commercial and residential pools. Drakeley is an active member of ACI Committee 506, Shotcreting. He is the first ACI Certified Shotcrete Examiner from the pool industry nationwide. Drakeley is also an ACI Certified Nozzleman, ASA Technical Advisor, Chair of the ASA Pool & Recreational Shotcrete Committee, and serves as Treasurer to the ASA Executive Committee. His writings have been published in national and international trade magazines, including* Shotcrete, WaterShapes, Pool and Spa, *and* Luxury Pools. *In addition, Drakeley is a Platinum Member of the Genesis 3 Group, a licensed member of the Society of Water Shape Designers, and a member of the Association of Pool and Spa Professionals (APSP). He is also the Concrete/Shotcrete Instructor at the Genesis 3 Pool Construction Schools and NESPA Region 1 Show in Atlantic City. As an instructor and trainer, Drakeley has given lectures on shotcrete applications for various pool trade shows and for World of Concrete. Drakeley is an expert witness regarding shotcrete applications for the swimming pool industry.*

Pedestrian Tunnel at Billy Bishop Toronto City Airport

By Matt Croutch

In early 2012, construction began on an underwater pedestrian tunnel that will link Billy Bishop Toronto City Airport to the mainland in Toronto, ON, Canada. The project will provide a predictable, efficient, and convenient access route for the airport's users. Tunnel construction will be complete by Winter 2014/2015 (Fig. 1).

The pedestrian tunnel will feature a modern, mechanized, underground walkway and will be powered by 100% green energy. To provide access to the pedestrian tunnel, a new pavilion will be constructed on the mainland, while an extension will be added to the airport terminal building on the island side.

Technicore Underground, a leading tunneling contractor, began excavation on the mainland and island shafts in May 2012. Once the shafts were dug, two purpose-built, Canadian-made tunnel-boring machines (TBMs), dubbed "Chip" and "Dale," were launched to bore the seven interlocking "tunnel drifts," forming what would become the unique arched-crown design of the main tunnel. The TBMs were designed and manufactured by Technicore Underground (Fig. 2). Three of the tunnel drifts were built to include new city of Toronto sanitary and water mains, which will help save Toronto taxpayers an estimated $10 million in duplicate construction efforts. Excavation of the tunnel was completed in October 2013, and shotcrete, waterproofing, and reinforcing steel layers were installed.

Fig. 1: In early 2012, construction began on an underwater pedestrian tunnel that will link Billy Bishop Toronto City Airport to the mainland

Original plans called for the use of wet-mix shotcrete, supplied from an on-site batch plant, to provide initial support during the tunneling process. A steel fiber-reinforced mixture with a specified fiber type and dosage was required in the original shotcrete specification. A number of factors led Technicore's project management team to investigate the use of dry-mix shotcrete. The ability to stop and restart the shotcrete process as required, without significant cleanup, was one of the key factors in choosing the dry process. Technicore turned to King Shotcrete Solutions to design a dry-process shotcrete mixture that met the hardened property requirements outlined in the specification.

King's Technical Services Team offered the option of both steel and macrosynthetic fiber-reinforced versions of its MS-D3 Accelerated Shotcrete. To meet the requirements of the specification, flexural toughness testing was mandated. Testing according to ASTM C1550, "Standard Test Method for Flexural Toughness of Fiber Reinforced Concrete (Using Centrally Loaded Round Panel)," was performed at Laval University, Québec, QC, Canada. Three panels were shot on site and after 24 hours were transported to the university, where they were tested for energy absorption at 7 days. The average corrected 7-day energy absorption value was 280 joules (0.27 BTUs).

After receiving the test results, Technicore submitted the macrosynthetic fiber-reinforced

Fig. 2: Two purpose-built, Canadian-made tunnel-boring machines, dubbed "Chip" and "Dale," were launched to bore the seven interlocking "tunnel drifts," forming the unique arched crown design of the main tunnel

mixture to the project engineers for approval and were soon given the authorization to proceed. Over 1200 tons (1010 tonnes) of King MS-D3 Accelerated Macro-Synthetic Fiber Reinforced Shotcrete were applied throughout the 550 ft (170 m) tunnel using an Aliva AL 252 dry-mix shotcrete machine (Fig. 3).

King provided a complete shotcrete solution, which included mixture design, equipment supply, material supply, and technical support. Representatives from King were on-site throughout the project to assist with all aspects of the shotcrete operation, from equipment operation to product placement.

The next phases of the tunnel project will include construction of the connecting terminal structures; installation of the moving walkways, escalators, and elevators; landscaping; as well as electrical, mechanical, and final finishing work.

When it opens, the pedestrian tunnel (Fig. 4) will have four moving sidewalks traveling at 1.4 mph (2.3 kph). From a bank of six elevators on the mainland side, travelers will go 100 ft (30 m) down to access the tunnel and travel along the passageway to the escalators, which will take travelers to the airport's check-in area. The complete journey will take fewer than 6 minutes and will dramatically improve passenger flow.

This is not the first attempt at building a tunnel to the Island Airport. In May 1935, Parliament approved $1 million to build the tunnel, with another $600,000 coming from the city of Toronto. On October 8, 1935, City Council voted to approve the plan and work began in earnest only days later.

A long ditch was hollowed out along what is now the Eireann Quay roadway, toward the seawall of the Western Channel, while another ditch was burrowed on the island side leading to the north seawall. Steel sheet piles were hammered into the ground to shore up the seawalls and enable excavation.

But work on the project ended as quickly as it had started when, shortly after construction began, the Federal Government issued an order to cease all work on the tunnel and fill in the holes and ditches.

As for the steel sheeting, it had no effect on the topography or surrounding environment, and was left in place. Fast-forward 77 years to the construction of the new pedestrian tunnel at Billy Bishop Toronto City Airport. Geotechnical plans and documents of public record indicated that there were tunnel remnants underground, but no one knew for sure what the pilings looked like.

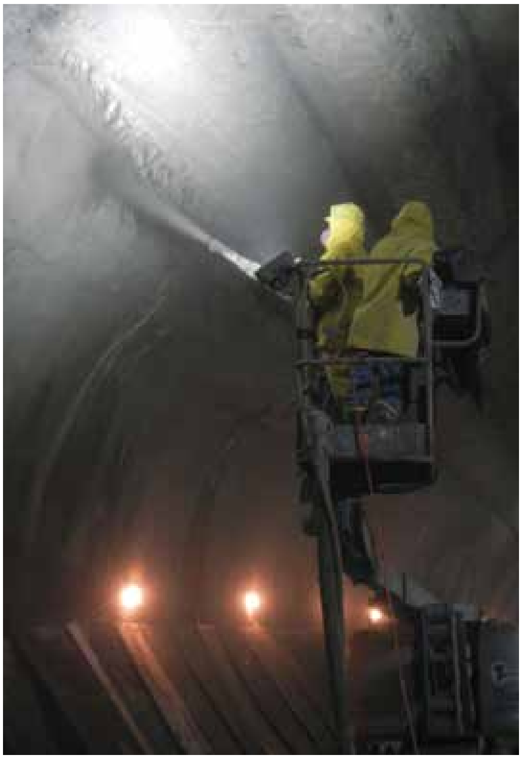


Fig. 3: Over 1200 tons (1010 tonnes) of King MS-D3 Accelerated Macro-Synthetic Fiber Reinforced Shotcrete were applied throughout the 550 ft (170 m) tunnel using an Aliva AL 252 dry-mix shotcrete machine

In August 2012, shortly after construction began, history met modern day when certain steel pilings were found at the end of a tunneling drill bit. The drill bit needed to be replaced, but the pilings were soon removed and construction soon resumed.

The use of shotcrete continues to play a major role in many of Toronto's ongoing tunneling projects, including the continued expansion of The Toronto Transit Commission subway system, the upgrading of Toronto Hydro's tunnel network, and the progress of a number of significant water distribution projects.

Matt Croutch *is a Technical Sales Representative for King Packaged Materials Company, Burlington, ON, Canada. He has 10 years of experience in the concrete construction industry, including the last 4 years working with shotcrete. Croutch is a member of the American Concrete Institute, the Building and Concrete Restoration Association of Ontario, and has been active in the promotion of the shotcrete process in the Ontario, Canada, market.*

Fig. 4: Three-dimensional cross section of pedestrian walkway. Billy Bishop Toronto City Airport Pedestrian Tunnel Project

Shotcrete versus Cast-in-Place for Pools

By Mason Guarino

Shotcrete and cast-in-place (CIP) concrete have both been used over the years to create the pool shell structure in swimming pool construction. Both shotcrete and CIP can produce a good-quality finished product with attention to material selection and placing quality. Concrete placed via the wet-mix shotcrete process rather than cast would be slightly modified to allow for lower slump and increased pumpability. The real differences in the two placing techniques stand out during the pool construction phase. The shotcrete process can shorten construction time, significantly reduce formwork requirements, eliminate post-form-stripping concrete surface touchups, create a monolithic structure, and eliminate the need for additional steps that CIP typically requires.

One of the most time-consuming steps in the concrete construction process is forming. Forming adds two steps to the pool construction process: formwork erection before casting, and formwork dismantling and cleaning after casting. CIP forming also requires both sides of the concrete walls to be formed and the forms are much more complex because they must be designed to handle the high internal pressure created by the fluid concrete filling the forms. In comparison, shotcrete requires forming only one wall surface and it is much lighter construction because it withstands much less pressure. Shotcrete forms only need to be rigid enough to handle the force of the shotcrete spray being applied without excessive vibration. Because the shotcrete forms are only one-sided and less substantial, much less formwork is required and the form stripping process is much quicker and with less waste (Fig. 1).

CIP walls frequently require touchups of water and air bubble voids, or areas that were not fully consolidated at the surface after forms were removed. This is so common that all specifications now have a section to cover how it should be done properly. With shotcrete, the final finished surface is the same exposed surface that the shotcrete crew places and finishes as they progress. The desired finish is chosen prior the start of the shotcrete process. The most common finish is a standard rod-cut finish. The rod-cut finish produces a straight and plumb wall with a rough texture. This rough texture is optimum for two reasons: second to a gun finish, it is the fastest way to finish a shotcrete wall; and it creates a great surface to later bond a tile or marcite plaster finish. CIP forms can leave two undesirable finishes when the forms are removed. There can be either excessive honeycombing that needs to be repaired prior to the final finish, or the forms create a smooth finish that will need to be roughened so the final finish will adhere properly. Sometimes finishing the final shotcrete surface will require a little more time during placement, as compared to surface touchup of CIP, but that is acceptable because shotcrete finishing produces the desired final finish with a more consistent appearance.

Swimming pool shells are structural concrete components and need to be as strong as reasonably possible. Swimming pools are fairly short in length and exposed to moisture throughout their life, so they do not experience excessive shrinkage or temperature movement and do not typically require expansion or contraction joints. Because most swimming pools do not require movement joints, they can be built as monolithic structures. Shotcrete is the only way to create a true monolithic structure for a pool, especially large pools. Shotcrete, when applied properly, has no construction joints. Swimming pools can take multiple days to finish and, with proper attention to shooting the pool floor and walls between sections, can be constructed as a complete monolithic structure. Large monolithic floors can easily be CIP and then completed with shotcrete walls to create a large monolithic pool. Large pools can easily have 300 to 600 yd^3 (229 to 459 m^3) just in the floor, and with a good flatwork crew, can

Fig. 1: Typical formwork for pool construction

easily be placed in 1 day. With proper attention to surface preparation at the floor-wall intersection, shotcrete walls can be built so there is a monolithic joint between the pool floor and walls. With the shotcrete process creating a monolithic joint, waterstops at the pool floor-wall joints are not needed as they are with CIP. Anyone who has experienced installing a bulb-style waterstop knows that this is very time-consuming and the waterstop itself can be expensive.

All aspects of shotcrete swimming pool construction help to create a stronger pool that is built faster. Faster forming practices, less surface touchup after forms are stripped, and fewer items installed to ensure the pool is as waterproof as possible contribute to shotcrete being the best way to build a pool structure. Shotcrete also commonly gains strength much faster than CIP concrete due to a higher cement factor and lower water-cementitious material ratio. It is not uncommon to see shotcrete hit the specified 28-day compressive strength in 7 days. This allows forms to be stripped faster and the pool can be backfilled more quickly. When the cost of shotcrete versus CIP in a swimming pool are compared for larger projects, the author does not believe that shotcrete is substantially less expensive. However, because it can produce a pool with superior durability and strength in less time, shotcrete is the concrete placing process that clearly needs to be the method of choice when building a swimming pool.

__Mason Guarino__ started in the pool industry when he was 14, learning how to install reinforcing bar. Since then, he has worked on all phases of swimming pool construction. Guarino has been with South Shore Gunite Pools & Spas, Inc., full-time since graduating from the Wentworth Institute of Technology with his BS in construction management in 2009. Guarino currently serves on ASA's Board of Direction and is an ACI Certified Nozzleman.

Shotcrete Accelerators for Wet-Mix

By Dan Millette and Marc Jolin

Unlike traditional concrete accelerators, shotcrete accelerators are not added to the mixture during batching, but rather introduced to the mixture at the nozzle in wet-mix shotcrete application. Dry-mix will sometimes have a powdered accelerator incorporated into the mixture that begins to react as soon as the water is added at the nozzle. These accelerators can provide fast setting or stiffening of the mixture, early-age strength development, the capability to attain increased layer thickness, improved overhead spraying performance, and reduced sagging, all resulting in a higher productivity.

Shotcrete accelerators work on the C_3A (tricalcium aluminate) fraction of the cement, influencing the rate of hydration, resulting in heat evolution and early-age formation of calcium silicate hydrate (C-S-H) gel (Fig. 1). There are two main types of accelerators used in wet-mix in North America. The first type of accelerator that we will look at is sodium silicate-based accelerator (water, glass, and modified silicates). These have been around a long time and are still being used in many applications. They work very quickly and allow the material to build well.

A sodium-silicate-type accelerator actually gels the water in the mixture to increase cohesion within the mixture as well as decrease the set time of the cement. Sodium silicate-based accelerators have a high alkali content and can be quite caustic, as the pH is above 11. Although these accelerators will display fast stiffening of the mixture, they can significantly decrease the final or 28-day strength of the mixture—up to a 50% reduction. Even a dosage of 5% by weight of cement has been known to decrease ultimate strength by as much as 25%. Durability can also be considerably reduced. Sodium silicate can also decrease waterproofing characteristics because of the leaching of lime when the concrete is subjected to continuous moisture. One other, potentially negative, effect is that these accelerators increase the risk of alkali-silica reaction (ASR) and leaching of water-soluble portions.

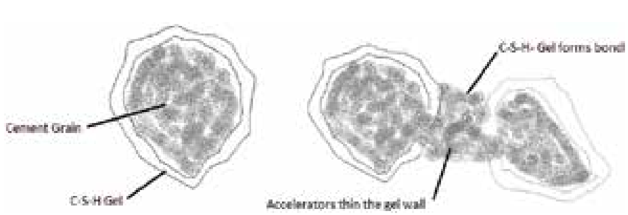


Fig. 1: C-S-H gel at work

Sodium silicates are relatively low in cost, so they are popular in instances where shotcrete is needed to attain a quick stiffening and then gain some early strength rather quickly. They are not recommended for permanent exposed shotcrete. Because of the high alkalinity of this type of accelerator and the high alkalinity of the shotcrete mixture, the mist that blows back from spraying the mixture can burn skin and eyes, so adequate protection must be used.

The second type of wet-mix accelerator is an aluminum-sulfate- or aluminum-hydroxide-based product that is commonly called alkali-free. These are often combined with various amines to boost their effectiveness. These accelerators are a little more sensitive than sodium silicates to several environmental and material conditions and do not always give as fast a stiffening effect, but they also do not have quite as severe a detrimental effect on 28-day strength when used at lower dosages. But even with these accelerators, a dosage of 10% by weight of cement can give up to a 25% reduction in 28-day strengths. Most modern-day specifications where accelerators are required insist on alkali-free accelerators only, as alkali-free accelerators do not have any effect on ASR.

Most alkali-free accelerators range from pH 2 to 3, which is fairly acidic. When spraying these, the acidity is tempered by the alkalinity of the concrete mixture so it is not as great a hazard to skin and eyes. But these accelerators are also very corrosive. Storage tanks for alkali-free accelerators must be either plastic or stainless steel—never store these accelerators in mild steel tanks or they can produce an explosive hydrogen gas.

Alkali-free accelerators are made by two different processes. The older, more common method is to dissolve solid flakes into a fluid using high-shear mixing. This produces a high-viscosity product much like the consistency of thick syrup. The solids tend to segregate out during storage so accelerators made from solids require fairly continuous agitation. This manufacturing method also uses a higher content of solids, making the accelerator slightly more reactive than the lower-viscosity materials.

The lower-viscosity alkali-free accelerators are made with liquid chemicals that do not require high-shear mixing and are usually closer to the consistency of water. Although these are slightly lower in solids contents, they do not segregate at all and are often said to better blend into the concrete mixture at the nozzle due to the lower viscosity, and often being as effective as the higher-viscosity products.

To get the optimum performance from any type of accelerator, it is very important to keep temperatures at a reasonable level. Ideally, concrete temperature should be between 70 and 80°F (21 and 27°C) to attain the optimum accelerator reaction. A 20°F (11°C) decrease in concrete temperature will roughly double the reaction time and conversely, a 20°F (11°C) increase will half it.

But you also need to keep the accelerator temperature at an appropriate level. It should be above 60°F (15°C) and preferably above 70°F (21°C). If the accelerator is too cold, it will not work nearly as well. Another problem with most accelerators is that when they are cold, they become more viscous, which makes it even more difficult to get it mix evenly into the stream of concrete at the nozzle.

When using accelerator in wet-mix shotcrete, make sure to use a proper dosing pump. Do not use a diaphragm pump. A diaphragm pump sends slugs of accelerator to the nozzle and if it is out of sync with the concrete pump you will get varying degrees of hard and soft shotcrete mixture on the sprayed surface.

Use a positive displacement pump such as a peristaltic or rotor-stator pump (Fig. 2 and 3). Make sure that the pump pressure is 10 to 15 psi (0.07 to 0.10 MPa) higher than the air pressure to the wet-mix nozzle or the air can keep the accelerator from getting into the air stream. Control the accelerator dosage with the pump. The pump should have a variable speed drive; and use that to control the flow. These pumps should all have stainless steel fittings due to the corrosivity of alkali-free accelerators.

Fig. 2: Peristaltic accelerator pump

Fig. 3: Rotor-stator accelerator pump

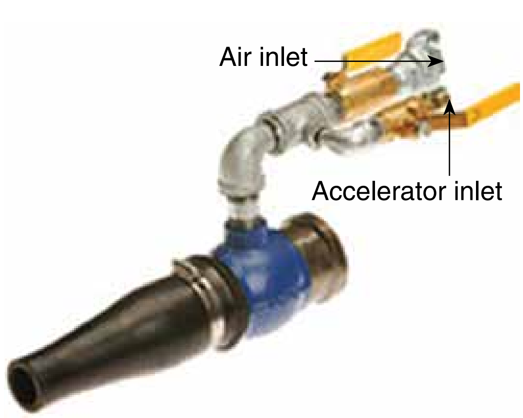


Fig. 4: Acme nozzle with accelerator port

There are all sorts of wet-mix nozzles on the market and everyone has their preference. Some nozzles have a connection for the accelerator on one side of the nozzle and the air connection on the other side. Some have only one inlet to the nozzle that is split into two. The type of nozzle shown tends to mix the accelerator into the concrete better than the ones with separate inlets. Better yet is to pump the accelerator into the air stream a few feet back from the nozzle, don't use a regulating valve for the accelerator. Simply an on-off valve allows for control of the accelerator with the pump (Fig. 4).

***Dan Millette**, a Mining Engineer, is the Director of the Mining and Tunneling Division of The Euclid Chemical Company. Millette has over 30 years of experience in the shotcrete industry and is a certified EFNARC Nozzleman Examiner. He is a member of ACI Subcommittee 506-F, Shotcreting-Underground, as well as a member of the Society for Mining, Metallurgy and Exploration (SME); the Canadian Institute for Mining, Metallurgy and Petroleum; and the Tunneling Association of Canada.*

***Marc Jolin**, FACI, is a Full Professor in the Department of Civil and Water Engineering at Laval University. He received his PhD from the University of British Columbia, Vancouver, BC, Canada, in 1999. An active member of Centre de Recherche sur les Infrastructures en Béton (CRIB), he is currently involved in projects on service life, reinforcement encasement quality, new admixtures, and rheology of fresh shotcrete. Jolin is an ASA member; an ACI Examiner for Shotcrete Nozzleman Certification (wet- and dry-mix processes); Chair of ACI Committee C660, Shotcrete Nozzleman Certification; and Chair of ACI Committee 506, Shotcreting.*

Part II of a Two-Part Series on Wet-Mix Equipment Maintenance

Maintenance Fundamentals for Nozzlemen: Often Overlooked Equipment and Maintenance Essentials Can Dramatically Influence In-Place Quality

Do you know what they are?

By Oscar Duckworth

A skilled nozzleman's control of the nozzle during placement is one of the most important factors that will determine in-place shotcrete quality. But like many things, there is much more to the task of proper nozzling than simply controlling the nozzle.

Regardless of a nozzleman's skill and experience, it is impossible to properly place wet-mix shotcrete with poorly chosen or improperly functioning placement equipment. Because a nozzleman's placement quality is reliant on the correct functioning of many individual equipment components, it is vital that a nozzleman possess fundamental knowledge of the operation and maintenance of these components.

Wet-Mix Placement Starts at the Pump

Wet-mix shotcrete is commonly placed using specialty concrete pumping equipment. Pumps are used to push concrete through a delivery system. Nozzlemen should be familiar with how various pump functions influence in-place shotcrete quality.

Most concrete pumps are positive displacement type. They use pumping pistons in action with a valve to pressurize the delivery system. Typical concrete pumps create moderate pressure to push materials within a normal slump range. Shotcrete placement requires considerable additional pressure to convey low-slump shotcrete materials through the delivery system.

Although traditional concrete pumps have been used in shotcrete operations, many manufacturers offer pumps configured specifically for wet-mix shotcrete use. These pumps offer robust hopper, feed auger, and wear components, and cooling configurations that are designed to facilitate the placement of low-slump concrete materials. Shotcrete pumps will provide lower placement volumes but have a much higher pressure potential than traditional machines.

Pump choices affect all aspects of shotcrete placement. Common concrete pumping equipment used for shotcrete placement can lead to costly placement and reliability problems. Nozzlemen often experience erratic material delivery, insufficient cylinder filling, low power, overheating, or excessive plugging when using poorly chosen concrete pumping equipment for wet-mix shotcrete placement. Nozzlemen require an even flow of material from the nozzle to precisely control material placement. Gunning with an irregular or "choppy" flow will not generate acceptable in-place material. Insufficient cylinder filling is the primary cause of uneven flow to the nozzle. A functioning auger is necessary to properly fill the material cylinders during placement. Worn or nonfunctioning augers produce irregular flow rates that diminish in-place quality (Fig. 1 and 2).

Pumps must be kept full. Allowing a pump to run low on material creates strong airbursts known as slugging. Like other forms of uneven flow, slugging will reduce accuracy; displace in-

Fig. 1: Missing auger cannot provide adequate cylinder filling. Uneven nozzle flow will affect nozzle placement quality

Fig. 2: Uneven flow (slugging) has displaced in-place shotcrete. Note signs of sagging below the wire reinforcement

place material; and cause sagging, sloughing, and voids within the work. If irregular flow occurs, the nozzleman should stop placement, investigate the cause, and correct before continuing.

Regardless of the pumping equipment used, the pump must be calibrated to operate within a smooth and manageable range. Nozzlemen should choose a flow rate that feels right. Skilled nozzlemen always work within a speed range so that nozzle thrust does not interfere with the ability to accurately direct the flow.

Wear items within the pump (cutting rings, wear plates, seating surfaces, and outlet seals) will affect placement quality if excessive wear has compromised seal integrity. Because wet-mix shotcrete is a combination of cementitious materials, aggregates, and water, the pump must be able to convey material to the nozzle under pressure without altering the mixture. Because high pressure is required to convey the mixture through the delivery system, wear items within the pump or placement system that leak will allow moisture to be squeezed from the mixture and lost. Poor seal quality can lead to dry-pack placement line blockages, segregation, buildup within the concrete pump valves, and placement difficulties. Skilled nozzlemen should be capable of identifying excessively worn components and schedule repairs or replacement before excess wear affects placement quality or safety (Fig. 3).

Nozzles Require Constant Maintenance

It is the nozzleman's responsibility to operate and correctly maintain the shotcrete nozzle. But

Fig. 3(a): Worn wear components will allow moisture to be squeezed from the mixture during pumping

Fig. 3(b): Wear components in good condition

Fig. 3(c): Hardened buildup restriction inside the S tube is caused by worn wear components occasionally, necessary maintenance of the nozzle is not completely understood, partially completed, or ignored. Many nozzlemen may not realize that poor or incorrect nozzle function can have a profound effect on a shotcrete mixture's plastic and hardened properties. Proper wet-mix nozzle function is primarily responsible for compaction and consolidation—the fundamental elements of shotcrete placement. Improper nozzle function limits a nozzleman's ability to provide acceptable in-place shotcrete.

Although wet-mix shotcrete nozzle designs vary, all nozzles must effectively diffuse the incoming mixture into fine particles, then highly accelerate the mixture's components to produce a high-velocity spray pattern. Shotcrete is defined as a method of placing concrete with high velocity to achieve compaction. Concrete requires compaction to be an acceptable building component. Typically, cast-in-place concrete is placed, and then consolidated by the use of a concrete vibrator. This standardized procedure generally produces well-consolidated concrete displaying good compaction and consolidation quality. Shotcrete, however, must be physically driven onto a receiving surface at high velocity to achieve similar or superior compaction/consolidation characteristics. To accomplish this, a nozzle must be properly chosen AND properly maintained or placement quality cannot be achieved.

Fig. 4: Note plugged air ring port on lower nozzle. A single plugged port will dramatically reduce in-place compaction/consolidation quality

Shotcrete nozzles are precision tools. With use, they require continuous maintenance. Inspection, disassembly, and cleaning of all air metering ports, and replacing worn components, must be performed daily by the nozzleman.

What Must Happen Within the Nozzle?

Nozzles possess air rings that use multiple small metered ports within the body. The air ring ports are designed to form high-energy air jets which must diffuse (break apart) the low-slump mixture delivered from the delivery system. Sufficient air volume and pressure is required to diffuse the mixture into individual fine particles as it passes through the nozzle plenum. After the mixture is diffused into small particles, it can be accelerated and focused into a high-velocity nozzle stream. Proper diffusion and acceleration of the mixture by the nozzle is critically important to successful shotcrete placement. The compaction/consolidation properties of the in-place material are highly dependent on the effectiveness of the nozzle's air ring port area to successfully diffuse and accelerate the concrete mixture. Air ring ports are prone to plugging through use or mishandling (Fig. 4).

If even one of the ports becomes restricted, a significant percentage of the material flowing through the nozzle will pass through the air ring area as a cohesive mass that is too large for the nozzle to properly accelerate. These larger particles will exit the nozzle lacking sufficient velocity to achieve satisfactory compaction and consolidation at the receiving surface. Reduced nozzle velocity and an uneven spray pattern will diminish in-place compaction/consolidation quality. Distinct changes in velocity or spray pattern are sure signs of port plugging. A knowledgeable nozzleman must be aware of these changes and stop to correct the problem. Port plugging is a constant risk to placement quality. When laying down a wet-mix nozzle, always leave the air valve slightly open to keep air ring ports clear.

Nozzle tips are a small cost when compared to other wear items. They must be regularly replaced to maintain proper nozzle function. When new, the nozzle tip's interior shape is designed to produce a focused, high-velocity spray pattern. However, nozzle tips wear quickly. They must be replaced when wear increases the tip's internal contour or diameter. Worn tips dramatically reduce nozzle velocity and focus. When shooting production work, nozzle tips

Fig. 5: Cut-down tip

wear to oversize within days. A worn tip should never be used during shotcrete placement. Never cut down or modify a nozzle tip. The common practice of "opening" or modifying the tip length to alter the spray pattern will result in unacceptable consolidation/compaction of in-place material. Both cut-down and worn tips should not be used for structural shotcrete placement (Fig. 5 and 6).

Air Supply Fundamentals for Nozzlemen

Nozzlemen must be aware of the strong relationship between air supply components and placement quality. A sufficient volume of dry, oil-free air at the nozzle is a primary requirement to generate satisfactory impact velocity. Both the compressor and air delivery system must be sized to generate sufficient nozzle velocity for the scope of work. The wet-mix process will normally require a minimum of approximately 200 ft^3/min (CFM) (6m^3/min [cmm]), depending on the nozzle type, the blow pipe orifice size, and placement volume per hour. Air supply lines must have a large enough diameter to provide adequate air volume to the nozzle. Regardless of the size of the

Fig. 6: Worn tip (right)

compressor, an air supply line that is too small cannot provide enough air volume to facilitate proper nozzle function. The practice of splitting one 3/4 in. (19 mm) air line to supply both the nozzle and blow pipe, or routing 3/4 in. (19 mm) lines long distances will not provide sufficient air volume to the nozzle. Keep the air compressor lines as short as practical, or use 1 in. (25 mm) or


Fig. 7: Air supply line diameter is critical to maintaining adequate nozzle velocity

larger air supply lines when longer air supply lines are needed (Fig. 7).

Sufficient Lighting is Necessary

Quality shotcrete is not possible without acceptable lighting. Lamps should be used in areas where shadows can obstruct vision such as under large overhangs, dark corners, or in underground applications.

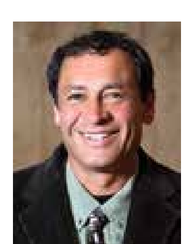
The nozzleman and blow pipe operator must be able to clearly see the receiving surface. Nozzleman must have a clear view of the receiving surface when applying shotcrete to ensure that the material is being applied at the correct angle, at the correct distance from the receiving surface, at a proper consistency, and at the specified thickness.

Putting It All Together

Wet-mix equipment selection and maintenance procedures affect shotcrete in-place properties. A capable nozzleman must possess sufficient knowledge and on-job experience to use the nozzle, and the many individual equipment components in a manner that will produce acceptable in-place material. Although nozzle skill is necessary for a quality shotcrete job, proper equipment function is a fundamental requirement. Quality in-place shotcrete is not possible without it.

Nozzleman Equipment Maintenance Checklist

- Select a wet-mix pump configured specifically for wet-mix shotcrete use.
- Adjust the pump to produce an even flow of material, without excessive nozzle thrust.
- Perform necessary pump maintenance before worn sealing surfaces and wear components affect placement quality.
- Perform required maintenance on the nozzle. Inspection, disassembly, and cleaning of all air metering ports, and replacing worn components, must be performed daily by the nozzleman.
- Provide enough air volume to generate satisfactory impact velocity. Both the compressor and air delivery system must be sized to generate sufficient nozzle velocity.
- Use appropriate lighting to assure that both the nozzleman and blow pipe operator can clearly see the receiving surface at all times.
- Be aware that YOU are in control of a complex system which requires many individual equipment functions. An understanding of the proper function of all required equipment is critical to proper shotcrete placement. If any part of the system is not functioning properly, STOP, investigate, and correct the problem before continuing.



*ACI Certified Nozzleman **Oscar Duckworth** is an ASA and American Concrete Institute (ACI) member with over 15,000 hours of nozzle time. He has worked as a nozzleman on over 2000 projects. Duckworth is currently an ACI Examiner for the wet- and dry-mix processes. He currently serves as ASA Executive Committee Secretary and newly appointed Chair of ASA's Education Committee. He continues to work as a shotcrete consultant and certified nozzleman.*

New Products & Processes

Normet Updates Underground Spraying Simulators

While the use of training simulators has been prevalent throughout the industry for a number of years, there was only a fairly limited selection of simulated training environments. Now, Normet has expanded this capacity, developing new environments where underground spraying can be practiced, including mines, tunnels, and even an operator's own scanned environment. There is also a wide range of Normet tunneling and mining sprayers to choose from, including the Spraymec 8100 VC, Spraymec 6050, 1050 WPC, MF 050 VC, or Alpha 30.

In the pretraining scenario, the trainee learns how to manipulate the spraying boom with the machine's original radio control. Once fluent with manipulation of the spraying boom, a basic spraying technique exercise can be started. This is an instructive exercise with spraying order, path, distance, and angle maneuvers. The spraying exercises include spraying in a straight tunnel, at a tunnel's end, inside a curved tunnel, or in a tunnel's cross section. "Competition mode is also available…as a little competition can always improve performance," the company added.

The new simulators have better-quality graphics and visual indicators to aid in training. According to Normet, the simulators' visual aids include colored markers that show, when spraying, colored concrete layers indicating the thickness of the concrete sprayed (for example, a red layer is too thick, a green layer is perfect, and a blue layer is too thin). It also has a nozzle angle indicator to show nozzle distance from the wall to teach distance in spraying. After each exercise, a detailed individual-operator report, based on performance, can be printed out or transferred as a text file. The report includes pictures and graphs on the accuracy of concrete thickness, sprayed concrete quality, nozzle distance, and angle accuracy.

"Trainees who have undergone Normet Academy's simulator training [have] shown an improvement in operator efficiency by 23 percent," the company added.

Schwing Adds New Boom Pump

Schwing has expanded their boom pump lineup with a new model, bringing the Schwing truck-mounted concrete pump with placing boom line to a total of 16 different models. The S20 offers a unique boom design in a compact package, affording placers, concrete contractors, and specialty contractors a versatile tool to expand concrete placing possibilities while also performing conventional work.

The four-section Double Z boom offers a total of 820 degrees of articulation with 270 degrees at both the third and fourth sections, allowing many possible configurations in confined spaces. Combined with a 12 ft 7 in. (3.8 m) unfolding height, the S20 can be used indoors, under overhead structures, and in tunnels. The standard truck is a Kenworth T370 with 330 hp and an automatic transmission. The overall reach of the boom is 63 ft 8 in. (19.4 m) vertically and 51 ft 10 in. (15.8 m) horizontally. The boom can rotate 370 degrees in either direction, enhancing versatility on tight projects. The boom is equipped with a full 5 in. (127 mm) pipe.

The S20's usage benefits from its convenient ability to perform as a line pump with a standard back-end 180-degree rotating outlet. The unit also features excellent storage for clamps, and an additional system with fold-down sideboard access on the driver's side to a 13 ft (4 m) loading deck.

The standard pump kit is the 2023-3 110/75 SC with 124 yd^3 (95 m^3) per hour output, operating through 9 in. (229 mm) diameter pumping cylinders. The twin-cylinder all-hydraulic unit sequences the pumping cylinders through the proven M Rock Valve, providing maximum sealing efficiency in a totally rebuildable valve with a minimum of moving parts. Contractors can pump with confidence in all situations with the S20, handling mixtures with up 2.5 in. (63.5 mm) aggregate and applying up to 1095 psi (7.5 MPa) on the concrete.

For more information, please visit **www.schwing.com**.

Awareness of Cement Burns

By Joe Hutter

Most experienced concrete professionals are familiar with the hazards associated with portland cement mixtures, yet despite the precautionary steps most of those professionals follow, hospital emergency rooms, year after year, see far too many cases of cement burns.

Cement in its dry state is not particularly harmful to skin. When mixed with water, however, calcium hydroxide, formed during the cement hydration process, is extremely alkaline with a pH between 12 and 13. In comparison, human skin has a pH of only 5.5. Prolonged exposure, or in some cases even limited exposure, to the corrosive effect of cement paste can result in severe damage to unprotected skin (Fig. 1).

Determining the cause of those burns is relatively easy. However, because the pain that accompanies cement burns can sometimes be delayed for hours, the victim may not be aware of the problem and the severity can be greater than it should be. Early identification of cement burns is therefore important so steps can be taken to treat the affected area.

Fig. 1: Prolonged exposure or, in some cases, even limited exposure, to the corrosive effect of cement paste can result in severe damage to unprotected skin

Cement burns can often start with minor discoloration of the skin but it is important not to assume that the severity of the burn will not get worse. Affected skin can gradually change to a deep purple-blue color, which can eventually progress to painful burns, severe blistering, and ulcerations. In some cases, cement burns can also lead to allergic dermatitis, which usually means an unexpected career change for shotcrete nozzlemen or other crew members who work with fresh concrete.

Preventing Cement Burns

The prevention of cement burns, like most workplace hazards, starts with education and training on the safe handling of wet concrete. Frontline supervisors should emphasize to shotcrete crew members the cause of cement burns and ensure that all crew members take the proper safety precautions to avoid injury.

Employers should always do their part to provide shotcrete crew members with a safe working environment, including access to the supplies necessary to treat skin that has been exposed to wet concrete. These supplies include sufficient clean, running water; a pH-neutral soap to help neutralize the effect of caustic cement (workplace cleaners that are caustic and abrasive or contain sensitizers such as lanolin, limonene, or perfume and irritants such as alcohol should be prohibited); and clean towels.

Protective clothing and personal protective equipment (PPE) will also play a critical role in the prevention of cement burns. Clothing should be the type that minimizes contact of the cement with the skin. Care should be taken to ensure that shotcrete rebound and fresh concrete cannot enter areas of friction such as sleeve cuffs and neck collars (Fig. 2). The initial layer of clothing should be kept clean and dry. If clothing does get saturated with cement paste, it should be removed and changed. A checklist of recommended clothing and PPE should include:

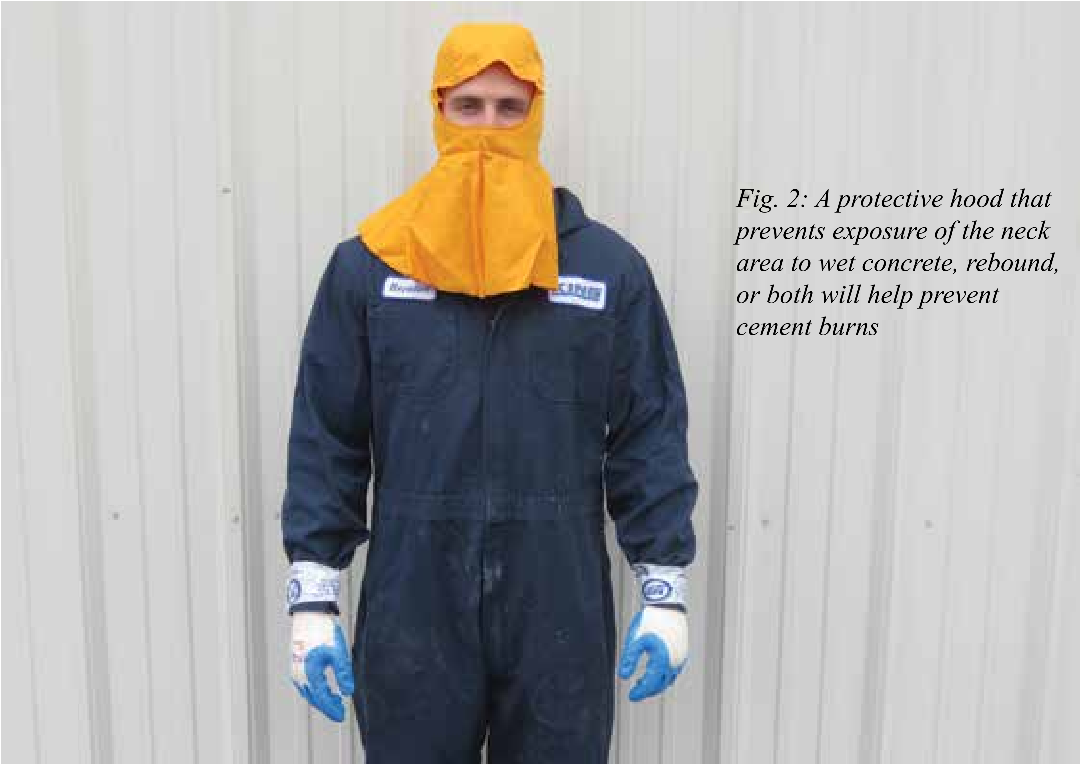


Fig. 2: A protective hood that prevents exposure of the neck area to wet concrete, rebound, or both will help prevent cement burns

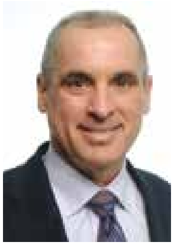
- Full-cover goggles or safety glasses with side shields;
- Snug-fitting alkali-resistant gloves;
- Long-sleeved buttoned shirts with the sleeves taped to the gloves to prevent wet concrete, rebound, or both from entering;
- A protective hood that prevents exposure of the neck area;
- Sturdy, waterproof safety boots;
- Coveralls or long pants tucked into boots and taped to prevent concrete, rebound, or both from entering (disposable, water-repellent coveralls are effective); and
- Jewelry such as watches and rings should be removed to prevent wet concrete from being trapped against the skin.

Treatment of Cement Burns

If a shotcrete crew member begins to feel a burning sensation on the skin, the process of treating the area should begin immediately:

1. Remove any contaminated clothing and avoid rubbing the affected areas during the removal process;
2. Gently remove any material from the skin using a pH-neutral soap and water;
3. Continue rinsing the area with clean water for a minimum of 20 minutes;
4. Pat the skin dry with a clean towel, being careful not to rub the affected area; and
5. Seek immediate medical attention (bring an MSDS to ensure the medical professional is aware of the type of exposure).

After the affected area has sufficiently healed, the shotcrete crew member should monitor the affected skin to ensure a repeat of the injury does not occur. In the event of a reoccurrence, the shotcrete crew member should investigate the possibility that skin sensitivity or allergic contact dermatitis has developed. In the event that it has, a doctor can help to determine if the individual should continue to work in a position where exposure to wet cement paste is likely.

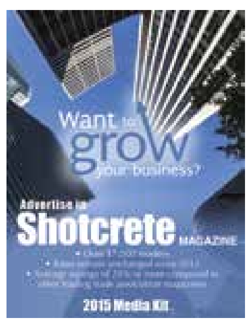


Joe Hutter *is the Vice President, Sales, for King Packaged Materials Company, Burlington, ON, Canada. He has more than 25 years of experience in the cement/shotcrete industry. He is a former President and an active member of ASA and has been Chair of the ASA Marketing Committee since its inception. Hutter is also a member of the American Concrete Institute.*

ASA at World of Concrete 2015

Please see the Staff Editorial on page 8 for a detailed description of the many initiatives ASA has planned for the upcoming World of Concrete show. Join us and help in communicating to the concrete industry the many benefits of the shotcrete process. Don't forget to register for a reduced-fee, exhibit-only pass using ASA's code, A17. New this year, all registrations will now have a fee, but as a cosponsor, using ASA's code gives you the lowest rate for an exhibit-only pass. Using this code is also a very easy way to support your association. If you have registration questions, please call (866) 860-1983 or e-mail registration@worldofconcrete.com.

2015 *Shotcrete* Magazine Media Kit Now Available



With a readership of over 17,000 subscribers, *Shotcrete* magazine reaches the shotcrete industry like no other resource. Advertising rates for this specifically targeted medium are very reasonable and well below the average rate for other publications in the concrete industry. This combination of exceptional access at affordable rates provides the shotcrete industry with an important and useful tool for promoting your products and services.

For more information, visit **www.shotcrete.org/media/pdf/ASAMediaKit.pdf** or call (248) 848-3780.

ASA Board Approves New Strategic Plan

This past summer, the ASA Executive Committee and select committee members participated in a strategic planning session at ASA's headquarters to establish an updated vision, mission, and future plan for the Association. The outcome of this planning session resulted in the identification of four main strategic priorities for ASA—professional development, outreach, credibility, and organizational strength—with the ultimate vision being that structures built or repaired with the shotcrete process are accepted as equal or superior to cast concrete. To achieve this future vision, ASA has set many goals and objectives by which to chart its products, programs, and resources over the next 3 to 5 years.

For a more detailed review of ASA's strategic planning process, along with a full outline of the strategic plan, please refer to the President's Message on page 2 of this issue.

"Like" ASA's Facebook Page

Now up to almost 900 "likes," ASA's Facebook page offers followers another easy way to stay up-to-date on the latest news regarding issues, products, and events in the shotcrete industry. If you're online, be sure to stay connected with us at **www.facebook.com/AmericanShotcreteAssociation**.

New ASA Committees and Chairs

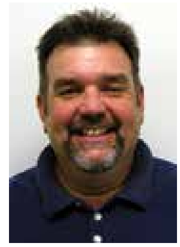
At its Fall 2014 committee meetings in Washington, DC, on October 25, 2014, ASA welcomed several new committees and Chairs to its working structure.

The Education Committee welcomed its new Chair, Oscar Duckworth. Duckworth has previously chaired the Safety Committee; he currently serves as ASA Secretary and is an approved Examiner for the ACI Shotcrete Nozzleman certification program.

The Marketing Committee began anew—having been separated out from the former (combined) Marketing &

Oscar Duckworth
Education Chair

Joe Hutter
Marketing Chair



Tom Norman
Membership Chair

Andrea Scott
Safety Chair

Michael Cotter
Awards Chair

Membership Committee—with a targeted emphasis on helping to grow the use and acceptance of shotcrete as an equal or superior method of concrete placement compared to cast concrete. Chair Joe Hutter, a Past President of ASA, leads this committee in marketing ASA's products and services in the interest of achieving this vision for the shotcrete industry.

The Membership Committee also began its more focused operation under Chair Tom Norman, a past ASA Director. This committee's ongoing focus will be in strengthening ASA's membership benefits and helping to increase participation in the Association's activities.

The Safety Committee welcomed its new Chair, Andrea Scott, who also currently serves as an ASA Director as well as a voting member on many other committees and task groups. Scott hopes to continue the mission of exploring and promoting safe practices in the shotcrete industry through ASA's current and future high-quality publications and programs.

The Awards Committee also met under the direction of new Chair Michael Cotter (immediate Past President and current ASA Officer) to judge this year's entries for the annual Outstanding Shotcrete Project Awards Program. This awards program serves as the foundation of ASA's annual awards banquet, which recognizes and highlights excellence in the implementation of the shotcrete process on unique and challenging concrete repair and construction projects.

For more information on ASA's many committees, please visit **www.shotcrete.org/pages/membership/committees.htm**. We welcome all those in the shotcrete industry to take part in our committees, which serve as the lifeline for ASA and its products and services.

Short Course on Shotcrete for Underground Support

The American Exploration and Mining Association (formerly Northwest Mining Association) will be hosting a short course, titled "Shotcrete for Underground Support," at its 2014 Annual meeting in Reno, NV, on Tuesday, December 2. Led by instructor Lihe (John) Zhang, Materials Engineer, LZhang Consulting & Testing Ltd., Vancouver, BC, Canada, this 8-hour course focuses on underground shotcrete for mines and tunnels.

The class will provide basic knowledge and case studies of underground concrete and shotcrete for site supervisors, nozzlemen, engineers, and designers. Topics to be covered include:

1. Concrete basics: chemistry of cement and concrete, concrete mixture design, concrete performance, supplementary cementitious materials, and chemical admixtures.
2. Specialty concrete for underground application: self-consolidating concrete (SCC), high-performance concrete, and fiber-reinforced concrete.
3. Quality control and troubleshooting for concrete: concrete batching, supply, delivery and risk, quality control testing and inspection, curing and protection, strength development, temperature (including temperature effect, hot-weather concrete, and cold-weather concrete), and mass concrete construction.
4. Shotcrete basics: ground support; wet-mix versus dry-mix process; and equipment and system for each process.
5. Fiber-reinforced shotcrete: mixing, pumpability, testing, and application.
6. Underground shotcrete application: batch, transport, remixing, and application.
7. Underground shotcrete application: hand nozzling and robotic sprayer application.
8. Underground shotcrete application: proper use of accelerator.

The cost of attendance for this course is $275. For more information, please visit **www.miningamerica.org**.

7th International Symposium on Sprayed Concrete for Underground Support

On June 16-19, 2014, the 7th International Symposium on Sprayed Concrete for Underground Support was held in Sandefjord, Norway. Over 120 attendees spent a total of 3 days discussing, sharing, and enjoying the advancement of sprayed concrete technology. Attendees were professionals from Norway, Sweden, Finland, Germany, Austria, Switzerland, Belgium, the United Kingdom, France, Spain, Chile, Canada, Australia, Malaysia, and China.

A total of 41 papers were presented on topics including the design of rock support systems, tunnel lining design concept, studies and evaluation of accelerators, fibers, mineral additives, testing methods for flexural toughness, early-age strength development, airflow, field large-scale testing, waterproofing membrane systems, measurement of shotcrete thickness with laser scanning, thermal image measurement of in-place shotcrete temperature, and underground shotcrete development in Europe, the United States, Canada, and Australia. Topics also include research and development, field trials, project reports, and durability of shotcrete.

For detailed information on the conference and conference proceedings, please contact Marc Jolin at marc.jolin@gci.ulaval.ca, or John Zhang at zhanglihe@gmail.com, or visit **http://sprayedconcrete.no**.

Left to right: Stefan Bernard, Australia Shotcrete Society; Nicolas Ginouse, Laval University, Canada; Marc Jolin, Laval University, Canada; Thomas Beck, MAPEI, Norway, Chair of the Scientific Committee; Ola Woldmo, Normet, Norway, Chair of the Organizing Committee; and Lihe (John) Zhang, LZhang Consulting & Testing, Canada

Shotcrete Used to Repurpose Burned Structure as Park Pavilion

A local treasure dating back more than a century, El Bethel Missionary Baptist Church was transformed into a public park memento after falling victim to an arson attack in 2007. Epoxy Design Systems successfully repurposed much of the remaining structure as a park pavilion in a manner that reflects the original architecture of the church by using QUIKRETE® Shotcrete MS.

Originally built in 1889, El Bethel Missionary Baptist Church served the post-Civil-War community of Houston's Fourth Ward until being replaced with a new sanctuary in 1997. Unfortunately, the vacant church burned down in 2007 in a case that remains unsolved today. Several years later, the City of Houston purchased the remains with plans to convert the area into a park memorializing the church, which is on the National Register of Historic Places and is one of the oldest sanctuaries in Houston.

Epoxy Design Systems removed all the unsalvageable elements of the three standing walls, made the necessary structural concrete repairs, and reinforced the surface with wire mesh before spray-applying more than 7000 ft^2 (650 m^2) of QUIKRETE Shotcrete MS on the adaptive reuse project. In addition to renovating and stabilizing the church, Epoxy Design Systems successfully incorporated relief designs in the walls and returns around columns, doors, and stained-glass windows that recaptured the look and spirit of El Bethel Missionary Baptist Church. Today, visitors can sit on attractive brick pews in the symbolic open-air church to enjoy views of the adjacent park.

For more information on QUIKRETE products and projects, please visit **www.quikrete.com**.

For more information on Epoxy Design Systems, please visit **www.epoxydesign.com**.

Industry Personnel

Brayman Construction Announces New President, COO

Frank A. Piedimonte

Brayman Construction Corporation, a heavy civil and geotechnical contractor, has promoted Frank A. Piedimonte to President and Chief Operating Officer.

This announcement was made by the Chairman and CEO, Stephen M. Muck, who stated, "The Board of Directors has full confidence in Mr. Piedimonte's ability to manage the day-to-day operations of the company and continue its growth and strategic development." Piedimonte has been with Brayman since 2004, when he joined the organization as a Senior Project Manager. In 2009, he was promoted to Vice President, and in 2011 to Executive Vice President of the Heavy Civil Division. Prior to Brayman, Piedimonte was Regional Manager for IA Construction Corp.

During his time at Brayman, Piedimonte has been the executive in charge of many notable construction projects in the region; he led the Trumbull-Brayman joint venture at Charleroi Lock and Dam ($97M), the Freeport Bridge Reconstruction ($63M), the Ironton-Russell Cable Stay Bridge over the Ohio River ($83M), and is currently the lead executive in charge of the Hulton Bridge Replacement ($64M) in Oakmont, PA.

Shotcrete Calendar

NOVEMBER 2-7, 2014
2014 International Pool | Spa | Patio Expo
Orange County Convention Center
Orlando, FL
www.poolspapatio.com

NOVEMBER 3, 2014
ASA 2014-2015 Graduate Scholarship Program
Deadline for submissions for the 2014 Scholarships
www.shotcrete.org/ASAscholarships

NOVEMBER 5-6, 2014
ASA Shotcrete Nozzleman Education
in conjunction with the
2014 International Pool | Spa | Patio Expo
Presenter: Bill Drakeley
Registration Code: **ASA**
Orange County Convention Center
Orlando, FL
www.poolspapatio.com/attendee/schedule/sessiondetails/12932

NOVEMBER 7, 2014
CONSTRUCTION 408: Construction Techniques for a Vanishing Edge Pool
in conjunction with the
2014 International Pool | Spa | Patio Expo
Presenter: Bill Drakeley
Registration Code: **FR01**
Orange County Convention Center
Orlando, FL
www.poolspapatio.com/attendee/schedule/sessiondetails/12935

NOVEMBER 12-14, 2014
ICRI 2014 Fall Convention
Theme: "Mega Projects"
InterContinental Kansas City at the Plaza
Kansas City, MO
www.icri.org

DECEMBER 1-5, 2014
American Exploration & Mining Association Annual Meeting & Short Course
John Ascuagas Nugget Casino Resort
Sparks, NV
www.miningamerica.org

DECEMBER 7-10, 2014
ASTM International Committee C09, Concrete and Concrete Aggregates
Sheraton New Orleans
New Orleans, LA
www.astm.org

JANUARY 29-30, 2015
Conference & Exhibition Shotcrete 2015
Alpbach Conference Centre
Tyrol, Austria
www.spritzbeton-tagung.com

FEBRUARY 2, 2015
ASA Committee Meetings at World of Concrete
Las Vegas Convention Center
Las Vegas, NV
www.shotcrete.org

FEBRUARY 3, 2015
ASA Shotcrete Nozzleman Education
Presenters: Oscar Duckworth and Marc Jolin
Las Vegas Convention Center
Las Vegas, NV
www.shotcrete.org

FEBRUARY 3, 2015
ASA 10th Annual Outstanding Shotcrete Project Awards Banquet
6:30 pm Reception | 7:30 pm Dinner
New York New York Hotel & Casino
Staten Island Ballroom
Las Vegas, NV
www.shotcrete.org

FEBRUARY 3-6, 2015
World of Concrete 2015
Visit the ASA booth: S10839
Use source code **A17** for reduced-price exhibit-only passes!
Las Vegas Convention Center
Las Vegas, NV
www.worldofconcrete.com

FEBRUARY 4, 2015
Advanced Shotcrete for Infrastructure, Rehab, and Recreational Construction
Presenters: Bill Drakeley and Lihe "John" Zhang
Las Vegas Convention Center
Las Vegas, NV
www.shotcrete.org

FEBRUARY 5, 2015
ASA Shotcrete Inspector Education
Presenter: Oscar Duckworth
Las Vegas Convention Center
Las Vegas, NV
www.shotcrete.org

Shotcrete Calendar

MARCH 25-27, 2015
ICRI 2015 Spring Convention
Theme: "High-Rise Repairs"
Millennium Broadway Hotel
New York City, NY
www.icri.org

APRIL 11, 2015
ASA Spring 2015 Committee Meetings
Marriott & Kansas City Convention Center
Kansas City, MO
www.shotcrete.org

APRIL 12-16, 2015
ACI Spring 2015 Convention
Theme: "Fountains of Concrete Knowledge"
Marriott & Kansas City Convention Center
Kansas City, MO
www.concrete.org

JUNE 8-11, 2015
The International Bridge Conference
David L. Lawrence Convention Center
Pittsburgh, PA
www.eswp.com

JUNE 14-17, 2015
ASTM International Committee C09, Concrete and Concrete Aggregates
Marriott Anaheim
Anaheim, CA
www.astm.org

NOVEMBER 7, 2015
ASA Fall 2015 Committee Meetings
Sheraton
Denver, CO
www.shotcrete.org

NOVEMBER 8-12, 2015
ACI Fall 2015 Convention
Theme: "Constructability"
Sheraton
Denver, CO
www.concrete.org

DECEMBER 6-9, 2015
ASTM International Committee C09, Concrete and Concrete Aggregates
Marriott Tampa Waterside Hotel
Tampa, FL
www.astm.org

Visit www.shotcrete.org and use the News & Events tab to click on Calendar for the most up-to-date list.

Shotcrete FAQs

As a service to our readers, each issue of *Shotcrete* will include selected questions and provide answers by the American Shotcrete Association (ASA). Questions can be submitted to info@shotcrete.org. Selected FAQs can also be found on the ASA website, **http://shotcrete.org/pages/products-services/technical-questions.htm**.

Question*: We are replacing an undersized box culvert carrying a creek under a road with a vehicular bridge. To reduce excavation limits, we are using top-down caisson wall construction with shotcrete facing between caissons for abutments and wingwalls. The shotcrete will be placed in lifts as soil is excavated between abutment/wingwall caissons.*

The architectural pattern for the face of the abutments and wingwalls is a rectangular pattern of an indented, V-shaped notch. The notches have a maximum depth of 2 in. (51 mm). The structural portion of the shotcrete wall will be 12 in. (305 mm) thick with steel reinforcement. Can this horizontal and vertical V-notch pattern be formed or stamped into the face of the structural wall (with additional thickness as required for pattern) in one wall placement? Or does the pattern have to be a separate placement after the structural wall is cured?

If this is done in two placements, I assume that we would need reinforcing bars from the structural portion of the wall into the architectural placement and reinforcement within the architectural placement to lock it in place. What is the minimum required thickness of the architectural layer to account for reinforcing bar embedded from the structural layer and the required reinforcing bar in the architectural layer?

Answer: There are many ways to approach this situation. It would be difficult, but not impossible, to install all of the work in a top-down sequence and end up with an architecturally uniform surface.

Approach 1: Install a minimal initial layer top-down with either fibers or welded wire reinforcement. Install dowels from the caissons into the structural facing layer. Install the facing from the bottom up with preplaced V-strips to make the pattern. Finish to the outermost face of the detail strips. Alternately tool the details, but likely more like 1 in. (25 mm) instead of 2 in. (51 mm).

Approach 2: Install the structural wall top-down, encapsulating the outer reinforcing steel to a plane at the depth of the detail strips. Prepare the surface by sandblasting or water blasting to create a favorable bonding surface. Install detail strips to the face of the roughened wall. Place and finish the finish layer to the depth of the detail strips.

If the base layer is properly prepared, the bond should be very good and adding dowels would be redundant. There is nothing wrong with redundancy and if so, the minimum layer thickness would be 2 to 3 in. (51 to 76 mm).

The nature of this work will mandate the use of a highly qualified shotcrete subcontractor who has experience in installing similar-quality architecturally significant walls.

Question*: Do we need to coat reinforcing steel after sand-blasting and prior to placement of product?*

Answer: The answer is no; shotcrete will bond well to sand-blasted reinforcing bar on overhead or vertical applications. Shotcrete, like conventionally placed concrete, can be placed over uncoated black bar or bar that is coated with rust inhibitors. In repair areas where there is heavy scale on the reinforcing bar and spalling of the concrete, the repair can sometimes include some sort of reinforcing bar treatment or inclusion of a rust inhibitor in the shotcrete mixture. It depends on the situation and the assessment of the design engineer as to what is necessary.

Question*: Is shotcrete applied to hardened cast-in-place concrete considered monolithic by the American Concrete Institute (ACI)? Is shotcrete-to-shotcrete considered monolithic by ACI? Can either of these connections be made watertight? Or at least as watertight as the concrete? Is shotcrete without admixtures truly watertight or waterproof? (My definition of "watertight" would be a measurable amount or more than leaching of moisture and calcium.)*

Answer: Shotcrete properly applied to a well-prepared existing concrete surface will create an excellent bond and structurally act as a monolithic system without joints or layers. Pulloff testing of shotcrete applied to concrete will often fail in the underlying concrete substrate, and not at the bond interface or within the shotcrete section.

Shotcrete is a method of placing concrete and should have similar watertightness characteristics. These characteristics can be enhanced with admixtures and supplementary cementitious materials such as silica fume. Please refer to the images of cores from shotcrete applied to existing concrete.

Shotcrete FAQs

Question: *I have a 24 in. (610 mm) thick concrete dome that serves as an enclosure to protect extremely sensitive and important equipment that needs to withstand high impact demands such as tornados or missiles. The contractor is proposing to use the shotcrete method with the following sequence: shoot approximately 1 in. (25 mm) (to achieve reinforcing bar cover); let stand for 8 hours; then place a reinforcing mat; then shoot the majority of the dome thickness; let stand for 8 hours; then place the other mat of reinforcing; then shoot the remaining concrete cover.*

I am concerned that, with an 8-hour duration between concrete placements, the three layers of concrete will not be adequately bonded such that they behave monolithically. In particular, I would be concerned that the aggregate of the concrete that is shot onto a mat of reinforcement will not be able to make its way "behind" the bar's deformation, thus causing voids.

Please let me know your thoughts on the aforementioned concerns, whether it would be reasonable to shoot a 24 in. (610 mm) dome with a minimum of two layers of reinforcement all at once, and whether any of the ACI codes or standards speak to shotcrete joints parallel to reinforcement.

Answer: Multi-layer buildout of shotcrete sections is very common and has decades of successful performance in existing structures. Shotcrete applied to a properly prepared, existing hardened concrete substrate (such as a previously shot shotcrete layer) develops an excellent bond. The high-velocity impact of shotcrete on the surface is in effect like sandblasting, and opens up the receiving surface immediately before exposing it to the fresh cementitious paste. Cores taken through multiple layered shotcrete sections exhibit no signs of reduced bond. Often it is nearly impossible to identify where one layer stops and the next starts.

Incremental placement of reinforcing bars in layered application is also common. Proper shotcrete consistency, nozzleman technique, and air velocity will force fresh cement paste around the back of the bar and fully encase the reinforcing bar, even when in contact with the previous hardened concrete surface.

Shooting a 24 in. (610 mm) thickness at one time with two layers of reinforcement in the mostly overhead orientation of a dome would require use of special concrete mixture designs with chemical accelerators, and would be very difficult to execute with consistent quality. Also, depending on the formwork design, unbalanced loading on the dome by shooting very thick sections adjacent to sections not yet shot would be a potential concern.

For more information on the performance of shotcrete in layers, you can review a recent article in *Shotcrete* magazine, "Shotcrete Placed in Multiple Layers does NOT Create Cold Joints," at **www.shotcrete.org/media/Archive/2014Spr_TechnicalTip.pdf**.

Question: *I am searching for criteria/guidelines or ratings on what different profiles are achieved by shotcrete. I am hoping there are installed shotcrete profile requirements with respect to final surface roughness. We manufacture a waterproofing system and are often asked to be installed over shotcrete, to which we have no objections. However, I am hoping there are criteria/guidelines/ratings on achieved profile of the finished surface. For example: The concrete industry often talks about roughness achieved by shotblasting and the surfaces getting to various degrees between CSP-1 to CSP-9.*

Is there a criteria/guideline/rating system, or something similar with shotcrete? Here is the link to what I am talking about: ***http://shotblastinc.com/industry-guidelines****.*

Answer: Shotcrete is a method of placing concrete. The surface texture of roughness varies considerably depending on the application and the abilities of the installer. The surface can vary from a rough nozzle finish to a smooth trowel finish and many variations between these two extremes. In buildings, the typical finishes are wood float, rubber float, or trowel finish. The owner and the architect determine what finish will be required and generally specify the finish in the construction documents. The documents which might be of help to you are ACI 506R, "Guide to Shotcrete," ACI 301, "Specifications for Structural Concrete," and ACI 117, "Specification for Tolerances for Concrete Construction and Materials."

Question: *An inspection report on our home indicated there was evidence of past rodent infiltration. An engineering consulting firm recommended that, to prevent rodents from burrowing underneath the foundation, we have a contractor apply shotcrete across the entire crawlspace bottom, then have a 2 oz. (60 mL) vapor barrier installed on top of it. The barrier would be glued or taped up the sides of the crawlspace.*

As there is some shrinkage of the concrete during the curing process, I would expect creatures could later emerge between the shotcrete and crawlspace sides. Have you heard this type of shotcrete application in a crawlspace as a structural pest barrier? What thickness should the shotcrete be? Is this use of shotcrete effective? Are there any potential drawbacks to using shotcrete in this way, such as possible problems with the house later on?

Answer: Shotcrete is a method of placing concrete and the properties of shotcrete are equivalent to those of cast concrete. The type of work you are describing is done in many cases with the shotcrete process and is commonly called "ratproofing." As you have engaged an engineer, we would suggest you follow his advice and he should determine the thickness required. Providing a row of dowels around the stem wall to tie the shotcrete to the wall should eliminate any significant separation between the shotcrete and the stem wall. Shrinkage of concrete between the walls may cause some minor hairline cracking, but nothing to allow ingress of rodents or insects.

Question: *We have a client who is looking to make a relatively deep cut in a mixture of soils and rock (approximately. 50 ft [15.2 m] high, maximum; the structures will be placed on a pad at the bottom of the cut). We are looking to provide a shotcrete facing for the entire cut area.*

The upper portion of the cut will be in soil; therefore, the design of a soil nail wall with temporary and permanent facing in the soil region seems to be relatively straightforward using design guidance in FHWA publications, Geotechnical Engineering Circular #7, and some software programs. Significant portions of the exposed cut face, however, consist of nondurable bedrock (claystone). We want to stabilize this area with shotcrete to prevent weathering and the generation of overhang conditions where the claystone is overlain by a more durable sandstone.

I have been unable to find design procedures or guidance on specifying shotcrete (thickness, reinforcement type, etc.) and whether or not rock bolts should be used. If so, how do you select the size, spacing, resin type, etc.?

Answer: Soil and rock stabilization is an excellent application for shotcrete. However, ASA as an association does not provide engineering design. We recommend consulting with a geotechnical engineer familiar with the local geology and soil conditions to evaluate potential lateral earth forces from the claystone. Once potential loads are established, a consulting engineer experienced with shotcrete in soil nailing applications will be able to design the soil nail facing. You can check our online Buyers Guide at **www.shotcrete.org/BuyersGuide** to find a consulting engineer experienced with shotcrete.

Question: *I need to know about use of carbon fiber in shotcrete. Would you please inform me about some resources? Is carbon fiber suitable for shotcrete?*

Answer: We would suggest that you refer to an ACI document, ACI 506.1R, "Guide to Fiber-Reinforced Shotcrete" (available here: **www.shotcrete.org/BookstoreNet/ProductDetail.aspx?itemid=506108**). Carbon fibers are suitable for use in shotcrete in suitably designed mixtures.

Question: *I own a home on a very busy street and the house placement borders the street, approximately 75 ft (23 m) from the curb. Traffic flow has increased over the past year, and I have tried all suggested and approved soundproofing wall systems with varied results.*

It would seem that a shotcrete product sprayed within a wall cavity would work great. My assumption is that I would need *to insulate the outward face of the cavity enough to prevent excessive condensation and moisture buildup. This would certainly solve the sound problem (depending on the mass sprayed). Are there any suggestions or references you might be able direct me to?*

Answer: A properly designed shotcrete composite wall system would certainly create a quiet atmosphere in the interior of the house. There are 3-D shotcrete wall systems on the market which use shotcrete on both the interior and exterior surfaces with a foam material in the center for insulation and vapor barrier. Attempting to do something like this to an existing structure would require a lot of analysis. Shotcrete is a method of placing concrete and adding shotcrete to an existing wall would significantly increase the weight of the wall and could overload the footings or impact other parts of the system. A structural engineer well-versed in residential construction should be consulted before attempting such a modification.

Question: *We are in the process of renovating a commercial pool with a gutter system. The plaster surface has been removed along with some of the concrete. The wall of the gutter on the water side is tiled and is crumbling away. Our plan is to shotcrete the walls and gutter.*

When we shoot the walls back we will be adding 1 to 2 in. (25 to 51 mm) of shotcrete at a maximum. Is this too thin for shotcrete? Also, the gutter edge will be 2 in. (51 mm) thick and 4 in. (102 mm) in height without any reinforcing bar—will this have much strength?

Answer: Shotcrete can be placed as thin as 1 to 2 in. (25 to 51 mm), but will do little more than to provide a new surface to apply the plaster. To do a proper job you need to remove all loose and deteriorated existing shotcrete and should likely add in a layer of reinforcement or use structural fibers (either steel or synthetic) in the shotcrete mixture. The surface preparation should be done to the standards outlined by the International Concrete Repair Institute (ICRI).

Question: *I have a project in Fort Worth, TX, where we will be placing shotcrete on some interior walls that will have steel embeds for other structural supports. Do you have an article or literature regarding good practices of shotcrete placement around steel embeds?*

Answer: Shooting around embeds can be very challenging. The most important factor is to have the work done by a shotcrete subcontractor who has done this successfully in the past and has ACI Certified Nozzlemen who are also experienced in this type of work. It has been done successfully on many projects in the past, but we do not have a published procedure to do this work.

Question: *We are building a pool using shotcrete, and our pool design team has been asked to use the Aquron pool shell protector. The info from Aquron says for best results, spray the CPSP the morning after the shotcrete has been applied. However, our shotcrete company told us to keep the shell damp for a minimum of 7 days. Could you weigh in on this?*

Answer: The ICC Building Code requires a 7-day wet cure, which is good practice for concrete or shotcrete. The Aquron Technical Data Sheet mentions prewetting the surface prior to application, but we do not see the direction on the timing. You may want to question the product representative regarding how to accomplish the ICC curing requirements and also get the best results from their product.

Question: *I am considering using shotcrete for lining stormwater conveyance ditches at a project site, and am trying to find any possible information on the potential for shotcrete (or other cement products for that matter) to leach selenium. Please advise if you have any information regarding this topic.*

Answer: Shotcrete is a method of placing concrete. Thus, testing for selenium appropriate for concrete is suitable for shotcrete. The Portland Cement Association (PCA) has published a paper on testing of cement for various constituent components, including selenium, to meet NSF 61 requirements. Their testing showed "Values for arsenic, cadmium, selenium, and silver were all below detection limits." The paper can be found at PCA's website: **www.cement.org/docs/default-source/fc-library/sp117.pdf**.

Question: *How soon after a surface is shotcreted can it be submerged with stream water? What if the water has no velocity?*

Answer: Shotcrete is a means of placing concrete and the same precautions should be taken. Once the shotcrete had taken final set, exposing it to water and submerging it in water should enhance its curing. If it is a pool or other deep structure, you should ensure that the shotcrete or concrete is strong enough to withstand any hydrostatic loading due to the filling of the structure.

CTS Cement Manufacturing Corporation

CTS Cement Manufacturing Corporation is the largest manufacturer of calcium sulfoaluminate (CSA) cement in North America with their proprietary Rapid Set® fast-setting hydraulic cement. Well-known for its versatility and high performance, Rapid Set cement is a more durable alternative to portland cement, and its rapid-setting properties make it an ideal solution for today's schedule- and budget-driven projects.

Use Rapid Set cement products for underground roadway repair for ramps, underground maintenance facilities, and anywhere rutted-out sections in mines need attention. Rapid Set products are preferred for extra-high-strength and abrasion-resistant shotcrete in high-traffic areas and in ore shafts. High-strength, low-shrinkage Rapid Set grout achieves strengths up to 7500 psi (55 MPa) in 4 hours. Rapid Set cement products achieve high strength much faster than most any other cement-based product in the market. Many installations can be put into service in as soon as 1 hour.

Rapid Set has emerged as an innovative alternative to portland cement in many areas, including tunneling and underground construction projects. It has been used for construction on above ground projects for years and exhibits properties uniquely suited to the harsh environment of underground construction.

Repairs performed with ordinary portland cement shotcrete mixtures can take up to 28 days before they reach design strength. This can slow down projects and cycle time, especially for mining and tunneling. Shotcrete, using Rapid Set, can reach full design strength in only a few hours. In about 15 minutes—without any accelerator—dry-mix shotcrete using Rapid Set commonly reaches strengths of 2200 psi (15 MPa); in an hour, the strengths can be close to 3600 psi (25 MPa).

Rapid-setting dry process shotcrete with red pigment for underground and tunneling applications
Photo courtesy of King Packaged Materials

The absence of accelerator is a savings, and also makes the process easier and safer. Crews are able to return to work hours earlier than when an accelerated portland cement mixture is used.

Shotcrete with Rapid Set has been used throughout the nation: in relining culverts in Colorado, in repairing pipes and culverts in New Jersey that ranged from 36 to 72 in. (915 to 1855 mm), and in repairing culverts in mountainous terrain in California. It was also used in highwall mining in Pennsylvania to strengthen weak highwall formations and protect workers from any loose debris.

Rapid Set works well in dry-mix shotcrete and is being used to line hundreds of sewer pipes, manholes, and drainage culverts. Often, Rapid Set shotcrete can be sprayed as a relatively thin layer due to its high strength and bonding characteristics. It is a very good choice for many types of shotcrete applications, including areas that need special attention where abrasion is an issue and shaft liners, grizzlies, hoppers, chutes, open drifts, and stopes where there is a lot of equipment traffic. Rapid Set works especially well in underground mining when it is necessary to move in and out of an area quickly.

For information on how your jobs can benefit from Rapid Set cement products, visit **www.ctscement.com**, or contact us at (800) 929-3030 or info@ctscement.com.

CTS Cement Manufacturing Corporation
11065 Knott Avenue, Suite A
Cypress, CA 90630
E-mail: info@ctscement.com
Phone: (800) 929-3030

Crew finishing Rapid Set shotcrete over reinforcing steel

Application of Rapid Set shotcrete on a repair of a highway overpass

2014 AMERICAN SHOTCRETE ASSOCIATION

Buyers Guide

The following list of ASA Corporate Members is current as of October 23, 2014. For a current listing, including the ability to search by seven major specialties (as well as over 100 subspecialties) and states/provinces served, visit the online ASA Buyers Guide at **www.Shotcrete.org/BuyersGuide**.

Name/Address	Contact information	Specialties: Admixtures	Cement/ Pozzolanic Matl	Consulting	Contractor	Equipment	Fibers	Shotcrete Materials/Mixes
Active Minerals International, LLC 34 Loveton Circle Sparks, MD 21152	Website: http://www.activeminerals.com Contact: Joey Bell Phone: 410-512-4120 E-mail: r.bell@activeminerals.com	•	•					
Advanced Shotcrete Inc. 887 N 100 E, Ste 4 Lehi, UT 84043	Website: http://www.advancedshoring.com Contact: Per-Ole Danfors Phone: 801-908-7664 E-mail: pdanfors@advancedshoring.com				•			
Aircrete Systems LP Inc. 4 Industry Way SE Calgary, AB T3S 0A2, Canada	Website: http://aircretesystems.com Contact: Raz Minutoli Phone: 877-984-7379 E-mail: raz@aircretesystems.com			•	•			
Airplaco Equipment Company 4141 Airport Rd Cincinnati, OH 45226-1643	Website: http://www.airplaco.com Contact: Tom Norman Phone: 513-321-4511 E-mail: sales@airplaco.com					•		
AMEC Environment & Infrastructure 4445 Lougheed Hwy, Ste 600 Burnaby, BC V5C 0E4, Canada	Website: http://www.amec.com Contact: John Laxdal, PE Phone: 604-294-3811 E-mail: john.laxdal@amec.com			•				
American Concrete Restorations Inc. 11S375 Jeans Rd Lemont, IL 60439-8839	Website: http://www.americanconcreterestorations.com Contact: Cathy Burkert Phone: 630-887-0670 E-mail: cathy@americanconcreterestorations.com				•			
American Standard Conc Pumping Hawaii Inc. 94-400 Koaki St Waipahu, HI 96797-2874	Website: http://www.ascphi.com Contact: Gregory L. Perrin Phone: 808-479-7867 E-mail: gperrin@ascphi.com			•	•	•		
Apex Testing Laboratories, Inc. 3450 3rd St, Ste 3E San Francisco, CA 94124	Website: http://www.apextestinglabs.com Contact: Abdel-Kader Khelifa Phone: 415-550-9800 E-mail: abdel@apextestinglabs.com			•				
Arco Gunite, Inc. 1448 N Glassell St Orange, CA 92867-3612	Contact: Tammy Counoupas Phone: 714-771-6022 E-mail: arcoguniteinc1976@yahoo.com				•			
Arnold Brothers Inc. 2437 SW Pine Island Rd Cape Coral, FL 33991	Website: http://www.arnoldbrothers.net Contact: Steve Arnold Phone: 239-633-9970 E-mail: keith@arnoldbrothers.net		•	•	•		•	•
ATEK Fine Chemical Co. Ltd. 704 Sangdang-ri, Wonnam-myeon Eumseong-gun Chungcheongbuk-do, NS 369-963, Korea	Website: http://www.atekfc.com Contact: Mi-Jung Kim Phone: 011-82432661985 E-mail: hslee@atekfc.com	•						

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Name/Address	Contact information	Admixtures	Cement/ Pozzolanic Matl	Consulting	Contractor	Equipment	Fibers	Shotcrete Materials/Mixes
		Specialties						
Atlantic Underground Services Ltd. 425 Pine Glen Rd Riverview, NB E1B 4J8, Canada	Website: http://www.ausltd.com Contact: Terry Keiver Phone: 506-387-8160 E-mail: info@ausltd.com				•			
Azteca Gunite 6626 Flintlock Rd Houston, TX 77040-4319	Website: http://www.aztecagunite.com Contact: Ozzie Martinez Phone: 713-462-5566 E-mail: info@aztecagunite.com				•			
Basalite Concrete Products—Vancouver ULC 8650 130th Street Vancouver, BC V3W 1G1, Canada	Website: http://www.basalitedrymix.com Contact: Dennis Ceolin Phone: 604-501-7941 E-mail: dennis.ceolin@paccoast.com	•	•	•			•	•
BASF Admixtures Inc. 23700 Chagrin Blvd Cleveland, OH 44122-5506	Website: http://www.basf-admixtures.com Contact: Jeannine Jones Phone: 216-839-7227 E-mail: jeannine.jones@basf.com	•	•					
Bekaert Corporation 1395 S Marietta Pkwy SE, Bldg 500, Ste 100 Marietta, GA 30067-4440	Website: http://www.bekaert.com Contact: William Geers, PE Phone: 813-313-7759 E-mail: bill.geers@bekaert.com			•			•	
BelPacific Excavating & Shoring Ltd. 3183 Norland Ave Burnaby, BC V5B 3A9, Canada	Website: http://www.belpacific.com Contact: Gregory Samcheck Phone: 604-205-0002 E-mail: greg@belpacific.com			•	•			
The Blanchard Group 2380 Route 315 Dunlop, NB E8K 2J6, Canada	Website: http://www.blanchardgroup.ca Contact: Rene Blanchard Phone: 506-725-2132 E-mail: rene@blanchardgroup.ca							•
Blastcrete Equipment Company PO Box 1964 Anniston, AL 36202-1964	Website: http://www.blastcrete.com Contact: Jim Farrell Phone: 256-235-2700 E-mail: jim@blastcrete.com			•		•		
Bona Vista Pools 40 Shields Court Markham, ON L3R 0M5, Canada	Contact: Melissa Brown Phone: 905-475-6980 E-mail: melissa@bonavistapools.com				•			
Boulderscape Inc. 33081 Calle Perfecto, Ste A San Juan Capistrano, CA 92675-4762	Website: http://www.boulderscape.com Contact: Mark Allen Phone: 949-661-5087 E-mail: steve@boulderscape.com				•			
Brayman Construction Corporation 1000 John Roebling Way Saxonburg, PA 16056-9778	Website: http://www.brayman.com Contact: Brian Hawk Phone: 724-443-1533 E-mail: b_hawk@brayman.com				•			
Buesing Corp. 3045 S 7th St Phoenix, AZ 85040-1170	Website: http://www.buesingcorp.com Contact: Kevin Somerville Phone: 602-233-3339 E-mail: ksomerville@buesingcorp.com			•	•			
BVR Construction Company Inc. 8 King Road Churchville, NY 14428	Contact: Chip Stephenson Phone: 585-458-9750 E-mail: cstephenson@bvrconstruction.com				•			•
California Skateparks 273 N Benson Ave Upland, CA 91786-5614	Website: http://www.californiaskateparks.com Contact: Joseph M. Ciaqlia Jr Phone: 909-949-1601 E-mail: info@californiaskateparks.com			•	•			

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Name/Address	Contact information	Specialties: Admixtures	Cement/ Pozzolanic Matl	Consulting	Contractor	Equipment	Fibers	Shotcrete Materials/Mixes
CanCrete 6290 Shawson Dr Mississauga, ON L5T 1H5, Canada	Website: http://www.cancreteequipment.ca Contact: Eric Duiker Phone: 416-749-2843 E-mail: marcia@cancreteequipment.ca					•		
CCS Group LLC 655 South St, Suite #2 Seward, NE 68434-2439	Website: http://www.ccsgrouponline.com Contact: Cheyenne Wohlford Phone: 855-752-5047 E-mail: cheyenne@ccsgrouponline.com			•	•		•	•
Cemen Tech Inc. 1700 N 14th St Indianola, IA 50125	Website: www.cementech.com Contact: Connor Deering Phone: 800-247-2464 E-mail: cdeering@cementech.com	•				•		
Cheyenne River Spec Mix PO Box 989 Rapid City, SD 57709-0989	Website: http://www.cheyenneriverspecmix.com Contact: Barry Mertes Phone: 605-342-8780 E-mail: bmertes@cheyenneriverspecmix.com		•					•
Clark Foundations, LLC 7500 Old Georgetown Rd Bethesda, MD 20814-6133	Website: http://www.clarkconstruction.com Contact: Irvin Ragsdale Phone: 301-272-8110				•			
Classic Tile & Plaster, LLC 746 Gary Dr Byram, MS 39272	Contact: Jorge De Ochoa Jr. Phone: 601-372-0164 E-mail: jd8a@icloud.com		•	•	•		•	•
Coastal Gunite Construction Company PO Box 977 Cambridge, MD 21613-0977	Website: http://www.coastalgunite.com Contact: R. Curtis White Jr. Phone: 410-228-8100 E-mail: curt@coastalgunite.com				•			
Construction Forms, Inc. PO Box 308 Port Washington, WI 53074-0308	Website: http://www.conforms.com Contact: Jim Bodeker Phone: 800-223-3676 E-mail: jim.bodeker@conforms.com					•		
Contech Services, Inc. PO Box 84886 Seattle, WA 98124-6186	Website: http://www.contechservices.com Contact: Peter Barlow Phone: 206-763-9877 E-mail: pete@contechserviceswa.com				•			
Cowin & Company Inc. PO Box 19009 Birmingham, AL 35219-9009	Website: http://www.cowin-co.com Contact: John J. Cowin Jr. Phone: 205-945-1300 E-mail: jcowinjr@cowin-co.com				•			
The Crom Corporation 250 SW 36th Ter Gainesville, FL 32607-2863	Website: http://www.cromcorp.com Contact: Lars Balck Jr., PE Phone: 352-372-3436 E-mail: lob@cromcorp.com				•			
Crown Valley Pools 725 N Los Robles Ave Pasadena, CA 91104	Contact: Raul Jimenez Phone: 626-796-9980 E-mail: rjcvps@gmail.com			•	•			•
Cruz Concrete & Guniting Repair Inc. 1405 Winesap Dr Manasquan, NJ 08736-4020	Contact: Warren C. Cruz Phone: 732-223-2206 E-mail: cruzconcrete@gmail.com				•			
C-TEC, Inc. 1928 S Lincoln Ave, Suite 100 York, NE 68467-9467	Website: http://www.ctecconcrete.com Contact: Greg Wurst Phone: 402-362-5951 E-mail: ctec@ctecconcrete.com				•			

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Name/Address	Contact information	Specialties						
		Admixtures	Cement/ Pozzolanic Matl	Consulting	Contractor	Equipment	Fibers	Shotcrete Materials/Mixes
CTS Cement Manufacturing Corporation 11065 Knott Ave, Suite A Cypress, CA 90630-5149	Website: http://www.ctscement.com Contact: Nick de Ocampo Phone: 650-773-4795 E-mail: ndeocampo@ctscement.com	•	•					•
Custom Construction & Design Inc. 6158 W 13400 S Herriman, UT 84096	Contact: Daniel A. Olshewski Phone: 801-254-0964 E-mail: ccdinc@xmission.com				•			
Custom Crete Inc. 4433 Terry O Ln Austin, TX 78745-2039	Website: http://www.custom-crete.com Contact: Bill Heath Phone: 512-443-5787 E-mail: bill.heath@oldcastle.com				•	•		•
DBM Contractors, Inc. PO Box 6139 Federal Way, WA 98063	Website: http://dbmcm.com Contact: Sue Wolf Phone: 253-838-1402 E-mail: suew@dbmcm.com				•			
Dees Hennessey Inc. 200 Industrial Rd San Carlos, CA 94070-6257	Website: http://www.deeshenn.com Contact: Daniel M. Evans Phone: 650-595-8933 E-mail: dhi@dees-hennessey.com				•			
Delta Gunite Solano Inc. 1735 Enterprise Dr, Suite #103 Fairfield, CA 94533-6822	Website: http://www.deltagunitesolano.com Contact: Philip Kassis Phone: 707-425-7293 E-mail: deltasolano@sbcglobal.net				•			•
Delta Industrial Services Inc. PO Box 1109 Delta Junction, AK 99737-1109	Website: http://www.deltaindustrial.com Contact: Mike Crouch Phone: 907-895-5053 E-mail: mike@deltaindustrial.com							•
Deluxe Shotcrete & Concrete Construction PO Box 385 Santa Rosa, CA 95402-0385	Website: http://www.deluxeshotcrete.com Contact: Kristen Humphreys Phone: 707-568-1200 E-mail: kristen@deluxeshotcrete.com			•	•			•
DN Tanks 11 Teal Road Wakefield, MA 01880	Contact: Rachelle Graham Phone: 781-224-5102 E-mail: rachelle.graham@dntanks.com				•			
Dome Technology 3007 E 49th N Idaho Falls, ID 83401-1337	Website: http://www.dometech.com Contact: Bryan Butikofer Phone: 208-529-0833 E-mail: butikofer@dometech.com				•			
DOMTEC International LLC 4355 N Haroldsen Dr Idaho Falls, ID 83401-1105	Website: http://www.domtec.com Contact: Ryan Poole Phone: 208-522-5520 E-mail: domtec@domtec.com			•	•			
Donald J. Scheffler Construction 15815 Amar Rd City Of Industry, CA 91744-2107	Website: http://www.donaldschefflerconstruction.com Contact: Donald J. Scheffler Phone: 626-333-6317 E-mail: mailbox@donaldjscheffler.com				•			
Drake Inc. 1919 Road Q Waco, NE 68460-8826	Website: http://www.drakeinc.net Contact: David Drake Phone: 402-362-1863 E-mail: davedrake@windstream.net				•			
Drakeley Industries LLC 74 Hickory Ln Bethlehem, CT 06751-2308	Website: http://www.drakeleypools.com Contact: William T. Drakeley Jr. Phone: 203-263-7919 E-mail: bill@drakeleypools.com			•	•			

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		Admixtures	Cement/ Pozzolanic Matl	Consulting	Contractor	Equipment	Fibers	Shotcrete Materials/Mixes
Drill Tech Drilling & Shoring, Inc. 2200 Wymore Way Antioch, CA 94509-8548	Website: http://www.drilltechdrilling.com Contact: Ryan Nagle Phone: 925-978-2060 E-mail: ryan@drilltechdrilling.com			•	•			
Eastco Shotcrete, LLC 1211 Kennedy Blvd Manville, NJ 08835	Website: http://www.eastcoastshotcrete.com Contact: Tommy Pirkle Phone: 908-526-2777 E-mail: tommy@eastcoastshotcrete.com				•			
Eastern Gunite Company Inc. PO Box 557 Exton, PA 19341-0557	Website: http://www.easterngunite.com Contact: Thomas F. Lyons Phone: 610-524-5590 E-mail: egunite@easterngunite.com				•			
Elasto Plastic Concrete PO Box 460 Waxhaw, NC 28173-1047	Website: http://www.elastoplastic.com Contact: Patrick Lewandowski Phone: 704-843-8401 E-mail: plewandowski@elastoplastic.com			•			•	
Elkin Hi Tech Inc. 1700 N 14th St Indianola, IA 50125	Website: http://www.elkinhitech.com Contact: Frank Holuta Phone: 724-349-6300 E-mail: elkin@elkinhitech.com					•		
Engineering & Construction Innovations Inc. 7012 6th St N Oakdale, MN 55128-6146	Website: http://www.eandci.co Contact: Shane McFadden Phone: 651-298-9111 E-mail: shane@eandci.co				•			
Epoxy Design Systems Inc. PO Box 19485 Houston, TX 77224-9485	Website: http://www.epoxydesign.com Contact: Hank Taylor Phone: 713-461-8733 E-mail: hank@epoxydesign.com			•	•			
Extreme Concrete Cutting of Gaffney LLC 115 Madison Ave Gaffney, SC 29340-4710	Contact: Christopher H. Myles Phone: 864-649-1111 E-mail: chrismyles@themylesgroup.com	•	•	•	•	•	•	•
Facca Incorporated 2097 County Rd 31 RR 1 Ruscom Station, ON N0R 1R0, Canada	Website: http://www.facca.com Contact: Don Gardonio Phone: 519-975-0377 E-mail: don@facca.com				•			
Fenton Rigging & Contracting Inc. Fenton Gunite Shotcrete Div. 225 Stone Mill Rd Jacksboro, TN 37757-4000	Website: http://www.fentonrigging.com Contact: Michael Milton Phone: 423-566-9909 E-mail: mmiltonhb@aol.com			•	•			•
Fibercon International Inc. 100 S 3rd St Evans City, PA 16033-9264	Website: http://www.fiberconfiber.com Contact: Nicholas Mitchell Jr. Phone: 724-538-5006 E-mail: nick@fiberconfiber.com				•		•	
Forta Corporation 100 Forta Dr Grove City, PA 16127-6308	Website: http://www.fortacorp.com Contact: Daniel T. Biddle Phone: 800-245-0306 E-mail: info@fortacorp.com						•	
Fred Pavlow Co. dba Add A Garage 2776 Broadway St San Francisco, CA 94115	Contact: Ken Bloch Phone: 415-760-9565 E-mail: no1garageman@yahoo.com				•			
Freyssinet Inc. 44880 Falcon Place, Suite 100 Sterling, VA 20166	Contact: Michael Louis Phone: 703-378-2500 E-mail: michael.louis@freyssinetusa.com				•			

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Name/Address	Contact information	Specialties						
		Admixtures	Cement/ Pozzolanic Matl	Consulting	Contractor	Equipment	Fibers	Shotcrete Materials/Mixes
Frontier-Kemper Constructors Inc. 1695 Allen Rd Evansville, IN 47710-3394	Website: http://www.frontierkemper.com Contact: Jim McMahon Phone: 812-426-2741 E-mail: jmcmahon@frontierkemper.com				•			
GA & FC Wagman, Inc. 3290 N Susquehanna Trl York, PA 17406	Website: http://www.wagman.com Contact: Russ Ringler Phone: 540-955-4034 E-mail: rhringler@wagman.com				•			
Gary Carlson Equipment Co. 1380 West County Road C Roseville, MN 55113	Website: http://www.garycarlsonequip.com Contact: Gary R. Carlson Phone: 763-792-9123 E-mail: garycarlson@garycarlsonequip.com			•		•		
Genesis 3, Inc. 110 Blossoms Ct Murfreesboro, TN 37129-3252	Website: http://www.genesis3.com Contact: Brian Van Bower Phone: 615-907-1274 E-mail: lisa@genesis3.com			•	•			
Georgia Gunite and Pool Company 828 Victoria Place Woodstock, GA 30189	Contact: Tina Davis Phone: 770-926-5150 E-mail: tina@georgiagunite.com				•			
Geostabilization International PO Box 4709 Grand Junction, CO 81502-4709	Website: http://geostabilization.com Contact: Kimberly Ruckman Phone: 970-210-6170 E-mail: kim@gsi.us				•			
Getman Corporation 59750 34th Ave Bangor, MI 49013-1259	Website: http://www.getman.com Contact: Gene L. Lomboy Phone: 269-427-5611 E-mail: glomboy@getman.com					•		
Gib-San Pools Ltd. 21 Milvan Dr Toronto, ON M9L 1Y8, Canada	Website: http://www.gibsanpools.com Contact: Edward D. Gibbs Phone: 416-749-4361 E-mail: ed@gsplc.ca			•	•			
Graciano Corporation 209 Sigma Drive Pittsburgh, PA 15238	Website: http://www.graciano.com Contact: Dave Sinclair Phone: 412-963-8400 x10155 E-mail: dsinclair@graciano.com				•			
Group Works LLC PO Box 7269 Wilton, CT 06897-7269	Website: http://www.groupworksllc.com Contact: James Scott Phone: 203-834-7905 E-mail: jamie@groupworksllc.com			•	•			
Gunite Specialists Inc. 152 Mathers Rd Ambler, PA 19002-4100	Website: http://www.gunitespecialists.com Contact: David Reeves Phone: 610-239-0988 E-mail: info@gsipoolfinishes.com				•			
Gunite Supply & Equipment Co. 1726 S Magnolia Ave Monrovia, CA 91016-4511	Website: http://www.gunitesupply.com Contact: Chris Marston Phone: 888-393-8635 E-mail: casales@gunitesupply.com					•		
Haggerty Pools 1 Emerald St Norwalk, CT 06850	Website: http://www.haggertypools.com Contact: Roger Haggerty Phone: 203-348-6899 E-mail: rhaggerty@haggertypools.com			•	•	•		
Hayward Baker Inc.—Craig Olden Division PO Box 5000 Little Elm, TX 75068-9000	Website: http://www.oldeninc.com Contact: Trevor Bray Phone: 972-294-5000 E-mail: tbray@haywardbaker.com			•	•			

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Name/Address	Contact information	Specialties						
		Admixtures	Cement/ Pozzolanic Matl	Consulting	Contractor	Equipment	Fibers	Shotcrete Materials/Mixes
Hayward Baker Inc. 515 Nine North Ct Alpharetta, GA 30004-2961	Website: http://www.haywardbaker.com Contact: Ryan Smith Phone: 770-442-1801 E-mail: rtsmith@haywardbaker.com				•			
HC Matcon Inc. Unit 4, 122 Earl Thompson Rd Ayr, ON N0B 1E0, Canada	Website: http://www.hcgroup.ca Contact: Martin Halliwell Phone: 519-623-6454 E-mail: martinh@hcgroup.ca				•			
Horseshoe Hill Construction Inc. 34 Nixon Rd Bolton, ON L7E 1W2, Canada	Website: http://www.hhcinc.ca Contact: Gordon Tozer Phone: 905-857-7400 E-mail: gord.tozer@hhcinc.ca				•			
Hydro Arch 900 W Warm Springs Rd, Ste 106 Henderson, NV 89011	Website: http://www.hydro-arch.com Contact: Andrea Scott Phone: 702-566-1700 E-mail: jmoore@hydro-arch.com				•			
Interconcrete Limited 836 Regional Road 90 Sudbury, ON P3L 1V9, Canada	Website: http://interconcrete.ca Contact: Mark Corner Phone: 705-694-6250 E-mail: mark.corner@interconcrete.ca			•	•		•	•
J Tortorella Swimming Pools Inc. 1764 County Road 39 Southampton, NY 11968-5204	Website: http://www.tortorella.com Contact: Joe Tortorella Phone: 631-728-1380 E-mail: info@tortorella.com	•		•	•			•
JE Tomes & Associates 2513 140th Pl Blue Island, IL 60406-3588	Website: http://www.jetomes.com Contact: Joseph E. Tomes Phone: 708-653-5100 E-mail: joe@jetomes.com	•	•					•
John Rohrer Contracting Company Inc. 2820 Roe Ln Kansas City, KS 66103-1543	Website: http://www.johnrohrercontracting.com Contact: Brandon D. McMullen Phone: 913-236-5005 E-mail: brandon@johnrohrercontracting.com				•			
K & G Concrete Inc. 2564 La Croix Dr Roseville, CA 95661	Website: http://kgconcretepumping.com Contact: Herman Keaven Guillory Phone: 916-539-6652 E-mail: keaven@kgconcretepumping.com	•	•	•	•	•	•	•
KHM Inc. PO Box 2672 Binghamton, NY 13902-2672	Contact: Kathleen Hall Phone: 607-773-0076 E-mail: khmwbe1989@stny.rr.com				•			
King Packaged Materials Company 3385 Harvester Rd PO Box 699 Burlington, ON L7R 3Y5, Canada	Website: http://www.kingshotcrete.com Contact: Joe Hutter Phone: 905-639-2993 E-mail: jhutter@kpmindustries.com					•	•	•
Knowles Industrial Services Corp. 295 New Portland Rd Gorham, ME 04038-1867	Website: http://www.knowlesindustrial.com Contact: Dan Maloney Phone: 207-854-1900 E-mail: dmaloney@knowlesindustrial.com				•			
Kryton International Inc. 1645 East Kent Ave Vancouver, BC V5P 2S8, Canada	Website: http://www.kryton.com Contact: Sarah Rippin Phone: 604-324-8280 E-mail: info@kryton.com	•						

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Name/Address	Contact information	Specialties: Admixtures	Cement/ Pozzolanic Matl	Consulting	Contractor	Equipment	Fibers	Shotcrete Materials/Mixes
Lafarge North America 20 Oak Hallow, Ste 260 Southfield, MI 48033	Website: http://www.lafargenorthamerica.com Contact: Ken Kazanis Phone: 248-594-1991 E-mail: ken.kazanis@lafarge-na.com		•	•				
Lanford Brothers Company Inc. PO Box 7330 Roanoke, VA 24019	Website: http://www.lanfordbrothers.com Contact: Patrick McDaniel Phone: 540-992-2140 E-mail: patm@lanfordbros.com				•			
Lehigh Cement Company/White Cement Div. 7660 Imperial Way Allentown, PA 18195-1016	Website: http://www.lehighwhitecement.com Contact: Larry Rowland Phone: 610-366-4600 E-mail: lrowland@lehighcement.com		•					
LRL Construction Co. Inc. PO Box 432 Tillamook, OR 97141	Website: http://www.lrlconstruction.com Contact: Denis Laviolette Phone: 503-842-5520 E-mail: info@lrlconstruction.com			•	•			
MacLean Engineering & Marketing Co. Ltd. 1000 Raglan St Collingwood, ON L9Y 3Z1, Canada	Website: http://www.macleanengineering.com Contact: Steve Czerny Phone: 705-445-5707 E-mail: sczerny@macleanengineering.com					•		
Mar-Allen Concrete Products Inc. 490 Millway Rd Ephrata, PA 17522-9528	Contact: Jeffrey L. Zimmerman Phone: 717-859-4921 E-mail: jlzimmerman@marallen.com				•			
The Marksmen Company 705 E Ordnance Rd, Suite 107 Baltimore, MD 21226-1760	Contact: Mark D. Miller Phone: 410-355-6080 E-mail: markmiller@marksmenco.com				•			
Mays Construction Specialties Inc. 2399 Riverside Parkway Grand Junction, CO 81505	Website: http://www.mays-mcsi.com Contact: Kyle R. Vanderberg Phone: 970-245-0834 E-mail: kvanderberg@mays-mcsi.com				•			
Metro Testing Laboratories Ltd. 6991 Curragh Ave Burnaby, BC V5J 4V6, Canada	Website: http://www.metrotesting.ca Contact: Neil McAskill Phone: 604-436-9109 E-mail: nmcaskill@metrotesting.ca			•				
Mid American Gunite Pools Inc. 1607 Eastern Ave Covington, KY 41014-1325	Website: http://www.midamericanpools.com Contact: Patrick M. Brennan Phone: 859-581-8566 E-mail: pool1boss@fuse.net				•			
Minova North America 150 Carley Ct Georgetown, KY 40324-9303	Website: http://www.minovausa.com Contact: Bryan Pfaff Phone: 678-634-9626 E-mail: bryan.pfaff@minovaint.com							•
Mosites Construction Company 4839 Campbells Run Road Pittsburgh, PA 15205	Website: http://www.mosites.com Contact: Erik Bertrand Phone: 412-923-2255 E-mail: erikb@mosites.com				•			
Multicrete Systems Inc. Unit 360, 555 Hervo St Winnipeg, MB R3T 3L6, Canada	Website: http://www.multicretesystems.com Contact: Georg B. Nickel, PE Phone: 204-262-5900 E-mail: gnickel@multicretesystems.com	•	•	•	•	•	•	•

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Name/Address	Contact information	Specialties: Admixtures	Cement/ Pozzolanic Matl	Consulting	Contractor	Equipment	Fibers	Shotcrete Materials/Mixes
The Nassal Company 415 W Kaley St Orlando, FL 32806-3942	Website: http://www.nassal.com Contact: Melissa Ruminot Phone: 407-648-0400 E-mail: mruminot@nassal.com			•	•			
Nathan Contracting 3996 Mt Royal Blvd Allison Park, PA 15101	Website: http://www.nathancontracting.com Contact: Nate Scigliano Phone: 412-487-7077 E-mail: nate@nathancontracting.com				•			
National Gunite Inc. 111 Roosevelt Blvd Johnstown, PA 15906-2736	Website: http://www.nationalgunite.com Contact: Lee Taylor Phone: 814-533-5780 E-mail: ltaylor@nationalgunite.com				•			
National Pools of Roanoke Inc. 3112 Melrose Ave NW PO Box 6354 Roanoke, VA 24017-5916	Website: http://www.nationalpools.com Contact: Jason Vaughan Phone: 540-345-7665 E-mail: jason@nationalpools.com				•			
Nationwide Shotcrete Inc. 23638 Lyons Ave, Ste 273 Newhall, CA 91321-2513	Website: http://nationwideshotcrete.com Contact: Jordan Harpole Phone: 661-799-3750 E-mail: jon@nationwideshotcrete.com			•	•			
NBIS 800 Overlook III 2859 Paces Ferry Road Atlanta, GA 30339	Website: http://www.nbis.com Contact: Lisa McAbee Phone: 866-668-NBIS E-mail: lmcabee@nbis.com			•				
New Line Skateparks Inc. 3-6923 Farrell Road SE Calgary, AB T2H 0T3, Canada	Website: http://www.newlineskateparks.com Contact: Dwayne Mazereeuw Phone: 403-697-5990 E-mail: dwayne@newlineskateparks.com			•	•			
Normet Americas Inc. 19116 Spring St Union Grove, WI 53182-9602	Website: http://www.normet.fi Contact: Chris Gause Phone: 262-878-5760 E-mail: chris.gause@normet.fi	•	•	•		•		
Northwest Cascade Inc. PO Box 73399 Puyallup, WA 98374	Website: http://www.nwcascade.com Contact: Douglas Watt Phone: 253-848-2371 E-mail: dougwatt@nwcascade.com				•			
Olin Engineering Inc. 15622 Computer Ln Huntington Beach, CA 92649-1608	Website: http://www.olinpump.com Contact: David O. Swain Phone: 714-897-1230 E-mail: dave@olinpump.com					•		
Olympic Pool Plastering & Shotcrete 2850 Simpson Circle Norcross, GA 30071	Contact: Shawn Still Phone: 770-409-1125 E-mail: smstill@olympicpool.net			•	•			•
Oscar Orduno, Inc. 5550 LBJ Freeway, Ste 525 Dallas, TX 75240	Website: http://www.oscarordunoinc.com Contact: Oscar Orduno Phone: 469-291-7981 E-mail: oorduno@oscarordunoinc.com				•			
Osco Gunite & Mudjacking Ltd. 5920 98 St NW Edmonton, AB T6E 3L5, Canada	Website: http://www.shotcreting.com Contact: Larry Hnatiuk Phone: 780-469-1234 E-mail: osco@mudjacking.com				•			
Palmetto Gunite Construction Company Inc. PO Box 388 Ravenel, SC 29470-0388	Website: http://www.palmettogunite.com Contact: Thomas A. Hendricks Phone: 843-889-2227 E-mail: tommy@palmettogunite.com				•			

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Name/Address	Contact information	Specialties						
		Admixtures	Cement/ Pozzolanic Matl	Consulting	Contractor	Equipment	Fibers	Shotcrete Materials/Mixes
PCI Roads LLC 14123 42nd St NE Saint Michael, MN 55376-9564	Website: http://www.pciroads.com Contact: Dave Graham Phone: 763-497-6100 E-mail: dgraham@pciroads.com				•			
PLI Systems, Inc. 3045 SE 61st Ct Hillsboro, OR 97123-3113	Website: http://www.plisystems.com Contact: Manuel Castaneda Phone: 503-649-8111 E-mail: peter@plisystems.com				•			
Polycrete Restorations Ltd. 202-204 Cayer Street Coquitlam, BC V3K 5B1, Canada	Website: www.polycreterestorations.com Contact: Balraj Mann Phone: 604-521-4300 E-mail: info@polycreterestorations.com			•	•			
The Pool Company Inc. 3077 20th St E, Suite D Tacoma, WA 98424	Website: http://www.thepoolcompanyinc.com Contact: Michael Basford Phone: 253-926-6875 E-mail: mick@thepoolcompanyinc.com			•	•			
Pool Engineering Inc. 1201 N Tustin Ave Anaheim, CA 92807-1646	Website: http://www.pooleng.com Contact: Ron Lacher Phone: 714-630-6100 E-mail: ronl@pooleng.com			•	•			
Power Shotcrete Shoring Ltd. 109-8918 Holt Rd Surrey, BC V4N 3S2, Canada	Website: http://www.powercivil.ca Contact: Kirk Gilchrist Phone: 604-597-1112 E-mail: nadink@powercivil.ca			•	•			
Precon Marine Inc. 1401 Precon Dr, Ste 102 Chesapeake, VA 23320-6314	Website: http://www.preconmarine.com Contact: Matthew Miller Phone: 757-545-4400 E-mail: agemmell@preconmarine.com				•			
Preload Inc. 49 Wireless Blvd, Suite 200 Hauppauge, NY 11788-3946	Website: http://www.preload.com Contact: Donald Cameron Phone: 631-231-8100 E-mail: dgc@preloadinc.com				•			
Prestige Concrete Products 7228 Westport Pl West Palm Beach, FL 33413-1683	Website: http://www.prestige-gunite.com Contact: Greg McFadden Phone: 561-478-9980 E-mail: gwmcfadden@prestige-concrete.com			•	•			•
ProShot Concrete Inc. 4158 Musgrove Dr Florence, AL 35630-6396	Website: http://www.proshotconcrete.com Contact: Patrick A. Mooney Phone: 256-764-5941 E-mail: patm@proshotconcrete.com				•			
Pullman-Shared Systems Technology, Inc. 127 Salem Ave West Deptford, NJ 08086-2076	Website: http://www.pullman-services.com Contact: Doug Rose Phone: 856-449-0902 E-mail: drose@pullman-services.com				•			
Putzmeister Iberica S A Camino de Hormigueras 173 Madrid 28031, Spain	Website: http://www.putzmeister.es/shotcrete Contact: Christine Krauss Phone: 011-34914288097 E-mail: kraussc@putzmeister.es					•		
Putzmeister Shotcrete Technology 1733 90th St Sturtevant, WI 53177-1805	Website: http://putzmeistershotcrete.com Contact: Robert J. Harmon Phone: 610-909-9519 E-mail: harmonb@putzam.com					•		

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Name/Address	Contact information	Specialties						
		Admixtures	Cement/ Pozzolanic Matl	Consulting	Contractor	Equipment	Fibers	Shotcrete Materials/Mixes
The Quikrete Companies 8530 Delaware Ave North Huntingdon, PA 15642	Website: http://www.quikrete.com/shotcrete Contact: Dennis Bittner Phone: 412-759-1333 E-mail: dbittner@quikrete.com		•					•
Quikspray, Inc. PO Box 327 Port Clinton, OH 43452	Website: http://www.quikspray.com Contact: T. Park McRitchie Phone: 419-732-2611 E-mail: park@quikspray.com					•		
Quorum Construction (BC) Ltd. 5350 272nd Street Langley, BC V4W 1S3, Canada	Contact: Corinne Jacobsen Phone: 604-607-8888 E-mail: cjacobsen@quorumgroup.net							
Ram Construction Services 13800 Eckles Rd Livonia, MI 48150-1041	Website: http://www.ramservices.com Contact: Tom Szabo Phone: 734-464-3800 E-mail: tszabo@ramservices.com			•	•			
Ram Jack of Charlotte, LLC PO Box 2991 Huntersville, NC 28070-2991	Website: http://www.ramjackcharlotte.com Contact: Mark Beckham Phone: 704-892-2900 E-mail: markramjack@bellsouth.net				•			
REED Shotcrete Equipment 13822 Oaks Ave Chino, CA 91710-7008	Website: http://www.reedpumps.com Contact: Mike Newcomb Phone: 909-287-2100 E-mail: mike.newcomb@reedmfg.com					•		
Repcrete Concrete Repairs & Cont. Co. PO Box 45962 Abu Dhabi, United Arab Emirates	Contact: Khaled Naddeh Phone: 01197126336128 E-mail: repcrete@emirates.net.ae				•			
Restek Inc. 6601 Boucher Dr Edmond, OK 73034-8582	Website: http://www.restekinc.net Contact: Ellery N. Brown Phone: 405-330-3950 E-mail: restek@flash.net				•			
Restoration East, LLC 4209 E Chase St Baltimore, MD 21205-3020	Website: http://www.restorationeast.com Contact: Louis Helmacy Phone: 410-563-4972 E-mail: louh@restorationeast.com				•			
RG Johnson Company Inc. 25 S College St Washington, PA 15301-4821	Website: http://www.rgjohnsoninc.com Contact: Tom Crooks Phone: 724-222-6810 E-mail: tom@rgjohnsoninc.com				•			•
Riverdale Mills Corp. PO Box 200 Northbridge, MA 01534-0200	Website: http://www.riverdale.com Contact: Christine Albone Phone: 800-762-6374 E-mail: lrwalsh@riverdale.com						•	
Robinson Concrete Pumping 1698 SE Deer Creek Dr Roseburg, OR 97470-3701	Contact: Rob Robinson Phone: 541-677-6444 E-mail: rcp@q.com				•			
Royal Enterprises 30622 Forest Blvd Stacy, MN 55079-8005	Website: http://www.royalenterprises.net Contact: Steve Bahe Phone: 651-462-6918 E-mail: sbahe@royalenterprises.net						•	
Russo Corporation 1421 Mims Avenue SW Birmingham, AL 35211	Website: http://www.russocorp.com Contact: Harris Wilson Phone: 205-923-4434 E-mail: hwilson@russocorp.com			•	•			

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Name/Address	Contact information	Specialties						
		Admixtures	Cement/ Pozzolanic Matl	Consulting	Contractor	Equipment	Fibers	Shotcrete Materials/Mixes
San Joaquin Gunite 5868 E Mustang Clovis, CA 93619	Website: http://www.sanjoaquingunite.com Contact: Scott Santellan Phone: 559-285-8965 E-mail: h55quad@aol.com				•			•
Schnabel Foundation Company 2950 S Jamaica Ct, Ste 107 Aurora, CO 80014-2686	Website: http://www.schnabel.com Contact: Todd Duncan Phone: 303-696-7268 E-mail: todd@schnabel.com				•			
Schwing America, Inc. 5900 Centerville Rd Saint Paul, MN 55127	Website: www.schwing.com Contact: Jason Zignego Phone: 651-429-0999 E-mail: tgoodroad@schwing.com					•		
Shotcrete Africa SCP (Pty) Ltd. PO Box 1709 Jukskei Park, NS 2153, South Africa	Website: http://www.shotcrete.co.za Contact: Dustin Strever Phone: 011-27110274337 E-mail: dustin@shotcrete.co.za		•	•	•	•	•	•
Shotcrete Auckland Ltd. PO Box 64439 Auckland, NS 2014, New Zealand	Contact: Glenn Tira Phone: 011-6421701807 E-mail: glenn@shotcrete.co.nz	•			•	•	•	•
Shotcrete Helmet PO Box 430 Stn Main Paris, ON N3L 3T5, Canada	Website: http://www.shotcretehelmet.com Contact: The St. George Company Phone: 519-442-2046 E-mail: info@shotcretehelmet.com					•		
Shotcrete Montana 19 S Woodard Absarokee, MT 59001-0685	Website: http://www.shotcretemt.com Contact: Lucille Mooney Phone: 406-328-7344 E-mail: lucille@shotcretemt.com				•	•	•	•
Shotcrete Systems Inc. 12965 San Fernando Rd Sylmar, CA 91342-3695	Website: www.shotcreteinc.com Contact: Rob Vonarb Phone: 818-833-1293 E-mail: rob@shotcreteinc.com				•			
Shotcrete Technologies Inc. PO Box 3274 Idaho Springs, CO 80452-3274	Website: http://www.shotcretetechnologies.com Contact: Kristian Loevlie Phone: 303-567-4871 E-mail: kristian@shotcretetechnologies.com	•	•	•	•			
Sika Corporation 201 Polito Ave Lyndhurst, NJ 07071-3601	Website: http://www.sikaconstruction.com Contact: Ketan Sompura Phone: 201-508-6698 E-mail: sompura.ketan@sika-corp.com	•	•					
South Industries 910 Twin Butte Road Menan, ID 83434	Website: http://www.southindustries.com Contact: Josh South Phone: 208-754-4422 E-mail: traci@southindustries.com				•			
South Shore Gunite Pools & Spas Inc. 7 Progress Ave Chelmsford, MA 01824-3606	Website: http://www.ssgpools.com Contact: Robert E. Guarino Phone: 800-649-8080 E-mail: rguarino@southshoregunitepools.com			•	•			
Southwest Contracting Ltd. 9426 - 192nd Street Surrey, BC V4N 3R9, Canada	Website: http://www.southwestcontracting.ca Contact: Scott MacCara Phone: 604-888-5221 E-mail: admin@southwestcontracting.ca				•			
Southwest V-Ditch Inc. 3625 Placentia Ln Riverside, CA 92501-1119	Website: http://www.swvditch.com Contact: Bob Shepherd Phone: 951-781-4303 x18 E-mail: mail@swvditch.com				•			

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Name/Address	Contact information	Specialties: Admixtures	Cement/ Pozzolanic Matl	Consulting	Contractor	Equipment	Fibers	Shotcrete Materials/Mixes
SPB Torkret Ltd. sp. z o. o. Spółka komandytowa, ul. Grabowa 8 Siekierki Wielkie, Wielkopolska 62-025 Poland	Website: http://www.torkret.com.pl Contact: Wlodzimierz Czajka Phone: 486-189-7810 x2 E-mail: czajka@torkret.com.pl			•	•			
Spec Mix Inc. 1230 Eagan Industrial Rd, Suite 160 Eagan, MN 55121-1293	Website: http://www.specmix.com Contact: Leah Cory Phone: 651-994-7120 E-mail: nblohowiak@specmix.com					•		•
SprayForce Concrete Services Ltd. 10 Brander Ave NW Langdon, AB T0J 1X2, Canada	Website: http://www.sprayforceconcrete.com Contact: Jay Unruh Phone: 403-936-0178 E-mail: info@sprayforceconcrete.com			•	•			
Stone Valley Construction Inc. 132 Coaldale Rd Philipsburg, PA 16866-2333	Contact: Ken Knepp Phone: 814-342-7151 E-mail: kknepp@stone-valley.com			•	•			
Strata Mine Services 67925 Bayberry Dr Saint Clairsville, OH 43950-9132	Website: http://www.strataworldwide.com Contact: Richard Werth Phone: 740-695-6880 E-mail: rwerth@stratamineservices.com				•			
Structural Shotcrete Ltd. 18453 67a Avenue Surrey, BC V3S 9B3, Canada	Contact: Lorne Rutt Phone: 604-575-2563 E-mail: lorne@structuralshotcrete.ca				•			
Structural Shotcrete Systems Inc. 12645 Clark St Santa Fe Springs, CA 90670-3951	Website: http://www.structuralshotcrete.com/index.html Contact: Jason Weinstein Phone: 562-941-9916 E-mail: jason1@structuralshotcrete.com				•			
StructureWerks 12600 Robin Ln, Ste 100 Brookfield, WI 53005-3124	Website: http://www.structurewerks.com Contact: Ross Preschat Phone: 262-781-4329 E-mail: rpreschat@structurewerks.com			•	•			
Subsurface Construction Company 1107 Fuller Street Raleigh, NC 27603	Website: http://www.subsurfaceconstruction.com Contact: Alex Smith Phone: 919-857-4609 E-mail: alex@subsurfaceconstruction.com				•			
Suburban Maintenance & Construction Inc. 16330 York Rd North Royalton, OH 44133-5551	Website: http://www.smciconstruction.com Contact: Eric Urdzik Phone: 440-237-7765 E-mail: eric.smci@gmail.com				•			
Sunwest Gunite Co. 7045 Luella Anne Dr NE Albuquerque, NM 87109-3907	Website: http://www.sunwestguniteco.com Contact: Gary O'Canna Phone: 505-821-2549 E-mail: garyocanna@gmail.com			•	•			
Superior Gunite / JW Gunite Company 940 Doolittle Dr San Leandro, CA 94577-1021	Website: http://www.shotcrete.com Contact: Larry J. Totten Phone: 510-568-8112 E-mail: larryt@jwgunite.com				•			
Takao Nagai Concrete Restoration 1755 W Armitage Ave Chicago, IL 60622-1163	Contact: Donald Redar Phone: 773-645-2061 E-mail: tabbott@bulley.com				•			
Terra Engineering & Construction Corporation 2201 Vondron Rd Madison, WI 53718	Website: http://www.whyterra.com Contact: Gary F. Zimmerman Phone: 608-210-3918 E-mail: gzimmerman@whyterra.com				•			

Name/Address	Contact information	Specialties: Admixtures	Cement/ Pozzolanic Matl	Consulting	Contractor	Equipment	Fibers	Shotcrete Materials/Mixes
Testing, Engineering & Consulting Services Inc. 235 Buford Dr Lawrenceville, GA 30046-4945	Website: http://www.tecservices.com Contact: James Glenn McCants III Phone: 770-995-8000 E-mail: tmccants@tecservices.com			•				
Texaloy Foundry Company Inc. PO Box 37 Floresville, TX 78114-0037	Website: http://www.texaloy.com Contact: Jack Rice Phone: 800-367-6518 E-mail: jrice@texaloy.com					•		
Thiessen Team USA Inc. PO Box 40 Elko, NV 89803-0040	Website: http://www.thiessenteam.com Contact: James Schumacher/Jessica Florence Phone: 775-777-1205 E-mail: jschumacher@thiessenteam.com	•		•	•	•	•	•
Top Gun of Virginia Inc. 10017 Richmond Hwy Lorton, VA 22079-2421	Website: http://www.topgungunite.com Contact: Jon Slaunwhite Phone: 703-550-9207 E-mail: info@topgungunite.com				•			
Top Shot Concrete Inc. 3807 Arthur Rose Avenue Saskatoon, SK S7P 0C7, Canada	Website: http://www.topshotconcrete.com Contact: Pat Donovan Phone: 306-242-4155 E-mail: pat@topshotconcrete.com	•	•	•	•	•	•	•
Topcor Services Inc. 12025 Industriplex Blvd Baton Rouge, LA 70809-5131	Website: http://www.topcor.com Contact: James M. Baker Phone: 225-753-7067 E-mail: jbaker@topcor.com			•	•			
Torrent Shotcrete Structures Ltd. #207-53 West Hastings Street Vancouver, BC V6B 1G4, Canada	Website: http://torrentshotcrete.com Contact: Gary Hawkins Phone: 778-239-4722 E-mail: garyh@torrentshotcrete.com				•			
Truesdell Corporation 1310 W 23rd St Tempe, AZ 85282-1837	Website: http://www.truesdellcorp.com Contact: Kurt Clink Phone: 602-437-1711 E-mail: kclink@truesdellcorp.com				•			
Turnstone Construction, Inc. 7004 180th Ave NE Redmond, WA 98052	Website: http://www.turnstoneconstruction.com Contact: John Fulford Phone: 425-881-0218 E-mail: john@turnstoneconstruction.com				•			
U S Concrete Products LLC 16 Greenmeadow Dr, Ste 202 Timonium, MD 21093-3231	Website: http://www.uscproducts.com Contact: Edward Brennan Phone: 410-561-8770 E-mail: ebrennan@uscproducts.com	•	•					•
Vancouver Shotcrete & Shoring Inc. #105 - 10185 199B Street Langley, BC V1M 3W9, Canada	Website: http://www.shotcreteshoring.com Contact: Rabi Gill Phone: 604-881-4898 E-mail: info@shotcreteshoring.com			•	•			
Venus Engineering LLC Office 303 New Bushaqar Building Near GGICO Metro Station Garhoud Deira, Dubai 115436, UAE	Website: http://www.veng.ae Contact: Mahdi S. Hanna Phone: 011-97142999015 E-mail: info@veng.ae				•		•	
Western Shotcrete Equipment Inc. HC 1 Box 193 Fairdealing, MO 63939-9708	Website: http://www.wseshotcrete.com Contact: Joe Harpole Phone: 573-857-2085 E-mail: josephharpole@wseshotcrete.com					•		

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Name/Address	Contact information	Specialties: Admixtures	Cement/ Pozzolanic Matl	Consulting	Contractor	Equipment	Fibers	Shotcrete Materials/Mixes
Whiteside Construction Corporation 1151 Hensley St Richmond, CA 94801-2162	Website: http://www.wesconshotcrete.com Contact: David Whiteside Phone: 510-234-6681 E-mail: drw@whitesideconstruction.com				•			
Wildcat Concrete Services Inc. PO Box 750075 Topeka, KS 66675-0075	Website: http://wildcatcompanies.com/concrete.html Contact: Stuart R. Johnson Phone: 785-233-1400 E-mail: stuartj@wildcatconcrete.com				•			
Wurster Engineering & Construction 34 Carrie Dr Greenville, SC 29615-5611	Website: http://www.wursterinc.com Contact: Daryl Wurster Phone: 964-627-7751 E-mail: daryl.wurster@wursterinc.com				•			
Xtreme Shotcrete 166 Woodside Ave Winthrop, MA 02152-2063	Website: http://xtremeshotcretema.com Contact: Michael Anthony Whitehead Phone: 617-846-3191 E-mail: whitehead0015@aol.com				•			


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• Over 17,000 readers
• Rates remain unchanged since 2012
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2015 Media Kit

New ASA Members

CORPORATE MEMBERS

Brayman Construction Corporation
www.brayman.com
Saxonburg, PA
Primary contact: Brian Hawk
b_hawk@brayman.com

CanCrete
www.cancreteequipment.ca
Mississauga, ON, Canada
Primary contact: Eric Duiker
eric@cancreteequipment.ca

Freyssinet Inc.
Sterling, VA
Primary contact: Michael Louis
michael.louis@freyssinetusa.com

Graciano Corporation
www.graciano.com
Pittsburgh, PA
Primary contact: Dave Sinclair
dsinclair@graciano.com

Shotcrete Systems Inc.
www.shotcreteinc.com
Sylmar, CA
Primary contact: Rob Vonarb
rob@shotcreteinc.com

CORPORATE ADDITIONAL INDIVIDUALS

Sarah A. Burress
Active Minerals
International
Sparks, MD

INDIVIDUALS

Ephraim Renno
Upright Krete Works
Denver, PA

STUDENTS

Sumanth Cheruku
Austin, TX

Sayyed Ali Dadvar
Esfahan, Iran

Benjamin Dymond
Minneapolis, MN

Farnam Ghasemzadeh
Raleigh, NC

AMERICAN SHOTCRETE ASSOCIATION

INTERESTED IN BECOMING A MEMBER OF ASA?
Read about the benefits of being a member of ASA on page 86 find a Membership Application on page 87.

AMERICAN SHOTCRETE ASSOCIATION

ASA Membership Benefits

	Corporate	*Corporate - Additional Individual*	Supporting Asscociation	Individual	Nozzleman	Employees of Public Authorities / Agencies	Student
Annual Dues	$750	$100	$500	$250	$50	Free	Free
Company & specialty information listed in ASA's online Buyers Guide and in hard copy via *Shotcrete*'s annual Buyers Guide	X						
Discount on ACI Shotcrete Nozzleman Certification and Education	X						
Opportunity to submit items for Industry News and New Products & Processes sections of *Shotcrete* magazine at no charge	X	X	X	X		X	
Discounted ASA Member prices on all ASA products	X	X	X	X	X	X	X
Networking and participation opportunities at Annual Membership Meeting and committee meetings	X	X	X	X	X	X	X
Opportunity to respond to bids from our Online Project Bid Submittal Tool	X	X					
Subscription to quarterly *Shotcrete* magazine (hard and electronic copy)	X	X	X	X	X	X	X*
Links to shotcrete-related government projects open for bid *(sent twice a month in the member edition of the ASA e-newsletter)*	X	X		X	X	X	X
Permission to include ASA logo on corporate letterhead and business cards	X	X		X		X	
Permission to display ASA logo on company website	X						
Discounted pricing on advertising in *Shotcrete* magazine, including free linked logo advertising from the ASA website homepage during your advertising quarter	X	X	X	X		X	
Voting privileges at meetings and director/officer elections	X	X		X			
Discounted advance general admittance registration to World of Concrete	X	X	X	X	X	X	X
Opportunity to submit entries for the annual Outstanding Shotcrete Project Awards Program	X						
Free Onsite Learning Seminars upon request			X			X	
Discounted Corporate Additional ASA Memberships are available for all company employees ($150 savings per employee)							
Discount on ASA Underground Shotcrete Education Program	X						
Complimentary copy of ASA's Shotcrete Specifiers Education Tool—a 4GB USB flashdrive	X					X	
Complimentary copy of "Sustainability of Shotcrete" each year	1		1			1	
Complimentary copy of ASA's "Safety Guidelines for Shotctete" in either protected pdf or hard-copy format	1						
Complimentary copy of ASA's Annual Nozzlemen Compilation each year					1		
Complimentary ASA shotcrete brochure each year	25	1	X**	1		1	
Complimentary ASA reflective hardhat sticker each year	10	1		1	1		
Education & promotion of your shotcrete industry to the overall concrete industry	**X**	**X**	**X**	**X**	**X**	**X**	**X**

* Student members outside North America will only receive electronic copies
**Upon request; limit 25 copies per year.

AMERICAN SHOTCRETE ASSOCIATION

38800 Country Club Dr., Farmington Hills, MI 48331
Phone: (248) 848-3780 Fax: (248) 848-3740
E-mail: info@shotcrete.org Web site: www.shotcrete.org

MEMBERSHIP APPLICATION

Name ______________________ Title ______________________

Company ______________________ Sponsor (if applicable) ______________________

Address ______________________

City / State or Province / Zip or Postal Code ______________________

Country ______________ Phone ______________ Fax ______________

E-mail ______________________ Web site ______________________

Please indicate your category of membership:

❏ Corporate	$750	
❏ Individual	$250	
❏ Additional Individual from Corporate Member	$100	
❏ Employees of Public Authorities and Agencies	Free	
❏ Nozzleman	$50	
❏ Retired	$50	(For individuals 65 years or older)
❏ Student	Free	(Requires copy of Student ID card or other proof of student status)

NOTE: Dues are not deductible as charitable contributions for tax purposes, but may be deductible as a business expense.

Payment Method:

❏ MC ❏ Visa ❏ Check enclosed (U.S. $)

Card# ______________________ Expiration date ______________

Name on card ______________________ Signature ______________________

Company Specialties—Corporate Members Only

Company Specialties are searchable in the printed and online Buyers Guide.

Admixtures
❏ Accelerating
❏ Air Entraining
❏ Foaming
❏ Retarding
❏ Shrinkage Compensating
❏ Special Application
❏ Stabilizing
❏ Water Proofing
❏ Water Reducing-Accelerate
❏ Water Reducing-High Range
❏ Water Reducing-Mid Range
❏ Water Reducing-Normal
❏ Water Reducing-Retarding
❏ Water Repellent

Cement/Pozzolanic Materials
❏ Cement-Blended
❏ Cement-Portland
❏ Cement-White
❏ Fly Ash
❏ Ground/Granulated Slag
❏ Metakaolin
❏ Pozzolan
❏ Silica Fume-Dry
❏ Silica Fume-Slurry

Consulting
❏ Design
❏ Engineering
❏ Forensic/Troubleshooting
❏ Project Management
❏ Quality Control Inspection/Testing
❏ Research/Development
❏ Shotcrete/Gunite
❏ Skateparks

Contractors
❏ Architectural
❏ Canal Lining
❏ Culvert/Pipe Lining
❏ Dams/Bridges
❏ Domes
❏ Flood Control/Drainage
❏ Foundations
❏ Grouting
❏ Lagoons
❏ Mining/Underground
❏ Parking Structures
❏ Pumping Services
❏ Refractory
❏ Repair/Rehabilitation
❏ Residential

Contractors, contd.
❏ Rock Bolts
❏ Rock Carving
❏ Seismic Retrofit
❏ Sewers
❏ Skateparks
❏ Slope Protection/Stabilization
❏ Soil Nailing
❏ Storage Tanks
❏ Structural
❏ Swimming Pools/Spas
❏ Tunnels
❏ Walls
❏ Water Features

Equipment
❏ Accessories
❏ Adaptors
❏ Air Vibrators
❏ Bowls
❏ Clamps
❏ Compressors
❏ Couplings
❏ Feeder/Dosing
❏ Finishing
❏ Grouting

Equipment, contd.
❏ Guide Wires
❏ Gunning Machines
❏ Hoses
❏ Mixers
❏ Nozzles
❏ Pipe/Elbows/Reducers
❏ Plastering
❏ Pre-Dampers
❏ Pumps
❏ Robotic
❏ Safety/Protection
❏ Silo Systems
❏ Valves
❏ Wear Plates

Fibers
❏ Carbon
❏ Glass
❏ Steel
❏ Synthetic

Shotcrete Materials/Mixtures
❏ Dry Mix
❏ Steel-Fiber Reinforced
❏ Synthetic-Fiber Reinforced
❏ Wet Mix

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