# Shotcrete MAGAZINE

A quarterly publication of the American Shotcrete Association

Volume 13, Number 3 ◆ Summer 2011

www.shotcrete.org

# Specifications & Evaluation


At King, we take pride in the fact that every bag of shotcrete we produce delivers the quality and consistency to satisfy even the most demanding shotcrete contractors. This pride also extends to our team of technical experts who are available to support you on any project. For all of your shotcrete needs, big or small, King delivers.

**www.kingshotcrete.com**

*KING PACKAGED MATERIALS COMPANY*

1 800 461-0566

www.kpmindustries.com

constructionproducts@kpmindustries.com

KING

*Mixing Strength With Satisfaction*

Circle #29 on reader response form—page 64

*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:

**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**



# Shotcrete MAGAZINE

Volume 13, Number 3
Summer 2011

## Features



## Departments



*On the cover: Placing and finishing structural shotcrete walls against one-sided forms, as specified. Photo courtesy of Johnson Western Gunite.*

# Member Participation

*By Patrick Bridger*

Our last ASA committee meetings were held on April 2 in the wonderful city of Tampa, FL. I'm pleased to say that attendance was the best I've ever seen at any of our meetings in recent years. I don't think the venue had anything to do with the attendance, but Tampa is a very nice place to go in the springtime. It was encouraging to see some new faces at the committee meetings and the Board of Directors meeting—a special thank-you goes out to Tom, Paul, Cathy, and Mason. In addition to the specific work of each ASA committee, the meetings provide each of us an opportunity to discuss and learn about the many different uses of shotcrete. The meetings are also an excellent chance to meet and learn from fellow shotcrete professionals while building a network of contacts and resources.

I frequently have the opportunity to speak with many ASA members who rarely or never attend the ASA committee meetings. I am surprised to hear that some of them are unsure about attending and participating with some of the long-time members who are regular attendees. I encourage each and every reader with the interest and ability to travel to attend any ASA function. I assure you that you will be welcomed and your opinions/input will be encouraged and valued. The next ASA committee meetings are scheduled for October 15, 2011, in Cincinnati, OH. You may want to consider staying for a few days after the ASA meetings to sit in on some of the ACI shotcrete committee meetings as well.

With a major review and improvement of ASA's policies regarding education and certification for the ACI Shotcrete Nozzleman Certification program now completed, we have a renewed focus on the important work being done by each ASA committee.

As a reader of *Shotcrete* magazine, you are probably most familiar with the efforts of the ASA Publications Committee. The Publications Committee's primary responsibility is this magazine. The committee is continually selecting themes for each issue, coordinating authors for feature articles, and managing content for the many regularly occurring columns and features. *Shotcrete* is **our** message board for the American shotcrete industry and beyond with a readership of over 17,000 in over 100 countries! In addition, advertising in *Shotcrete* is a great way to make the industry aware of your business. Please contact Ted Sofis, Publications Committee Chair, if you are interested in contributing future content to this wonderfully executed publication.

There are so many exciting initiatives underway within the ASA committees that we have decided to add a new feature to *Shotcrete.* The ASA Committee Chair Memo debuts in this issue. The memo will rotate among the ASA Committee Chairs and give our readers a chance to learn about each committee, the work they are engaged in, and the reasons to become involved with the committee. I am sure you will enjoy the first edition of the new feature from Bill Drakeley, the newly appointed Chair of the Pool & Recreational Shotcrete Committee. Bill has many exciting ideas, including plans for ASA to host an Outreach Forum during the 2011 International Pool | Spa | Patio Expo in Las Vegas, NV, at the Mandalay Bay Convention Center and Casino Hotel. The Outreach Forum will help shape and refocus the role ASA plays in the pool and watershapes industry. The forum is open to anyone interested in pool and spa construction using shotcrete, and I'm sure this will prove to be an interesting discussion for those who attend. Mark your calendar and plan to meet in Jasmine E on Level 3 of the Mandalay Bay South Convention Hall on Wednesday, November 2, 2011, at 5:00 p.m. Pacific time.

In addition to committee activity, I want to remind our readers and members about the Annual ASA Outstanding Shotcrete Project Awards program. Each year, up to six awards are presented to recognize innovative projects in which shotcrete plays a significant role. This is an opportunity not only for contractors, but also suppliers and engineering firms to submit applications for outstanding projects that they have been associated with. It's always interesting to see the project submittals and award winners who do such a good job of demonstrating the quality, versatility, and sustainability benefits of the shotcrete process. I encourage you to submit one or more projects for the Seventh Annual Outstanding Shotcrete Project Awards using ASA's new online application, which has greatly simplified the application process. Please visit **www.shotcrete.org** and submit your application by September 1, 2011. Don't miss this outstanding opportunity to showcase your organization and its work in the industry.

Our association comprises contractors, engineers, suppliers, and others with a vested interest in promoting the infinite uses of the process of spraying concrete. Since the inception of ASA, I have seen this industry grow by leaps and bounds. Shotcrete is accepted as a construction method and is now in the forefront of many construction projects around the world. We have all benefited from the work of this association over the last 10+ years. With strong and growing member participation, we will continue to increase the awareness of this construction method and its many benefits.

# Message from the Publications Chair

*We at the American Shotcrete Association (ASA) are very proud of the inclusive nature of our organization. ASA includes—among its members—engineers, contractors, manufacturers, and suppliers who work in the various shotcrete-related fields. Shotcrete is an important method of efficiently placing cement-based materials in many different industries and for a variety of installations. Shotcrete is widely used for bridge rehabilitation, pool building, slope stabilization; the creation of artificial rock features, culverts, arches, tunnels, dams; and in mines and many varied industrial applications. For this reason, we have several committees covering safety, publications, education, sustainability, marketing, underground, and pool and recreational shotcrete to address issues in various aspects of work in the shotcrete industry. In the upcoming issues of* Shotcrete *magazine, we are creating a new column in which the Chair of each committee will address a topic or issue on a rotating basis that is relevant to the committee's work. The intent of this is to inform the readers of what each committee is working on and to include and engage those of you who work in those areas of the shotcrete industry. We encourage and welcome your involvement in ASA. Hopefully, you will find the features interesting and informative.*

*Sincerely,*
*Ted W. Sofis*

# Pool Shotcrete: Shotcrete for the Pool Industry

*Bill Drakeley*

As the new ASA Pool & Recreational Shotcrete Committee Chair, I thought it might be a good idea to take a look at the current state of our spraying process. Legitimate acceptance by the end user and/or design professionals requires us to constantly reevaluate and reassess to stay ahead of all things (structurally) in pool building. There has recently been an increase in pool shotcrete teachings or print-related "how to's," which has reaffirmed our organizational lead role in structural concrete applications using the shotcrete process. As of 2011, the Pool & Recreational Shotcrete Committee is taking a stance as an industry leader by evaluating who we are now and where we are going.

## Pool & Recreational Shotcrete Committee

Growth and success as a committee is only as good as our membership participation. As of February 2011, we have a total of 31 corporate members who, in some way or another, build or aid in the construction of shotcrete swimming pools. Of the total membership, only a handful (at best) have consistent participation and only a few actually attend yearly Pool & Recreational Shotcrete Committee meetings. With these numbers, it's hard to gain any momentum as a proactive group and, more importantly, as a resource for pool construction. Knowing this, ASA is now promoting an Outreach Forum during the International Pool | Spa | Patio Expo in Las Vegas. This meeting will allow ASA to share its processes with the pool construction industry and address specific needs brought to the forum from pool builders. The full agenda will be made available on ASA's Web site in the weeks immediately preceding the meeting.

## Positions

To begin our group foundation as the standard-bearers for shotcrete resources, we need to first promote basic accepted values. With that said, ASA's Pool & Recreational Shotcrete Committee and Board of Directors have reestablished a 4000 psi (27.6 MPa) minimum for compression strength concrete used for pool construction. This benchmark is nothing new. ACI 318-08 shows these durability requirements in Table 4.2.2. Pool construction is concrete placed via the shotcrete process. Water-retaining concrete has different exposure conditions and is meant to have a low permeability based on these conditions. By referring to Table 4.2.2, one can see the direction and positions our committee is taking. ASA and its Pool & Recreational Shotcrete Committee will be establishing (like the following example) benchmark performance criteria for all things shotcrete that necessitate watertight performance.

Basically, the idea is to have a watertight pool shell prior to any surface application. We feel that this minimum value (4000 psi [27.6 MPa]) is more than an adequate start to watertight concrete. There are a few commercial pool designers that have a watertight tank test as part of the bid process. The tank test specifically requires the contractor to fill a pool with water in its concrete state after curing but before plaster or surface application. This test ensures that the concrete is

**Table 4.2.2—Requirements for Special Exposure Conditions**

| Exposure condition | Maximum water-cementitious material ratio ($w/cm$)* by weight, normalweight concrete | Minimum $f_c'$, normalweight and lightweight concrete, psi (MPa)* |
|---|---|---|
| Concrete intended to have low permeability when exposed to water | 0.50 | 4000 (27.6) |
| Concrete exposed to freezing and thawing in a moist condition or to deicing chemicals | 0.45 | 4500 (31) |
| For corrosion protection of reinforcement in concrete exposed to chlorides from deicing chemicals, salt, saltwater, brackish water, seawater, or spray from these sources | 0.40 | 5000 (34.5) |

*When Table 4.2.2 is considered, the lowest applicable maximum $w/cm$ and highest applicable minimum $f_c'$ shall be used.

watertight for the owner. George Yoggy, a founding member of ASA and modern-day shotcrete expert, describes watertight shotcrete applications as such:

"Spraying concrete onto a surface at high velocity is, in theory, the perfect concrete placement method. Individual aggregate particles of various sizes, coated with cement paste, are driven into place to form a void-free mass of fully compacted concrete. This strong, dense, well-bonded material is ideal for rock and ground support, linings, and liquid retaining structures."

Pool strengths less than 4000 psi (27.6 MPa) directly indicate that the process has not been implemented correctly. Engineering and/or specifying anything less than 4000 psi (27.6 MPa) indicates that:

1. The specifier does not truly understand the shotcrete process or is purposely degrading it; and
2. This is an indefensible position to be in if and when failures occur.

The ASA Pool & Recreational Shotcrete Committee members will be creating position modules/papers designed for the pool sector. Specifically, we will be addressing the structural shotcrete process not only in terms of psi values but also mixture designs and application methods. We will also make recommendations regarding the pool structure as it relates to shotcrete (such as substrate characteristics of forms or steel work with regard to concrete implementations, testing methods, curing proceedings, and so on).

## Certification

An aid in the effort to promote good shotcrete practices is the ACI Nozzleman Certification Program. This certification, when coupled with an ASA education session, is a great resource package for nozzleman knowledge. The pool sector itself is slowly but surely coming around on the importance of certification. Educational forums such as the International Pool | Spa | Patio Expo, Genesis 3 Construction School, and the Atlantic City/NESPA show curriculum have had speakers supporting and promoting the benefits of the ACI Nozzleman Certification Program.

Currently, 150 individuals are certified in the dry-mix process (gunite) for the vertical position and 700 individuals are certified in the wet-mix process for the vertical position. These numbers include all industries. The pool sector is a small fraction of these total numbers and frankly needs more participation. A refresher on ACI nozzleman certification will be made at the ASA Outreach Forum in Las Vegas.

## Going Forward

The next order of business is for all those involved or interested to meet and discuss the direction of the shotcete process through ASA. Mark your calendars for the beginning of November and the International Pool | Spa | Patio Expo in Las Vegas. The ASA Outreach Forum will take place in Jasmine E on Level 3 of the Mandalay Bay South Convention Hall on Wednesday, November 2, 2011, at 5:00 p.m. Pacific Time. There is no cost to attend the forum. We (the shotcrete community) will have an opportunity to come together and become unified, giving our product and positions the correct set of core values. One message—one industry-unified voice with clarity and conviction—will eliminate ignorance and make shotcrete construction the preferred choice in concrete applications.

There are no more excuses for being uninformed. With our set values and certification program, any guesswork in pool construction should be eliminated; and we as a group can collectively raise the bar.

### ASA Pool & Recreational Shotcrete Committee

Bill Drakeley, Chair

Oscar Duckworth
Roberto Guardia
Mason Guarino
Ron Lacher
Chris Marston
David Morowit
Tom Norman
Raymond Schallom
James Scott
Joe Tortorella
Marcus von der Hofen
Jerry Werner
Lihe Zhang
Chris Zynda

# A Tough Decision and New Opportunities

*By Chris Darnell, ASA Executive Director*

*Melissa McClain*

Many of you reading this, especially if you are a member of ASA, know and appreciate our Administrative Assistant, Melissa McClain. Melissa has been with ASA for over 4 years and has been an integral part of ASA's efforts and successes. Of the many fine qualities and abilities Melissa has brought to ASA, perhaps the most important has been her concern and commitment to the success of ASA and its members. In other words, Melissa has always truly cared about ASA and that care is clearly evident in her work.

In the past year, a number of issues have directly impacted Melissa's position and the focus of her work. At the top of this list was the reorganization of ASA certification/education operations. In addition, a new Executive Director was appointed 2 years ago. Not surprisingly, Melissa not only accepted the resulting changes and new challenges, but also embraced them. Her understanding of the potential benefits and strong desire to make ASA succeed was critical to the advancements and achievements realized in recent years.

Earlier this year, Melissa received the joyous news that she and her husband are expecting their third daughter this summer. With child care plans in place, preparations were made for Melissa's maternity leave and return in the fall to her evolving position.

In late spring, Melissa and her husband found out about a fundamental change in a family member's plans that would directly impact their child care plans. After much family discussion and analysis, Melissa had to make the very difficult decision to step down from her position this summer and take on an even more important and challenging role—caring for three little girls under the age of four.

As I mentioned previously, Melissa's decision to leave was a very difficult one. She has truly enjoyed her work, particularly the relationships she has developed with the volunteers who make up ASA.

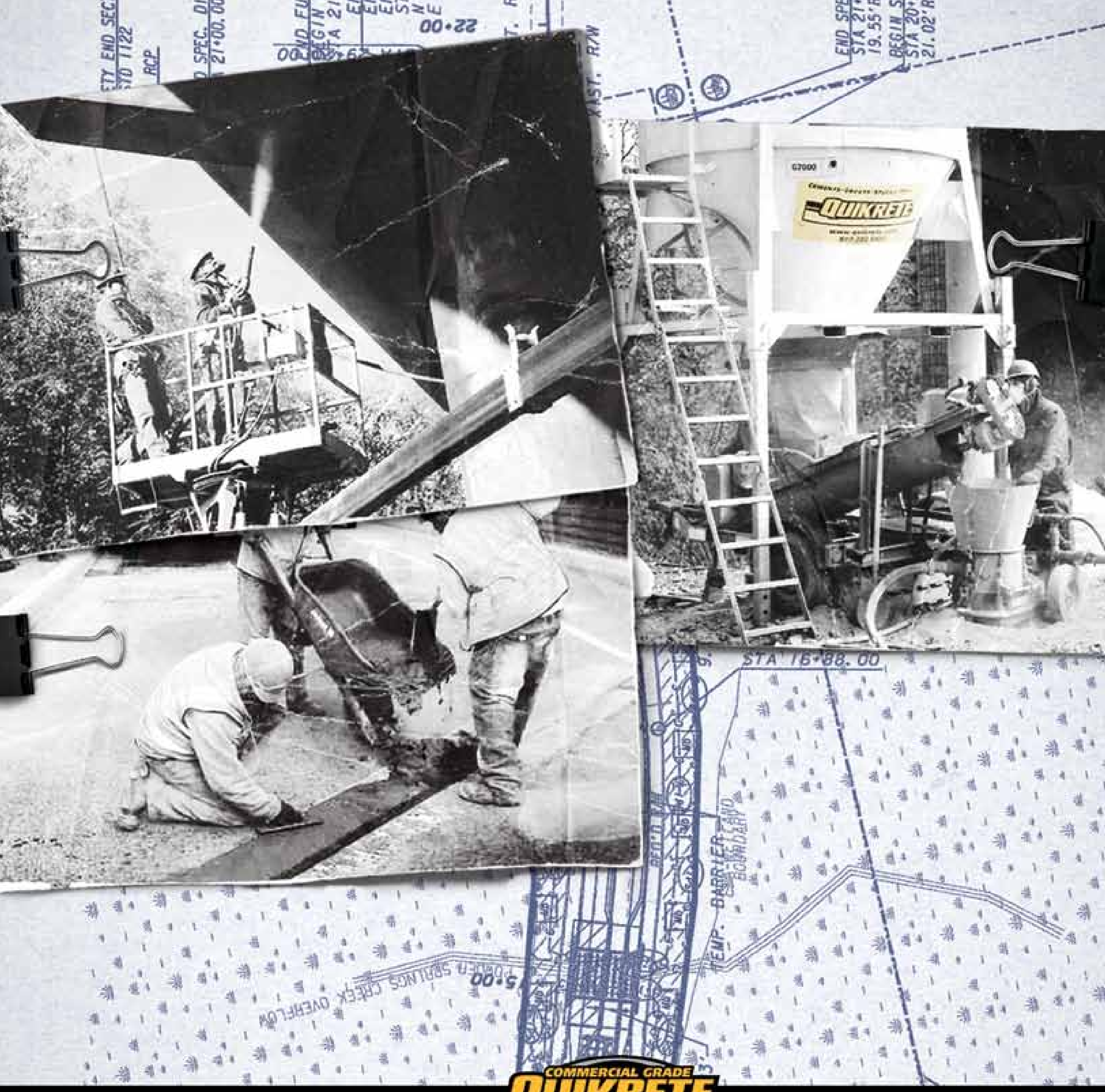
While losing Melissa will be a challenge for the ASA staff, we will directly benefit from the framework she has put in place and the expanded role of her position that she was working to develop. Melissa has helped us put changes in place that were originally planned for late 2011. ASA is changing the position's title to Programs Coordinator to more accurately reflect the actual responsibilities and work being performed. More of the day-to-day administrative/processing work previously included in this position is being moved to others to allow for the additional expansion of duties within the position. This restructured position will play a big part in the future growth of ASA and the services it provides the shotcrete industry.

By the time this issue is in print, we will have selected the best possible candidate to serve as ASA's Programs Coordinator. We plan to introduce that person in the fall issue of *Shotcrete* magazine.

Unfortunately, by the time you read this, Melissa will have left ASA and will be fully engaged in the next stage of her life. ASA's loss is definitely a big gain for three special little girls.

Melissa, on behalf of ASA and an especially appreciative Executive Director, thank you for all your efforts. They have been significant and you will be missed! May God bless and keep you and your growing family safe and well!

*Any messages and well wishes for Melissa can be sent to info@shotcrete.org and we will make sure they are forwarded to her.*





Circle #5 on reader response form—page 64

# Shotcrete Testing—Who, Why, When, and How

*By Charles S. Hanskat*

## Who Needs It?

If you are an architect or engineer (A/E) who routinely uses shotcrete in your projects, you likely already know why, when, and how to specify shotcrete. Sorry, this article probably won't be giving you much new information; but it should be a great refresher.

There are many examples of construction team professionals, however, who may not be as knowledgeable in specifying testing of shotcrete and should find this article of distinct interest.

Are you one of these?

- The specifying A/E involved in a new project where the owner has suggested shotcrete or industry standard designs include something called "shotcrete"; or
- An A/E responsible for the field administration of an existing project and the contractor have suggested the value engineering use of shotcrete instead of cast concrete for some of the structural components of the job; or
- You are a design-build contractor and one of your subcontractors is using shotcrete in his portion of the project; or
- An owner who is concerned about the quality and durability of your project; or
- A shotcrete contractor and neither the owner nor the specifier has included testing in the project.

Thus, the short answer to the question "Who needs it?" is everyone involved in designing, producing, placing, and evaluating shotcrete in a concrete structure.

## Why Test Shotcrete?

So why do we want to test shotcrete? The primary goal of any testing is to confirm that the shotcrete placed meets the project requirements. This is a quality control (QC) issue for the material supplier and contractor and a quality assurance (QA) issue for the owner and A/E.

But isn't shotcrete just concrete that is placed at a high velocity using air pressure? Don't the usual concrete tests work? The answer is yes and no, and the answer depends on whether we are using dry- or wet-mix shotcrete and whether we are evaluating hardened shotcrete in-place or using a sample for lab testing.

In wet-mix shotcrete, the concrete mixture is either batched and delivered by a ready mix concrete supplier or maybe mixed on site and fed directly to the shotcrete pump. The concrete is then pumped to the nozzle at the end of the delivery hose where air pressure "shoots" the material out of the hose and onto the structure. With wet-mix shotcrete, testing of the fresh concrete material after batching would certainly follow the same testing requirements as cast-in-place concrete. This would include items such as slump, air content, unit weight, and temperature. Further, it may be advisable to take several test cylinders of the batched concrete to have a representative sample of the concrete as delivered.

Dry-mix shotcrete is an entirely different process where air pressure is used throughout the length of the delivery hose to convey a dry mixture of cementitious material and aggregate to the nozzle. Water isn't added to the dry mixture until it enters the nozzle at the end of the shotcrete delivery hose. Immediately after passing by the water jets in the nozzle, the dry-mix shotcrete is shot onto the structure surface. Thus, there is no batch of fresh, wet concrete material to test for the routine concrete tests.

## When and How Do We Test?

There are three distinct times that shotcrete testing is needed:

- Preconstruction;
- During construction at the time of placement; and
- After hardening and appropriately cured and aged.

### Preconstruction Testing

Many projects use preconstruction test panels when the project has heavy, congested reinforcing in the structural sections to be shot (refer to Fig. 1). The test panels are fabricated to mirror the types of congestion that are to be expected in the project. They are used to qualify three different aspects of the shotcrete: 1) the material being shot; 2) the equipment used for shooting; and 3) the nozzleman doing the shooting. Thus, for test panels to accurately reflect each aspect, the actual shotcrete mixtures, equipment, and nozzlemen for the project must be used.

Separate test panels should be used for mixture proportion evaluation and for nozzleman qualification. ACI 506R-05 recommends mixture proportion test panels measuring 24 x 24 x 3-1/2 in. (610 x 610 x 90 mm) with flared sides and no reinforcement. The nozzleman qualification test panels should be large enough to simulate the actual project conditions with a minimum size of 30 x 30 x 3 in. (760 x 760 x 75 mm) and use reinforcing that models the size and complexity of reinforcement to be shot on the project. The orientation of the panels (horizontal, vertical, or overhead) should also match the orientation of the work on the project (refer to Fig. 2). Once the shotcrete has sufficiently hardened and aged, both types of test panels are then cored to provide 3 in. (75 mm) diameter cores (refer to Fig. 3) for evaluation of the quality of encasement or for further laboratory testing. The unreinforced cores should be tested for compressive strength. ACI 506.2-95, "Specification for Shotcrete," lists contractor requirements for testing.

Preconstruction test panels may also be used to provide architectural "mockups" of the completed shotcrete color and surface finishes. Architectural panels would need to be shot with the same mixture proportions (including admixtures) and then finished with the same techniques to be used on the project. A minimum size of an architectural mockup panel should be 30 x 30 x 3 in. (760 x 760 x 75 mm). Different sizes may be needed, however, to give the full effect of a particular surface treatment. An architectural mockup helps the owner, A/E, and contractor agree on what the final product will look like before it is used on a project.

Finally, in the preconstruction period, the wet-mix shotcrete mixture proportions may be tested. Concrete mixture designs are often provided from previous experience of the concrete supplier or the testing laboratory doing the mixture design. When new components are used in a shotcrete mixture, however, such as new suppliers for supplementary cementitious materials (SCMs) or different combinations of admixtures (such as retarders, high-range water-reducing admixtures [HRWRAs], and accelerators), it may be prudent to evaluate the mixture before testing on site. Test batches of a proposed mixture may be cast in standard cylinders or forms and then tested at the appropriate age. The mixture proportioning tests may include simple 28-day compressive strength or more advanced properties such as set time, very-early-age strength (for example, 8-hour strength has been used in some tunnel work) or drying shrinkage potential.

## Testing during Construction at Time of Placement

One of the most important times to test shotcrete is during construction at the time of placement. At this time in the construction work,

*Fig. 1: A typical preconstruction test panel with congested reinforcement*

*Fig. 2: Overhead shooting*

*Fig. 3: Coring of a test panel*

*Fig. 4: A typical shotcrete test panel being shot during construction*

we are most interested in the fresh shotcrete properties. It is also the time we produce test panels for subsequent testing of the hardened shotcrete properties.

Testing of fresh shotcrete helps to confirm that important aspects of the specified mixture proportions have been met and the temperature of the shotcrete does not exceed the specified maximums. This testing generally does not verify the amount of cementitious materials or aggregates in the mixture. Thus, it is highly recommended that each delivery of concrete include on the delivery ticket a record of water, admixtures, cement, SCMs, and aggregates used in producing that specific batch and not just repeating the theoretical mixture design. Any water added on site should also be noted on the delivery ticket by the driver.

For wet-mix shotcrete, where the concrete is batched before pumping, sampling of the concrete before pumping would include these fresh concrete properties:

- Slump (ASTM C143);
- Air content (ASTM C231 or ASTM C173);
- Concrete temperature (ASTM C1064/C1064M); and
- Density (ASTM C138).

These fresh concrete properties are readily tested using current ASTM standards. These tests can also be performed on concrete created with prebagged shotcrete mixtures that are mixed on site.

Also, during shotcrete placement, test panels will be made for determining the hardened shotcrete properties after appropriate curing and aging of the panels. Test panels will be produced for each mixture, each nozzleman, and each work day or for every 50 yd$^3$ (38 m$^3$) of shotcrete placed, whichever results in the most panels. These test panels should be at least 16 x16 in. (400 x 400 mm) with a depth of at least 3 to 5 in. (75 to 125 mm) and are generally shot in a vertical orientation (refer to Fig. 4), unless the project needs to dictate shooting in another orientation.

Even though shotcrete test panels will be produced for either wet- or dry-mix shotcrete to determine hardened shotcrete properties, it would also be advisable to periodically prepare standard cylinders (6 x 12 in. [150 x 300 mm] or 4 x 8 in. [100 x 200 mm]) for each concrete mixture as delivered before pumping. These cylinders should be field cured on site. The cylinders do not need to be tested and could be considered as an insurance policy. They can be invaluable if shotcrete problems arise on the project and one must try to determine whether the problem was caused by the concrete materials, the ready mix supplier, or some flaw in the shotcreting application.

## After Hardening and Appropriately Cured and Aged

Hardened shotcrete properties are normally determined by laboratory testing. Usually, samples are extracted from the previously prepared test panels. Cores may also be extracted from the in-place structure for testing. Care must be exercised, however, in taking cores to be sure no critical reinforcement is severed in the coring process or the compressive capacity of the cored member is significantly decreased.

The most common test on hardened shotcrete is the compressive strength at 28 days of cores taken from the test panels (ASTM 1604/C1604M). Some applications also require particular compressive strengths at less than the 28-day period. This is common in underground applications and in some structures with early post-tensioning requirements. The compressive strength is considered adequate if the average of the three cores from a test panel or from in-place shotcrete exceeds 85% of the specified compressive strength and no single core is less than 75% of the specified compressive strength.

Bond strength testing may be required when shotcrete is required to adhere to a previously existing material. Bond strength is tested using the provisions of ASTM C1583/C1583M. Common acceptance criteria for bond strength is that the average of the bond strength of the specified number of cores should exceed the specified minimum strength and no single core bond strength should be less than 75% of the specified strength.

Flexural properties are usually only required for fiber-reinforced shotcrete (FRS). When FRS is specified, flexural strength is evaluated using beams sawed from test panels tested in accordance with ASTM C1609/C1609M and for residual strength in accordance with

ASTM C1609/C1609M or ASTM C1399/C1399M. For toughness, tests should be in accordance with ASTM C1550.

Boiled absorption and the volume of permeable voids testing (ASTM C642) may be required for structures that need enhanced liquid tightness or resistance to aggressive environmental exposures. The test is sometimes used to provide an overall indication of the quality of the shotcrete mixture, particularly in dry-mix shotcrete. Many factors, however, including admixtures, aggregate, and shotcrete placing, can affect the porosity of shotcrete, so it should not be considered an absolute measure of shotcrete quality. When required, the mean average of tests on three specimens from a test panel, or from in-place shotcrete, should be less than or equal to the specified boiled absorption and/or the specified volume of permeable voids limits at the specified test age with no single test greater than the specified boiled absorption plus 1%.

Drying shrinkage of the shotcrete can be tested using general provisions of ASTM C157. Because the shotcrete is shot into a large panel and not into the relatively small mold specified by ASTM for the shrinkage test beam, it is recommended that a beam approximately 11.25 in. (285 mm) in length be sawed from a test panel. As most shotcrete uses coarse aggregate less than 1 in. (25 mm), a 3 in. (75 mm) thick panel with a 3 in. (75 mm) wide cut should approximate the ASTM requirements. The A/E should specify in the contract documents drying shrinkage limits that are appropriate for the design of the structure.

## Other Testing

When problems are suspected in shotcrete placed in a structure, the evaluation of the potential deficiencies can be conducted identically to the methods used for normal cast concrete. This may include nondestructive testing such as ultrasonic pulse velocity, impact echo, impulse response, or ground-penetrating radar. A Windsor Probe may be used for evaluating in-place strength.

Also, with partial or full-depth cores, the shotcrete material may be evaluated with petrography or further chemical or physical tests. Petrography can give information on in-place air content, estimated water-cementitious material ratio (*w*/*cm*), quantity of cementitious material, presence of alkali-silica reaction (ASR), or delayed ettringite formation (DEF), as well as the evaluation of the general quality of the concrete paste and aggregate matrix. Advanced chemical analysis can yield information on potential detrimental contaminants, such as chlorides and sulfates, in the concrete. Finally, additional physical tests for shear, tension, and compression can be conducted on cores extracted from the structure.

## Resources for Specifiers and Additional Information

ACI 506 is the technical committee charged with producing standards, specifications, guides, and reports that deal with all aspects of shotcrete. Current ACI 506 documents include:

- ACI 506R, "Guide to Shotcrete"—This is a nonmandatory guide to all aspects of shotcrete design and construction. It has some excellent guidance on both materials and testing of shotcrete. A revision to the guide is under active development by the committee and is due out soon.
- ACI 506.1R, "Guide to Fiber-Reinforced Shotcrete"—This nonmandatory report focuses on the benefits and use of fiber-reinforced shotcrete.
- ACI 506.2, "Specification for Materials, Proportioning, and Application of Shotcrete"—This mandatory specification provides requirements to contractors using shotcrete on projects. Specifiers should review the document in full and determine what portions apply to their specific project. The mandatory and optional checklist items in the document provide guidance to the specifier on items that must be specified (mandatory) in the contract documents and those that should be considered (optional). Although the currently available version is from 1995, a new version of the specification should be available later in 2011 or early 2012.
- ACI 506.4R, "Guide for the Evaluation of Shotcrete"—A nonmandatory report focused on procedures used to evaluate the quality and properties of in-place shotcrete. This has some good information, although it is somewhat dated.
- ACI 506.5R, "Guide for Specifying Underground Shotcrete"—If you are specifying underground shotcrete, this should be a document you review thoroughly. It is the most current ACI 506 document and gives you great guidance on the aspects needed to specify underground shotcrete.
- ACI 301, "Specifications for Structural Concrete"—This mandatory specification provides requirements for contractors in general building construction. Alhough it doesn't cover shotcrete at all, some provisions, such as mock-ups for architectural treatments and concrete testing, may be beneficial for review.

Please be aware that in developing specifications for your projects, you shouldn't simply reference nonmandatory ACI reports and guides, as they aren't written in enforceable language. You can, however, take provisions of those nonmandatory documents and make them mandatory in your specification. Also, in referencing ACI specifications, the following guidance should be followed:

> "ACI Specification XYZ is to be used by reference or incorporation in its entirety in the Project Specification. Do not copy individual Sections, Parts, Articles, or Paragraphs into the Project Specification, because taking them out of context may change their meaning.
>
> If Sections or Parts of ACI Specification XYZ are copied into the Project Specification or any other document, do not refer to them as an ACI specification, because the specification has been altered."

***Charles S. Hanskat** is a Principal at Concrete Engineering Group, LLC, a firm he founded in 2008 located in Northbrook, IL. He received his bachelor's and master's degrees in civil engineering from the University of Florida. Hanskat is a licensed professional engineer in 22 states. He has been involved in the design, construction, and evaluation of environmental concrete and shotcrete structures for nearly 35 years. Hanskat is an ASA Board member and Chair of the ASA Sustainability Committee. He is also a member of ACI Committees 301, Specifications for Concrete; 350, Environmental Engineering Concrete Structures; 371, Elevated Tanks with Concrete Pedestals; 372, Tanks Wrapped with Wire or Strand; 373, Tanks with Internal Tendons; 376, Concrete Structures for Refrigerated Liquefied Gas Containment; 506, Shotcreting; and Joint ACI-ASCE Committee 334, Concrete Shell Design and Construction. Hanskat's service to the American Society of Civil Engineers (ASCE), the National Society of Professional Engineers (NSPE), and the Florida Engineering Society (FES) in over 50 committee and officer positions at the national, state, and local level was highlighted when he served as State President of FES and then as National Director of NSPE. He served as a District Director for Tau Beta Pi for 25 years from 1977 to 2002. He is a Fellow of ACI, ASCE, and FES and a member of ASA, NSPE, ASTM International, AWWA, and ASHRAE.*


GUNITE.
Dry-mix done right.
AIRPLACO
914 MOBILE BATCH PLANT
AIRPLACO
914 MOBILE BATCH PLANT
AIRPLACO

# Performance-Based Specifications for Shotcrete Contracts

By Phil T. Seabrook

Performance-based specifications (P-BS) for concrete projects have recently been introduced to the North American construction industry. They have been in use in Europe and elsewhere for some time. To the best of the author's knowledge, they have not seen significant use for shotcrete work. Because shotcrete is simply an alternate method of placing concrete, however, there does not appear to be any reason why shotcrete P-BS should not evolve. This article discusses the potential for the use of P-BS in shotcrete contracts and notes some realities in that process.

The original North American impetus for P-BS came from the ready mixed industry that saw such specifications as a method of protecting proprietary technology embedded in their mixture proportions. Recently, the American Concrete Institute (ACI) has been active in developing the base for such specifications. An ACI Innovation Task Group (ITG) has recently published ITG-8R-10, "Report on Performance-Based Requirements for Concrete."[1] ACI also devoted three major sessions at the ACI Spring 2011 Convention to this development. Some information presented herein is from those sessions.

## Nature of P-BS

There are a number of definitions for P-BS, but ITG-8R-10[1] states:

> *A performance specification defines required results, the criteria to judge performance, and verification methods without requirements for how the results are to be obtained.*

In addition, ACI notes that P-BS are "alternate" forms of a specification.[1]

It should be recognized that the use of P-BS is an evolving process. Much of this evolution is currently being driven by various government authorities.

Most prescriptive specifications now contain some performance elements. An example is the requirements for compressive strength. Some authorities have presented hybrid specifications containing a mixture of prescriptive and performance requirements.

Those currently using P-BS are unified in stipulating that a fundamental requirement is trust between the parties of the contract. Related to this, there has to be shared risk among these parties. They then list these needs:

- A designer/specifier who has sufficient technical knowledge to define the end product and how to test it;
- An owner who is prepared to enter into a contract where trust is a base and is also prepared to share in risks, presumably with the benefit of a more cost-effective and/or longer service-life structure;
- A specification that is clear, achievable, measurable, and enforceable;
- Sufficient lead time so that the necessary qualification tests can be conducted. Further, appreciation that the up-front costs for qualification may be high;
- Contractors and shotcrete mixture suppliers who have the ability to interpret the specification and respond in a technically sound form;
- A functional quality management system (QMS). This is also an evolving technology with North American contractors and suppliers. The contractor has to have a responsible and functional quality control program, and the owner then should have a complementary quality assurance program. The contractor's quality management plan should require approval by the owner;
- Acceptance criteria. This has to be based on a statistical approach, perhaps a Lot system where, for example, a Lot could be defined as each day's placement;
- A process to address the situation if the acceptance criteria are not met. This normally would include dispute resolution methods;
- Service life should be the base of the P-BS requirements. This leads to the use of modeling. There are now available models for service life but they mostly focus on chloride ion ingress and may not relate to a particular project's shotcrete environmental exposure; and
- A bonus/penalty provision. This is stated by current users to be a necessary incentive for the contractor.

With regard to bonus/penalty, this is obviously a challenge and begs the question, "If P-BS is of such a claimed benefit, why is an incentive necessary?" Authorities who shared their experience with P-BS stated that the contractors all achieved bonus. Some authorities admit to setting the bar low so that a positive experience on initial contracts would be readily achieved, then the bar could be raised later. It is interesting to reflect on how bonus/penalty could be worked into a shotcrete contract. As for concrete, however, bonus could simply result from meeting the performance criteria.

The matter of service life needs further exploration. It is now common for authorities to require 75 years for infrastructure projects. Then there is the challenge of defining how much maintenance is included in the calculation of life. The writer is not aware of any shotcrete projects where service life was specified or assessed by the designer. However, there is no reason why shotcrete could not be modeled in the same way that concrete is currently treated. Given that much of today's shotcrete contains silica fume, and all service life models of concrete with silica fume show great advantages, the service life of shotcrete could be long with proper design and construction. Interestingly, according to Marc Jolin of the University of Laval, Quebec, QC, Canada, the university is now undertaking a project to evaluate the service life of various common shotcrete mixtures.

To model a shotcrete mixture, it would be necessary to shoot a panel of the proposed mixture and core samples from it. The samples would be tested for diffusion and other transport properties required for the model. These properties would then be fed into the model with parameters of the structure and the projected service life would result.

## Claimed Benefits of P-BS

The fundamental justification for P-BS in concrete construction is that it opens the door for innovation by the contractor (and concrete supplier) and now possibly a shotcrete subcontractor. This is certainly true. Unfortunately, in some cases, this has translated into opening the door to construction or material choices that are simply cheaper and not necessarily in the interest of concrete performance. The justification assumes that the parties are capable of taking advantage of the benefits of P-BS through their technical abilities.

Innovation results in the use of materials and construction systems that are more suited to the contractor's system. Contractors can take advantage of new technology—the use of new admixtures being an example. By definition, this should also be more cost effective. Proponents claim that P-BS leads to sustainability, which comes from the more efficient use of materials and possibly extended service life.

Sustainability is of current interest to ASA and the concrete industry, and it is discussed in a number of issues of *Shotcrete* magazine, such as the Spring 2011 issue.[2] Of the suggested sustainability features of shotcrete in *Shotcrete*, the formwork savings would probably be most important here, although schedule acceleration would also be of interest to most owners.

As an example of the present stage of P-BS evolution, one authority put out tenders for a concrete infrastructure project based on both prescriptive and P-BS specifications. Tendered costs were similar, and the authority concluded that the contractors in its area were not ready to take advantage of P-BS.

## Acceptance Criteria

Those using P-BS all acknowledge that establishing acceptance criteria is a major challenge. Included in the criteria must be the required sampling plan, typically defining some form of core extraction. Such plans would be fundamental parts of the QMS.

Consider the example of acceptance of concrete compressive strength. Current codes require sampling at the end of the concrete truck chute for concrete acceptance (also sometimes for wet-mix shotcrete). For P-BS, the sampling for the owner's purposes would likely be in-place, which would leave testing of as-delivered concrete to the contractor's or ready-mixed supplier's quality control. This is a logical separation of responsibilities, but it would be necessary to define those responsibilities in a contract between the contractor and supplier. Would failure of compressive strength be the result of the mixture, the consolidation in shooting, or the subsequent curing?

Following are examples of some acceptance criteria that might be considered for shotcrete work (Table 1). In all cases, there is a challenge to define the "what if" the acceptance criteria are not met. This is where the penalty provisions have been used in some contracts. Many of these criteria measured by testing could not be confirmed until the shotcrete is months old.

For most tests, it is necessary to define the required average value and also some minimum/maximum. This accounts for the within-test variations and isolated local lower-quality shotcrete. The spread between average and minimum/maximum can be varied with the precision of the particular test. As an example, the current ACI 318 code defines strength acceptance as having the average strength of cores greater than 85% of the specified strength with no single core less than 75% of that strength.

**Table 1: Acceptance Criteria for Shotcrete**

| Property | Criteria | Comments |
|---|---|---|
| Dimensional tolerance | Easily defined. ACI 117 is a guide. The main interest may be shotcrete thickness. | Need to define the type, amount, and frequency of measurement. |
| Surface finish | Common criteria are those in prescriptive specifications. Hard to quantify as performance. | No problem for as-shot. |
| Compressive strength | Criteria well established. Would probably require in-place sampling as well as panels for quality control. | Only an indirect measure of durability. |
| Absorption | Acceptance criteria well established and recognized in the industry. | Can be used as both a qualification and quality control test. |
| Water-cementitious material ratio (*w/cm*) | This is currently the base for durability assessment of concrete in all codes. | Some are measuring this in the field with the microwave test. Presumably that test could be used for both wet- and dry-mix. |
| Resistance to chloride ion penetration[3] | General criteria for acceptance now available. | Test not commonly conducted on shotcrete but it could be done. Test normally conducted on concrete at 28 to 56 days or later age. |
| Diffusion, surface, and bulk | Test procedures established, but no quantified acceptance generally recognized. | Considerable research ongoing. A few authorities have used diffusion for qualification and even quality control. |
| Freezing-and-thawing resistance | Criteria for acceptance well established. | Test seldom conducted on shotcrete. Beam samples would have to be cut from shot panels. Qualification test only. Test can take 6 months. |
| Bond to substrata | Test procedure available, and there is a general agreement on achievable values for shotcrete. | Test results highly variable, requiring a large number of tests and proper interpretation. |
| Reinforcing bar encapsulation | This would have to be defined by the designer. | The use of core grades in the current ACI 506.2 standard is being discontinued for all applications except nozzlemen certification, so new criteria has to be developed. ACI 506 is addressing this. |

Note that a number of these tests would only be used for qualification of the mixture. Considerable lead time would be required to complete them. Such lead time is seldom available in most current contracts.

Also, Table 1 shows that a significant challenge in acceptance is in defining workmanship properties.

## Application of P-BS to Shotcrete Work

The requirement to use in-place samples for assessment of the end product can readily be accommodated in shotcrete.

The pending revised ACI 506.2,[4] "Specification for Materials, Proportioning, and Application of Shotcrete," has many of the elements that would be required for compliance with a P-BS contract. Examples include:

- The shotcrete industry has embraced the ACI Nozzleman Certification and most experienced shotcrete contractors can readily provide certified nozzlemen. Certifications are a normal requirement of P-BS. They are not currently available for general contractors;
- The specification will require extensive preconstruction submittals with verifiable technical content. These submittals will include items such as documented properties of the proposed mixture and possibly projected service life based on a specified service-life model; and
- ACI 506.2[4] will require the contractor to conduct quality control and the owner to do the quality assurance. This is intrinsic in P-BS.

Therefore, the shotcrete industry is already in a position to comply with some of the normal P-BS requirements.

P-BS today are normally considered only for large projects, particularly large infrastructure projects. They also require contractors and suppliers with advanced technical knowledge to design and produce the required end product.

P-BS is ideal for design-build projects because, by definition, these projects are performance-based. It is possible that increases in design-build projects will lead the development and adoption of P-BS.

## A Look to the Future

P-BS is not for all projects. Most projects, however, could benefit from hybrid specifications that combine prescriptive and performance-based specifications.

Projects where P-BS are currently being used are not those that would commonly be undertaken by shotcrete contractors, except perhaps as a subcontractor. However, there is no reason why the shotcrete portion of a large contract could not be performance-based.

This is an evolving process and, as the industry becomes more sophisticated, it is probable that some shotcrete contractors will look to P-BS to take advantage of their innovative approaches to common concrete construction challenges. Innovative uses of shotcrete can also result in substantial advances in sustainability of the final concrete structure.

## References


1. ACI Innovation Task Group 8, "Report on Performance-Based Requirements for Concrete (ITG-8R-10)," American Concrete Institute, Farmington Hills, MI, 2010, 46 pp.
2. Darnell, C., "Sustainability" column, *Shotcrete*, V. 13, No. 2, Spring 2011, p. 46-47.
3. ASTM C1202-10, "Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration," ASTM International, West Conshohocken, PA, 2010, 7 pp.
4. ACI Committee 506, "Specification for Materials, Proportioning, and Application of Shotcrete (ACI 506.2-95)," American Concrete Institute, Farmington Hills, MI, 1995, 8 pp.



***Phil T. Seabrook****, FACI, PEng, PE, is the President of his own private consulting firm, Phiz Engineering Ltd., Vancouver, BC, Canada. He has over 50 years of expertise in concrete materials, including a significant amount in shotcrete. Seabrook is a Warden of the Iron Ring for Canada, Past President of Levelton Consultants, and Past President of the Association of Professional Engineers and Geoscientists of British Columbia. A member of the American Concrete Institute (ACI), he was a founding member of the BC Chapter and served as its President. Nationally, he is a long-term member of ACI Committee 506, Shotcreting, and has been the Chair of ACI Committee 506-0E, Shotcreting-Specifications, since 1995, and serves on a number of other ACI committees. Seabrook recently received an award for 50 Years of Service from ACI. In Canada, he was Chair of the 1994 edition of CSA A23.1 on concrete. Seabrook received numerous awards over the years, including the prestigious Consulting Engineers of BC Meritorious Achievement Award and APEGBC's McLachlan Award for outstanding technical, professional, and community service contributions. Seabrook is the author of many technical papers. Recent activities include dispute resolution in construction failures and quality management for large infrastructure projects.*


Circle #35 on reader response form—page 64

# Differences and Similarities of Shotcrete Specifications

*By Cathy Burkert*

In my years of working as a shotcrete contractor in the state of Illinois, the Department of Transportation (DOT) has revised the shotcrete specification numerous times. This article will briefly discuss the differences and similarities between the state's previous specification, "High Performance Shotcrete," and its most recently adopted version, "Structural Repair of Concrete." Even though both specifications have the same expectancy—to repair concrete using the high-quality shotcrete method—they differ in ways that are both beneficial and detrimental to the shotcrete industry.

## Overview

In June 1994, the Illinois Department of Transportation (IDOT) adopted the "High Performance Shotcrete" specification. Other sister state agencies, such as the Illinois Toll Highway Authority and the city of Chicago, also soon followed in the adoption of this specification. Unfortunately, most agencies did not often list this item for concrete repair on projects but instead used a formed concrete repair specification. The previous specification for formed concrete repair had no procedure for the placement of concrete. As a result, contractors were using "bird's mouths" on forms and pouring concrete in by bucket. On many repair projects, the agencies would have clearly benefited from using the shotcrete process rather than the form-and-pour method. In my experience as a contractor on various projects, we would occasionally submit the shotcrete process for consideration, especially in difficult placing areas such as overhead repairs. These agencies had previous poor experiences with gunite (dry-mix shotcrete) and did not feel that shotcrete was as good as formed concrete repair. Problems with poor-quality gunite were predominant at a time when sand and cement were site-mixed before the widespread availability of prebagged materials, and there were resultant failures due to poor-quality control of mixture proportions. Problems also arose from unqualified contractors who didn't really know shotcrete. These contractors attempted to place shotcrete using inadequate equipment, untrained nozzlemen, and improper curing, which resulted in poor-quality shotcrete.

Twelve years later, in March 2006, with much more knowledge, confidence, and information about the wet-mix shotcrete process, IDOT, followed by their sister agencies, adopted a new specification—"Structural Repair of Concrete." This specification combined both formed concrete repair and the wet-mix shotcrete process, allowing the contractor to choose the method of placement for the project.

Contractors primarily choose to use the wet-mix shotcrete process over the form-and-pour method for its advantages in green building, safety, and quality. Shotcrete has the inherent ability to minimize or sometimes eliminate the use of formwork, saving lumber or steel and the energy to manufacture, transport, and dispose of the formwork at the end of the project. Shotcrete delivers a freshly mixed concrete material on a consistent basis to properly encase the reinforcing steel. Contractors also have the benefit of touching the receiving surfaces only once and not having to revisit them to strip forms, fill holes, grind, and so on. The energy savings from the use of shotcrete versus the form-and-pour method is significant. For more information on the sustainability of shotcrete, go to the ASA Web site's Sustainability page (**www.shotcrete.org/sustainability.html**).

Contractors also use shotcrete for safety reasons because the air and water hoses used in shotcreting offer considerably less risk than manhandling formwork and scaffolding at different elevations. In addition, if concrete placement is interrupted in the middle of casting a patch area, instead of having to remove the form and prepare the green concrete for subsequent casting, the use of shotcrete placement merely requires a light water- or sand-blasting of the area. The shotcrete process also allows for a visual inspection of the encapsulation of the reinforcing bar, whereas pumping blind into a closed form can easily result in honeycombed concrete or concrete with voids.

The following are a few of the significant changes the state of Illinois has made to their concrete repair specification to ensure a high-quality repair.

## Contractor/Nozzleman Qualifications

The American Concrete Institute (ACI) and its primary sponsoring group, ASA, established the Shotcrete Nozzleman Certification program in 2000. The current "Structural Repair of Concrete"

*Use of the shotcrete process on the Dan Ryan Expressway in Chicago, IL. Shotcrete was chosen over the form-and-pour method for its advantages in green building*

specification only requires the shotcrete personnel performing the work to have a current ACI nozzleman certification for vertical and overhead wet-mix applications. The previous specification, "High Performance Shotcrete," did not require the nozzleman to be ACI-certified for any work—instead, the shotcrete contractor and the shotcrete nozzleman had to have a minimum of 3 years of experience and were required to submit a list of five projects similar to the work being performed.

*Use of the shotcrete process on the Abraham Memorial Bridge in LaSalle, IL. The contractors chose the shotcrete process following the IDOT "Structural Repair of Concrete" specification*

The project experience submittal required the nozzleman to provide a list of project names, owners, the general contractor's name, the name of the owner's representative, addresses and telephone numbers, a brief description of the work, the total cost of the shotcreting portion of the project, the date of completion, and the equipment used. In the interest of quality, the state should have adopted the proof of contractor experience in addition to nozzleman certification because shotcrete is a specialized construction process and requires years of experience and, as we are all aware, a nozzleman is only one person on a trained crew.

## Material

The "Structural Repair of Concrete" specifies a prepackaged, preblended, IDOT-approved dry combination of materials, in which the contractor adds only water on site. The prebagged shotcrete mixture provides a more regulated process, delivering material with consistent mixture proportions. The old "High Performance Shotcrete" specification only required a 3.5:1 (sand:cement) mixture, with a prepackaged dry combination of enhancer/admixture to be combined on site with the water used to hydrate the shotcrete. The difference can be compared to making a cake. Instead of making a homemade cake, where you add your own flour, sugar, baking soda, and so on, now contractors just purchase a "pre-boxed" mixture. Although the expense can be higher, they are more certain to get the appropriate amount of each ingredient.

## Surface Preparation, Product Placement, and Curing

While both specifications required the removal of all loose and unsound concrete, followed by sandblasting of the exposed area and reinforcing bar, the new specification further requires a saw-cut edge and strict time limits for placement. Additionally, the "Structural Repair of Concrete" specification clearly states that "formed concrete repair shall not be used for overhead applications." Thus, only shotcrete is allowed when overhead repairs are needed. Both specifications discuss the necessary requirements for placement during hot and cold temperatures, but the new specification now mandates the use of wet curing with cotton mats, except on overhead applications, where the use of a curing compound is permitted. The old "High Performance Shotcrete" specification simply required curing to be done according to the manufacturer's recommendation. The new specification also references ACI 506R, "Guide to Shotcrete," which provides a great deal of additional information on the materials, properties, and application of shotcrete. As the guide states, "the best method for curing is to keep the shotcrete wet continuously for 7 days" to fully develop its potential strength and durability. The current "Structural Repair of Concrete" specification requires coverage of the freshly placed shotcrete with cotton mats or application of a curing compound within 10 minutes. The old "High Performance Shotcrete" specification suggests that, if the use of wet curing is chosen, "The Contractor shall begin curing operations as soon as the Shotcrete has hardened sufficiently to prevent marring the surface."

A time limit is necessary, but it seems impractical to shoot a large-sized patch and finish the patch within 10 minutes. Ideally, the specification should be revised to address the need to prevent plastic shrinkage cracking with either an evaporation retarder or misting within a short time frame (10 minutes may still be too short), and then allowing the 7-day wet curing (used to delay drying shrinkage) to proceed once a later section is ready.

## Testing

Although both specifications require an 18 x 18 x 3.5 in. (450 x 450 x 90 mm) test panel to be shot daily, the compressive strength requirements have changed from being tested and producing minimum compressive strengths at 3, 7, and 28 days (3000, 4000, and 5000 psi [21, 28, and 35 MPa]), respectively, to a 14-day test result (4000 psi [28 MPa]). Requiring 4000 psi (28 MPa) at 14 days will generally produce a compressive strength of 5000 psi (35 MPa) at 28 days with most properly designed shotcrete mixtures. In addition, the new "Structural Repair of Concrete" specifies that an air content test be taken from the end of the nozzle tip prior to placement with a measurement of between 4 and 8%. This helps verify the actual air content in the shotcrete being applied to the structure and is called the "as-shot" air content. The as-shot air content can be tested either by shooting and filling up the air content meter or by scraping shotcrete off the freshly shotcreted surface. The as-shot air content generally drops to a level of 3 to 5%, regardless of the air content before the concrete enters the shotcrete pump. This even occurs when an air-entrained agent is used in the shotcrete with as-batched air contents as high as 10%. It should be noted, however, that this test can only be used for nonaccelerated shotcrete.

## Conclusion

As new information and technology on shotcrete becomes available from both ACI and ASA, the state of Illinois has revised its concrete repair specification as needed. As a shotcrete contractor, we have successfully placed shotcrete following the new "Structural Repair of Concrete" specification on numerous structures throughout the state of Illinois. In 2008, we repaired over 24,000 $ft^2$ (2230 $m^2$) on the Abraham Lincoln Memorial Bridge in LaSalle, IL, and received the 2008 ASA Award for Infrastructure Project of the Year and the IDOT Bridge Rehabilitation Contract of the Year. In 2009, we repaired over 21,000 $ft^2$ (1951 $m^2$) of shotcrete on the Dan Ryan Expressway and received the 2009 ASA Award for Infrastructure Project of the Year. The shotcrete solution resulted in a long-term, affordable repair.

While IDOT's specification for "High Performance Shotcrete" is obsolete and should no longer be referenced, the current "Structural Repair of Concrete" specification can be found on IDOT's Web site at **www.dot.state.il.us/bridges/GBSP53.pdf**.

***Cathy Burkert*** *received her bachelor's degree in business management and thereafter started working at American Concrete Restorations, a Chicago-based shotcrete contractor. She joined the laborers' apprenticeship program to learn the intricate details of the trade. After 2 years in the program, she began running her own shotcrete crews and shortly after earned the title of Field Office Coordinator. In March 2009, Burkert became the first female ACI-certified nozzleman for the wet-mix, vertical, and overhead processes. Burkert has been involved with two ASA infrastructure award-winning projects: the Abraham Lincoln Memorial Bridge in 2008 and the Dan Ryan Expressway in 2009.*

Circle #42 on reader response form—page 64

*Reprinted with permission from the September 2009 issue of* WaterShapes *magazine*

# The Elevated Game

By George Yoggy

**Materials scientist and concrete expert George Yoggy has studied the shotcrete and gunite processes for more than 50 years, focusing not only on tunnel and mine construction, but also turning his eye toward watershapes. Here, he reviews industry standards for the density, strength, and permeability of pneumatically placed concrete shells and urges watershapers to step up and adopt the standards and practices followed by others in the concrete industry.**

In the world of concrete science and application, innumerable variables have an influence on whether a concrete installation is successful or not. These include, but are not limited to, the skill of the applicator, the suitability of the mixture design, the temperature at the time of application, the equipment used, the water-cement ratio (*w/c*), and the size of the aggregate.

For all the seeming complexity, however, the nature of the material itself invests the process with a few immovable facts. One of these directly undermines the swimming pool industry's "standard" that calls for a compression strength of 2500 psi (17.2 MPa) for pneumatically placed concrete (that is, gunite or shotcrete). It's not because the standard is inadequate *per se*; rather, it's because it is virtually impossible, with proper application, to produce a gunite or shotcrete structure at such a low level!

If that comes as a surprise to you, read on: To explain why no such thing as 2500 psi (17.2 MPa) pneumatically placed concrete exists, we first need to examine the nature of concrete and then take a look at the developmental history of the gunite and shotcrete processes.

## Through the Pump

The main reason behind the impossibility of 2500 psi (17.2 MPa) gunite or shotcrete has to do with the velocity at which the material is applied. As it moves past the nozzle, the concrete strikes the substrate with such force that it is inevitably compacted—meaning it will always have greater strength than you can achieve using cast-in-place methods.

So regardless of the mixture design, the resulting structure's density (or compressive strength) will be *at least* 4000 psi (27.6 MPa) in the shotcrete (wet) process and even greater with the gunite (dry) process. Without significant errors in application (to be discussed in the following), you simply cannot avoid producing shells with compressive strength far exceeding 2500 psi (17.2 MPa)—which means the industry standard is essentially meaningless.

Moving past that observation, let's look at some other concrete fundamentals.

First of all, it's helpful to know that the terms "gunite" and "shotcrete" are essentially verbs rather than nouns and refer to processes and actions rather than results. The stuff that constitutes the shell of a swimming pool, spa, or fountain, in other words, is *not* gunite or shotcrete but is, in fact, simply concrete—*concrete placed pneumatically at high velocity*, to be more exact.

The nature of these application methods has a direct effect on the mixture design of the concrete. If you're pouring a footing for a home or a column for a building, for example, standard practice dictates the use of a fairly coarse aggregate in 1 or 1.5 in. (25 or 38 mm) dimensions. With the gunite or shotcrete method, by contrast, the material has to move through a hose and nozzle, which means you must downsize the aggregate considerably and increase the amount of sand in the mixture to make it flow properly.

By definition, concrete is a combination of coarse and fine aggregates coated and bound together by cement paste. By *decreasing* the size of the aggregate, you effectively *increase* the surface area of the aggregate and thereby increase the requisite amount of cement. In other words, the amount of cement required in the mixture is determined by aggregate size and the aggregate's resulting surface area.

For comparison, if you were preparing for a cast-in-place application using 1 to 1.5 in. (25 or 38 mm) aggregate, the production of 1 $yd^3$ (0.8 $m^3$) of concrete would require inclusion of 500 to 550 lb (227 to 250 kg) of cement. If you were to downsize the aggregate to 3/8 in. (10 mm) (as is generally found in gunite and

shotcrete applications), that same 1 $yd^3$ (0.8 $m^3$) of concrete would have to include 650 to 750 lb (295 to 340 kg) of cement in the mixture to accommodate the greater surface area. These differences in aggregate size and cement content will, all other things being equal, result in stronger concrete in the latter case than you could achieve in the former.

And if you combine smaller aggregate and more cement with the velocity aforementioned, the product will inevitably exceed a compressive-strength level of 4000 psi (27.6 MPa).

## Filling Voids

Let's paint this picture with a bit more detail, starting with the fact that the aggregate in concrete generally constitutes about 65% of the mixture. The key beyond that is use of material that fills the voids so the finished product is solid.

Consider a jar filled with rocks: A relatively small number of larger rocks will fill the jar to capacity, but this leaves substantial voids. To fill them, you add smaller rocks that fill in much of the empty space, then add sand to fill the even smaller voids. Finally, you add water, which fills the tiniest of the remaining spaces.

The same principles apply with concrete, and that's true even with the small starting aggregates used with gunite and shotcrete, although filling these voids means using greater amounts of fine aggregate (sand) and more cement to ensure that there will be enough cement paste to cover the increased surface area of the smaller aggregate. The upshot of this manipulation of the mixture is increased density—and, therefore, higher levels of compressive strength with gunite and shotcrete.

When you combine all of this, it's easy to see why people who work with gunite and shotcrete in constructing mines and tunnels scratch their heads when they see that the pool industry has pegged its standard at 2500 psi (17.2 MPa) and are forced to wonder further if watershapers have any clear sense of the nature of the materials and processes they're using.

Yes, you can achieve that low, 2500 psi (17.2 MPa) level of compressive strength using cast-in-place concrete, but to do so with the gunite or shotcrete methods, you would have to *torture* the process with improper practices to get there—perhaps by mishandling mixture times relative to temperature or repositioning the concrete once it's been placed or using rebound (with the latter two possibilities technically meaning that the concrete is no longer "pneumatically placed") or engaging in any of a host of other possible abuses.

The point is, if you manage to produce pneumatically placed concrete that has a compression strength of less than 4000 psi (27.6 MPa), *by definition* it must be considered substandard because something had to have gone terribly wrong to produce such a result.

I believe that this has flown under the radar for so long because, compared to other applications, the preparation of shells for watershapes is not

critical in construction terms. With an average pool, even 2500 psi (17.2 MPa) concrete that is coated with plaster and filled with water will be strong enough to hold that water in place and resist most ground forces. The proof in the pudding is the fact that most pools do not fail.

That said, however, if the water table changes or the plaster fails or there are soil conditions that create dramatic movement or differential settlement, it may very well prove to be the case that a substandard concrete product will be *entirely* inadequate. And at a time when increasing numbers of vessels have more daring shapes and performance features (including perimeter overflows and vanishing edges), the resulting structural variables make the strength of the concrete a more critical factor in the product's ability to withstand the tests of time.

In other words, as the watershaping industry elevates the artistry and technical sophistication of its designs, the issue of proper application becomes far more important. The plain fact is, these are jobs that must be done right—the first time, every time.

## Backing Up

Let's put all of this information in a grander historical context to understand where misunderstandings about the nature of gunite and shotcrete might have emerged.

Briefly, the "cement gun" was invented in 1909 by Carl Akeley (who, by the way, also invented the movie camera). He was working at the Chicago Museum of Natural History, patching and modeling prehistoric animals, and was frustrated by the constant need to prepare fresh batches of plaster and portland cement, much of which went to waste before he could use it.

An inventive sort, he noted the need for a ready flow and supply of cementitious material and developed a system in which a dry cement mixture was contained in a pressurized container. He attached a hose and developed a nozzle assembly that had the ability to add a measured flow of water to the mixture as it exited the nozzle. Along the way, he discovered that he created a superior product by adding sand—and the rest is history.

Before too long, Akeley's invention was commercialized by the Cement Gun Co. of Allentown, PA, which marketed the system as Gunite. After extensive testing and product development, it was determined that the ideal velocity for the process was between 350 and 400 ft/s (107 to 122 m/s)—a standard applied to this day and one always recognized as a critical factor in the strength and quality of the finished product.

For the next 20 years, Akeley's system met with amazing success and rapid acceptance, and it wasn't long before a swimming pool was constructed using the Gunite process.

That happened in 1932 at Lehigh Valley Country Club in Allentown, which made sense because the owners of the Cement Gun Co. were club members. It was an experiment, but from the start they knew pools and pneumatically placed concrete were a perfect match—and the modern pool construction industry was born.

Fast forwarding to 1962, the country club decided to update the pool with a new plaster surface as well as some new skimmers and light niches. They hired a contractor who, after a day or two of chipping at the old concrete, went back to the club's board of directors and asked for financial relief because the shell was so hard that he was going through drill bits and bull points at such a pace that he knew he'd lose money on the job.

This was no surprise to the folks at the Cement Gun Co., who had learned a lot about their product in the intervening years and had done a great deal to standardize its use. Indeed, their work rests, to this day, at the core of standards recognized and maintained by the American Concrete Institute (ACI) and ASTM International.

I might add that *nowhere* in that vast body of knowledge will you find *any* reference to 2500 psi (17.2 MPa) pneumatically placed concrete. In fact, studies dating to 1915 show conclusively that, when delivered at velocities of 350 to 400 ft/s (107 to 122 m/s), properly mixed and hydrated gunite is superior to cast-in-place concrete in bondability, density, permeability, and compressive strength. Straight through the 1950s, it was generally recognized that pools built using the Gunite process were of the highest available quality and structural strength.

## Rapid Expansion

The tide began to turn as early as 1952, when the contracting division of the Cement Gun Co. went out of business and the parent company concurred with ACI's recommendation that it should cede its exclusive control of the Gunite process and open it to the industry. At that point, small-g gunite came on the scene.

At that time, the modern American suburb was emerging—and swimming pools were becoming an increasingly popular addition to single-family homes. With that expanding business base, numerous swimming pool contractors entered the marketplace, pioneered the concept of the middle-class swimming pool,


*This 1949 publication from the Cement Gun Co. recalls the earliest known use of gunite in the construction of a swimming pool as far back as 1936 in Allentown, PA*

**Proper use of either the gunite or shotcrete processes flows from a well-established body of knowledge based on years of experience in applications in which the success of projects is a matter of life or death, not of guesswork or old habits.**

and pulled a new generation of gunite-application companies into the mix.

Without the licensing authority of the Cement Gun Co. to guide this development and train application crews as it had in the past, however, the gunite business became less disciplined and more inconsistent with respect to product quality. That gradual decline never happened in critical applications, because work on mines, highways, and tunnels necessitated the pursuit of very high sets of standards. Where pools were concerned, however, that same necessity did not apply and, in many quarters, a fundamental understanding of both the gunite process and product were lost.

Even so, gunite dominated in the pool industry straight through the 1960s and into the '70s. That situation began changing by 1972, with the advent of the concrete pump and the development of the "wet" or "shotcrete" process, which really took hold in the pool market late in the 1970s.

Today, the shotcrete process is considered by many to be superior to the gunite process as a result of the consistency and reliability of batch mixtures compared to the street mixing used in the gunite process. Truth is, during shotcrete's early years, the product went through some difficult growth stages.

Mostly, these issues had to do with attempts to increase the pumpability of material: Early applicators had trouble controlling (and even holding onto) the hoses, so velocities and hose sizes both began to shrink. The result before long was that applicators weren't so much *compacting* concrete as they were simply *stacking* it—a situation that was eventually and thoroughly rectified with improvements to shotcrete rigs and equipment but led to the development of some bad habits along the way.

At the same time, market pressures led to some changes in the mixture that resulted in production of weaker concrete, all in the name of minimizing costs. During the 1980s and into the '90s, it was also common to encounter problems with concrete staying in mixers too long; with too much water being added; with the use of rebound; and, in some situations, with the addition of detergent admixtures to ease pumping. All of these factors conspired to result in terribly compromised concrete products.

## THE PERMEABILITY DEBATE

Beyond the increasing creativity of watershape designs, another issue that is pulling the watershaping industry back into the fold of the greater concrete industry is a growing set of discussions about permeability and the level to which pneumatically applied concrete—whether gunite or shotcrete—should or can be classed as permeable, slightly permeable, or impermeable.

We can all accept the thought that pools, spas, fountains, and other bodies of recreational and decorative water should be able to contain water. What many people also accept—erroneously—is that pneumatically placed concrete is, by nature, permeable. That is so only in an environment in which substandard application practices are acceptable.

In fact, the permeability of pneumatically placed concrete structures is a non-issue: When you use a proper mixture design and combine it with proper application methods, the resulting 4000 psi (27.6 MPa) (or greater) material is classified as having low permeability—meaning that even without a lining in the form of plaster or an exposed-aggregate finish, the shell itself should hold water.

What many contractors fail to realize is that the "business end" of the concrete is the side that comes in contact with the soil: This is the surface exposed directly to groundwater with no more than density to prevent intrusion of a sort that can corrode reinforcing steel. When the concrete is less permeable, it protects the structure's integrity; conversely, if the shell is more permeable, it's at far greater risk of failure.

In assessing the permeability of concrete, scientists measure the passage of chloride ions that travel with water as it enters the material. Just as the compressive strength of properly applied pneumatic concrete is a well-established scientific fact, so, too, is the permeability of concrete. In this there is no dispute: 4000 psi (27.6 MPa) concrete has low permeability and, with proper concrete coverage of reinforcing steel, will protect itself from intrusion of potentially corrosive groundwater.

It all adds up to a simple picture: With proper compression resulting from proper mixing and use of proper application techniques, pneumatically applied concrete is virtually free of voids, has low permeability, and will withstand the tests of time.

**– G.Y.**

This unsteadiness in the face of a changing marketplace is, I believe, what led to the odd notion that 2500 psi (17.2 MPa) strength was acceptable, even though the practices that had led to that assumption were completely substandard.

None of this, I might add, ever altered the fact that proper mixture designs and application velocities were resulting in compressive strengths of 4000 psi (27.6 MPa) or better: The truth is that watershaping applications simply haven't been classified as critical in the concrete industry and therefore attracted little technical attention—a situation that has changed in recent years with the development of more advanced and intricate designs.

## The Right Stuff

As I see it, the watershaping industry can easily catch up and get back on track with the rest of the concrete-using industries with a simple, direct process of education.

Training for concrete application, for example, already exists in the programs of ACI, the American Shotcrete Association (ASA), and the Portland Cement Association (PCA). The specifics of proper concrete application—that is, what's involved in rising to ACI, ASA, or PCA standards—are not terribly complex, but they do require basic training.

What has happened through the years in which outright product failures were rare is, in my opinion, that watershapers had latched onto the idea that common practice informally handed down through the years was sufficient in getting the job done. While that may arguably have been adequate practice at one point in time, it is increasingly less defensible: It's time to step up and get acquainted with how things should be done rather than how they've been done in the past.

There are no secrets or scientific mysteries at work here: Proper use of either the gunite or shotcrete processes flows from a well-established body of knowledge based on years of experience in applications in which the success of projects is a matter of life or death, not of guesswork or old habits.

I applaud those in the watershaping industry who've started a critical evaluation of the way things are done and have changed their application processes to conform to the concrete industry's standards. It's the practical thing to do—and the right one as well.

*George D. Yoggy has been directly involved in shotcrete and concrete applications for more than 40 years. Yoggy retired from Master Builders in 2000 and is a consultant to the tunnel and shotcrete industries. He lectures at various training programs on the use of shotcrete, is an approved ACI Examiner, and serves on several technical committees for ACI, ASTM International, ASA, and the American Underground Construction Association. He continues to be an active participant and respected leader in industry initiatives.*

# Does the SHOTCRETE WORLD need to know about YOUR COMPANY and its PRODUCTS or SERVICES?

## If the answer is "YES" then read on.


Advertising in *Shotcrete* magazine is the most cost-effective way to reach the shotcrete industry.

Each issue of *Shotcrete* magazine reaches a growing number of **over 17,000 readers** that includes current and potential designers, specifiers, and purchasers of shotcrete across 95 countries.

The many benefits of advertising in *Shotcrete* have significantly increased with the addition of the electronic version of the magazine.

**All advertisers in *Shotcrete* will now have their advertisement appear in *BOTH* the printed copy and the new electronic copy of the magazine at no additional charge.**

The electronic copy of *Shotcrete* is sent to all subscribers, and advertisements include a hot link to the advertiser's Web site.

You can also hire our design department to create professional advertising design for your company. From concept to production and printing, we can produce the promotional materials for your ad campaign.

Your advertisement in *Shotcrete* will reach the companies and people that you need to grow your business. The cost for advertising is very affordable, and will certainly provide you with the most "bang" for your advertising dollars.

**Shotcrete** MAGAZINE
A quarterly publication of the American Shotcrete Association

**To obtain a media kit, arrange for advertising, or for answers to questions, contact: info@shotcrete.org or visit our Web site at www.shotcrete.org**




Circle #43 on reader response form—page 64

# Nozzleman Techniques: Improve Accuracy and Reduce Fatigue

By Oscar Duckworth

If there is one thing all skilled nozzlemen have in common, it is that they make their job look easy. The nozzle appears weightless in their hands, but anyone who has ever held a nozzle knows better. Although strength and stamina are important, a skilled nozzleman does not rely on brute strength. Overpowering the nozzle is never a long-term strategy. Mastery of the nozzle requires knowledge of techniques that offset the weight and thrust of the nozzle. Balance, physical efficiency, and the use of shooting positions that combine mobility with precise nozzle control are traits shared by all skilled nozzlemen. Good nozzlemen are artists—their movements are deliberate and perfectly executed. Their skill and experience are obvious to anyone who sees them work. Mastery of the craft requires study, practice, and sufficient time to learn the essential techniques used by all skilled nozzlemen. Professionals from every craft must master specific movements or positions to provide optimum efficiency. Athletes continually practice movements and refine techniques to boost performance. Like athletes, skilled nozzlemen select equipment, control timing, and use specific techniques to improve their performance. All professional nozzlemen share similar shooting positions, methods, and equipment configurations to diminish the risk of injury, minimize fatigue, and maximize placement accuracy.

*Fig. 1: Although visibly similar, nozzle end hoses may feel very different to a nozzleman. Choose an end hose that is sufficiently rigid, not "doughy"*

## Safety First

Professional nozzlemen are exposed to unique hazards that are specific to the craft. A placement system's weight and occasional violent thrust can create the risk of injury at any time. If scaffolding is required, it must be sufficiently wide to safely work without compromising balance. Adequate hand rails are **mandatory**. Shotcrete placement equipment can generate enormous pressure if there is a blockage within the system. A placement system rupture caused by a blockage can generate explosive force. It is essential that the nozzleman can signal to quickly stop the pump. A nozzleman should not operate equipment that cannot be immediately stopped in the event of an emergency. Wear the personal protection devices (PPDs). PPDs are there for **your** protection. Gloves, dust masks, safety glasses, ear protection, boots, and hard hats are requirements of a naturally hazardous job.

## Equipment Choices Affect the Nozzleman's Body

Shotcrete placement systems must be properly sized. Placement systems and nozzles 1-1/2 and 2 in. (38 and 50 mm) in size are commonly used for most wet- and dry-mix hand nozzle applications. The placement system weight dramatically impacts the nozzleman's mobility. Professional nozzlemen carefully consider the weight of every component that must be lifted. Hoses used near the nozzle must be sufficiently rigid to resist kinking or collapsing during placement. Soft, "doughy" hoses should not be used as the nozzle end hose (Fig. 1).

## Adjust the Pump or Gun to Run as Smoothly as Possible

Smooth shifts and a predictable flow of material are necessary to precisely control material placement. Slugging or bursts of air will affect a nozzleman's balance and reduce placement precision. Uneven material flow can be caused by worn wear components, poor shift calibration, or nonfunctioning augers (Fig. 2). Guns and pumps must be kept full. Allowing a pump to run low on material creates unpredictable airbursts that can unbalance any nozzleman. If material flow is irregular, the nozzleman should stop and investigate the cause before continuing.

*Fig. 2: A wet-mix pump with missing auger cannot effectively fill material cylinders. Unpredictable flow and slugging will affect nozzleman placement quality*

## Adjust Placement Speed to Your Own Comfort Level

High flow rates generate excess thrust that must be counteracted by the nozzleman. Modern shotcrete placement equipment can convey material much faster than a nozzleman can accurately place it. The mark of a master nozzleman is not how quickly he can install material—it is the precision with which the material is placed with proper consolidation. Choose a flow rate that feels right. A nozzleman must work within a speed range such that thrust generated by excess flow does not interfere with the nozzleman's ability to accurately direct the flow.

## Work in Positions that Use the Body's Frame to Provide Natural Balance and Mobility

Any worker attempting to operate a nozzle for the first time will likely either hoist the placement hose and nozzle up and over his shoulder or try to hold it from the side. After a short but valiant struggle, the nozzle usually wins. Professional nozzlemen realize that these awkward positions generate poor results. A nozzle held from the side or over the shoulder limits the nozzle's range of movement and overall placement precision (Fig. 3(a) and (b)). Over the shoulder and from the side shooting positions transfer the system's full weight as an off-center load through the nozzleman's back. Pump surges then produce continuous twisting forces that must be counteracted by the nozzleman's back, hips, and upper body. Poor shooting positions affect placement quality, reduce

(a) (b)

*Fig. 3: Examples of awkward nozzle positions. Nozzles held (a) over the shoulder or (b) from the side reduce mobility, range of motion, and overall placement precision*

Fig. 4: Professional nozzleman demonstrates excellent shooting positions

Fig. 5: Professional nozzleman works in a relaxed, well-balanced position. Note: Hose is relatively rigid and remains firmly on the ground behind the nozzleman

mobility, create unnecessary fatigue, and may cause back injuries.

To hold the nozzle professionally, face the work squarely with your chest, head, and shoulders facing the work. Place one foot well ahead of the other to counteract nozzle thrust. Route the placement hose directly behind you and up, between your legs, centered within your frame (Fig. 4). This position optimizes natural balance and provides the nozzleman with the maximum range of motion. Use your feet, legs, and arms—not your back—to manipulate the nozzle position.

## Minimize Fatigue—Force the Hose to Hold Itself Up (So You Don't Have To)

Study the photograph in Fig. 5. The hose is placed on the ground and arced upward by the nozzleman's legs. The nozzle end hose **must** be sufficiently rigid to continue its upward arc. The nozzleman's right hand holds the hose against his body and maintains hose curvature. The nozzleman's left hand appears to hold the entire

*Fig. 6: Expert nozzleman maintains optimum nozzle position at various heights*

hose up, but is actually pulling downward to both bend the hose and counteract nozzle thrust. This position effectively transfers much of the placement system's weight and thrust to the ground rather than through the nozzleman's body, considerably minimizing required effort. This posture is the foundation of all effective shooting positions.

Figure 6 demonstrates variations of excellent nozzleman posture. These positions combine maximum range of motion and precise nozzle control while greatly reducing fatigue.

Effective shooting positions are used by all professional nozzlemen to improve placement accuracy and offset the weight and thrust of a nozzle. It is the precision with which the material is applied—not the effort required—that defines a professional nozzleman.

## Checklist

- Posture, movement, and mobility strongly affect overall placement precision.
- Study shooting positions used by experienced nozzlemen. Practice techniques that provide excellent mobility and range of movement.
- An effective shooting technique is reliant on effective placement equipment. Use properly sized, well-maintained equipment to generate a smooth, predictable nozzle stream.
- Select a flow rate that feels right. The ideal flow rate balances maximum placement precision with minimum fatigue.
- Shoot like a professional—diminish fatigue by using shooting positions that offset the weight and thrust of the nozzle.

*ACI Certified Nozzleman **Oscar Duckworth** is an ASA and 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 process. He continues to work as a shotcrete consultant and a certified nozzleman.*

*Reprinted with permission from Creamer Media's* Engineering News*: **www.engineeringnews.co.za***

# Changing Methods of Sinking Vertical Shafts in Mining

*By Natasha Odendaal*

The way the mining industry and contractors work with vertical shafts is changing through the introduction of technologies such as Murray & Roberts (M&R) Cementation's advanced shaft-lining technology.

"Currently, the mining industry is discussing options for safer methods of sinking vertical shafts and the changes needed to eliminate parallel activities in a vertical shaft," says M&R Cementation Business Development Executive Allan Widlake. The company believes the lining technology will bring about significant change in shaft sinking.

The shaft-liner machine remotely shotcretes lining from the top to the bottom of the shaft, up to a depth of 492 ft (150 m), within 7 days.

"As there is no need for any personnel to descend into the shaft at any time during the process, this makes this shaft-lining system safer than the conventional methods used," says Widlake.

This is echoed by M&R Cementation Senior Project Manager Pat Muller: "The remotely operated shotcrete system eliminates the risky, costly, and time-consuming process of lowering employees and equipment down the shaft to apply the lining."

The shaft liner can be adjusted to accommodate shaft diameters from 4.9 to 26.25 ft (1.5 to 8 m) by attaching different leg attachments to the spray head. The process takes place at a rate of 317.8 $ft^3$ (9 $m^3$) in a 12-hour shift.

Progress can be observed through cameras mounted on the spray head, enabling operators to verify the quality and process of spraying for the client's and the contractor's records.

"The system requires two operators who have full control of all functions during the scanning and spraying process, such as the hydraulic pump, winch speed, rotation speed, drycrete feed rate, addition of air and water, and recorded DVD footage," says Muller.

At the end of the process, a detailed report is generated as proof that all the required specifications have been met.

"The remote shaft-liner shotcretes safely, cost effectively, and on time, providing a high-quality finish," Muller says.

The system is mobile and is transported to the required location using a 7- to 10-ton truck.

## Testing Technology

The shaft-liner technology will be employed for the first time in Botswana during a turnkey contract, secured in November by M&R Cementation, to raise-drill and support two 19.7 ft (6 m) diameter vertical shafts, which will be sunk to a depth of 361 ft (110 m) at Debswana's Morupule colliery.

The scope of work includes the project management of the commissioning, manufacture, supply, and installation of two 1 MW fans in the upcast shaft and is expected to be completed by June.

The Morupule colliery supplies coal to the Morupule Power Station, and this contract forms part of the current expansion program, which will increase capacity from 1 to 3 million tons a year.

# Flexibility of Shotcrete—Pools, Spas, and Waterfalls

By Jamie Scott

Shotcrete is often used on large industrial or municipal projects, such as concrete domes, bridge restoration, and tunnel work. Due to shotcrete's inherent flexibility and the creativity it gives a designer, it is the preferred method for building residential watershape projects, such as pools, spas, and waterfalls.

In spring 2008, a homeowner who was interested in creating a waterfall in her small hidden backyard was interviewed. The rear of the property presented some distinct challenges for construction access, as half of the Greenwich, CT, property was massed with a wall of ledge rock approximately 20 ft (6 m) tall. With its aged appearance and cragginess, however, it was also well situated for integration with moving water. Previously, others had attempted to create some sort of waterfall using a masonry basin and recirculating hose. After this initial attempt at creating a waterfall failed, the homeowner sought out a more serious, permanent approach to the project.

Not only did the homeowner want to enjoy the sound and sight of water falling down the ledge, she also needed a therapeutic function for a disabling injury, which the warm water and action of a heated spa could provide. The final design consisted of a waterfall cascading down over the ledge rock approximately 10 ft (3 m) into an integrated waterfall basin surrounded by the separate waters of the therapeutic spa.

In designing these watershapes, the following key factors were taken into consideration:

- The ledge rock;
- The severe space limitations of the backyard; and
- The need to build a tightly curved, structually sound watershape that met the homeowner's needs.

The ledge rock was the first, obvious, and somewhat overwhelming issue. Watershapers strive to get the structures "into the ground" for aesthetic and functional reasons. This site, however, did not allow this. This particular part of the state is known for its very dense rock, and the homeowner's budget did not allow for much ledge-rock removal. The site also only allowed a narrow walkway into the backyard with virtually no room for machinery access. Pneumatic drills with "feather and wedge" tools allowed for a small thickness of rock to be taken out—not a lot, but enough for the structure to be anchored into the rock beneath.

*Rigid forming to remove vibration during shotcrete*

*Shotcrete waterfall basin and spa ready for plaster*

*Waterfall running over ledge rock into waterfall basin*

*Waterfall and shotcreted spa working together*

Essentially, the spa and catch basin structure was built out of ground. The structure was rigidly formed using No. 4 steel reinforcement. In the spa business, steel reinforcement is often oversized to create a rigid steel cage that does not sag under the weight of workers and provides a more stable cage for supporting plumbing.

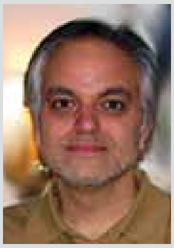
Limited space was also a significant obstacle. As previously mentioned, the backyard was narrow with no real access. Also, the existing landscape and tree roots were to remain untouched. It became clear as the project progressed that the shotcrete process was a key advantage in working in this small and limited space. The concrete was delivered to the backyard through the hose, and the tightly curved shapes were easily handled by the versatility of shotcreting.

A significant side note involves the recirculation systems. In 2007, there was a nationally publicized case emanating from this town about a young child who lost his life in a swimming pool due to entrapment. The builder was charged with criminal acts, including manslaughter. The town's reaction was to go back several years to review all swimming pool drain installations to ensure that they were properly installed and, of course, to scrutinize any future installations.

The waterfall basin and spa were built to provide two entirely separate recirculating bodies of water. With the basin only 2.5 x 4.5 ft (0.76 x 1.37 m) in size, it was a challenge to place the suction fittings so that they would draw properly and still meet building code specifications. Plumbing in the 8 x 5 ft (29 x 18.5 m) spa was slightly less of a challenge, but it still called for ingenuity in design and installation due to the limited surface space.

The dry-mix shotcrete method was used, with a 4:1 mixture (sand:cement) proportion. Following the 1-day shoot, the shotcrete shells were moist-cured for 7 days using soaker hoses. The structure was completed with a masonry façade and a dark gray aggregate interior finish. Finally, several large stones were worked into the upper ledge along the waterfall route to help direct and contain the flow.

The end result was a beautiful waterfall that met the homeowner's aesthetic and functional needs. Using shotcrete presented the opportunity to be creative and integrate the new structures into the challenging site.



***Jamie Scott** is a third-generation watershape designer and builder who has worked in the swimming pool and landscape industries for 39 years. He received his BS in business and accounting from Southern Methodist University, Dallas, TX. Scott co-owned a high-end pool and landscape firm until 1998, when he divested to found a new firm, Group Works LLC, based in Wilton, CT. Through Group Works LLC, Scott has aligned himself with Genesis 3 and other organizations that focus on continuing education and increasingly higher standards in the watershape industry. He is a Platinum Member of Genesis 3 and a certified member of the Society of Watershape Designers. Scott is also an APSP Certified Professional Builder and an ASA member and has trained with the Portland Cement Association. Additionally, he is on track to become a registered landscape architect. Scott and Group Works LLC have been featured in regional and national publications.*

# Shotcrete Calendar

SEPTEMBER 12-15, 2011
**Sixth International Symposium on Sprayed Concrete**
Tromsø, Norway
Web site: **www.sprayedconcrete.no**

OCTOBER 12-14, 2011
**ICRI 2011 Fall Convention**
Theme: "Water & Wastewater Treatment Plant Repairs"
The Westin Cincinnati
Cincinnati, OH
Web site: **www.icri.org**

OCTOBER 15, 2011
**ASA Fall Committee Meetings**
Millennium Hotel & Duke Energy Convention Center
Cincinnati, OH

OCTOBER 16-20, 2011
**ACI Fall 2011 Convention**
Theme: "Bridging Theory and Practice"
Millennium Hotel & Duke Energy Convention Center
Cincinnati, OH
Web site: **www.concrete.org**

OCTOBER 30-NOVEMBER 4, 2011
**International Pool|Spa|Patio Expo**
Conference: October 30-November 4
Exhibits: November 2-4
Mandalay Bay Convention Center
Las Vegas, NV
Web site: **www.poolspapatio.com**

NOVEMBER 2, 2011
**ASA Outreach Forum: Pool & Recreational Shotcrete**
Mandalay Bay Convention Center
Level 3; Room: Jasmine E
Las Vegas, NV

DECEMBER 4-7, 2011
**ASTM International Committee C09, Concrete and Concrete Aggregates**
Tampa Marriott Waterside
Tampa, FL
Web site: **www.astm.org**

JANUARY 23, 2012
**ASA World of Concrete Annual Meetings**
Las Vegas Convention Center
Las Vegas, NV

JANUARY 23-27, 2012
**World of Concrete**
Seminars: January 23-27
Exhibits: January 24-27
Las Vegas Convention Center
Las Vegas, NV
Web site: **www.worldofconcrete.com**

MARCH 17, 2012
**ASA Spring Committee Meetings**
Hyatt Regency
Dallas, TX

MARCH 18-22, 2012
**ACI Spring 2012 Convention**
Theme: "The Art of Concrete"
Hyatt Regency
Dallas, TX
Web site: **www.concrete.org**

APRIL 18-20, 2012
**ICRI 2012 Spring Convention**
Hilton, Quebec
Quebec, QC, Canada
Web site: **www.icri.org**

MARCH 19, 2012
**ASA Spring Underground Committee Meeting**
Hyatt Regency
Dallas, TX

JUNE 24-27, 2012
**ASTM International Committee C09, Concrete and Concrete Aggregates**
Sheraton San Diego Hotel & Marina
San Diego, CA
Web site: **www.astm.org**

OCTOBER 20, 2012
**ASA Fall Committee Meetings**
Sheraton Centre
Toronto, ON, Canada

OCTOBER 21-25, 2012
**ACI Fall 2012 Convention**
Theme: "Forming Our Future"
Sheraton Centre
Toronto, ON, Canada
Web site: **www.concrete.org**

OCTOBER 22, 2012
**ASA Fall Underground Committee Meeting**
Sheraton Centre
Toronto, ON, Canada

# Crossing the Line

By Oscar Duckworth

I appear to possess a unique talent. No matter how I route my wet-mix placement system, it's always in someone's way. Actually, most of us share the same challenge. Soon after we lay out a hose, every piece of equipment within 10 miles needs to drive over it. Of course, most equipment operators don't ask—they just do it. A select few may drive over first, then ask if it's okay. Unfortunately, it's never okay. Any placement hose that is run over while under pressure can create a dangerous bursting hazard that may cause injury or property damage if the hose fails.

## Can a Placement Hose Be Driven Over When the Pressure Is Off?

Any empty-braided fabric or steel-braided placement hose rated for shotcrete use (1250 psi [8.6 MPa] or above) may be driven over by rubber-wheeled machinery without damaging the hose. A steel pipe (slick line) used to convey

Fig. 1(a): Hose section displaying inner liner area and braided fabric cords

Fig. 2(a): This nearly new hose has burst within days of being run over by equipment. Note the lack of external evidence of internal abrasion damage, as seen in Fig. 2(b)

Fig. 1(b): Interior view of inner liner failure caused by crushing

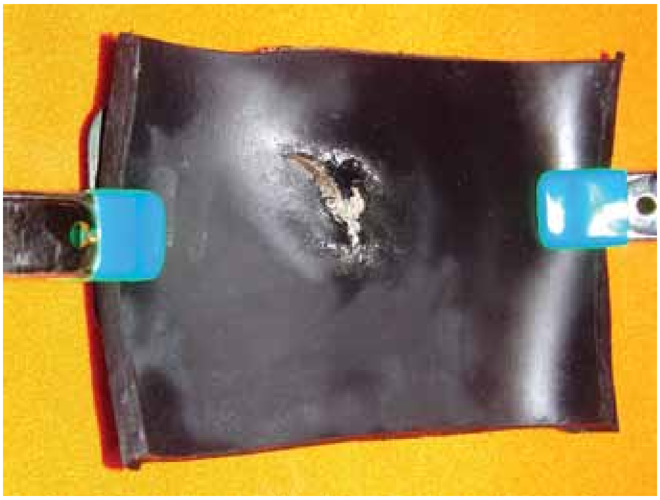


Fig. 2(b): Interior view of burst area

shotcrete can be crushed or severely deformed if run over by larger-wheeled construction equipment. A dented or deformed slick line will quickly plug and have accelerated wear from the interior. Damaged slick line cannot be made safe—it must be discarded.

If a placement hose is not pressurized, but filled with concrete, it should not be run over. A placement hose's smooth inner liner can be permanently damaged by being run over, even once (Fig. 1(a) and (b)).

Angular coarse aggregates in the shotcrete mixture can pierce the placement hose's inner liner if the hose is crushed from its exterior. A small protrusion or tear in the inner liner will allow pressurized shotcrete mixture into and through the hose's vulnerable inner braided area. Occasionally, a bubble on the hose's exterior will give a warning signal of a pierced inner liner.

More often, the line will simply burst without warning days or weeks later, right at the point of the original damage (Fig. 2(a) and (b)).

## If Possible, Disconnect the Line and Let Equipment Through

The best method to reduce damage is to be aware. Relieve pressure, disconnect the line, and move it out of the way to allow equipment or vehicles through. If crossing over a line cannot be avoided, place the line in a small trench or set timbers on either side of the line to help distribute the vehicle weight to the sides and not on the hose. Never allow an unprotected placement line full of concrete to be run over.

All job sites are busy job sites. When possible, relieve pressure, disconnect, and recouple the line. Protect the system from damage by using common sense measures. Time and effort spent protecting the placement system from equipment damage will save money in less frequent hose replacement and make the job site safer for everyone in the long run.

*ACI Certified Nozzleman* ***Oscar Duckworth*** *is an ASA and 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 process. He continues to work as a shotcrete consultant and a certified nozzleman.*

## Putzmeister Underground Concreting Division Forms Partnership with GHH and Mine Master

Putzmeister has reached an agreement with GHH and Mine Master for the distribution and service of drilling jumbos, bolting rigs, and load-haul dumpers to complement the company's shotcreting equipment for tunneling. The cooperation between the companies will start with Putzmeister distributing and marketing GHH and Mine Master machines in Madrid, Spain, where the headquarters of Putzmeister's underground concreting division is located. This initial agreement might be the starting point for a possible global cooperation.

Putzmeister is a global market leader in shotcreting equipment for the stabilization of excavations, galleries, and slopes in tunneling and mining, whereas GHH and Mine Master provide machinery for the previous working stages of drilling and earth removal. Through this mutually complementary product range, the companies broaden the product offering around the tunneling process, resulting in synergy effects for customers of the Iberian Peninsula. Equipment and service solutions for all working stages can now be obtained from one source.

With almost 30 years of experience in the development and manufacturing of shotcreting equipment, Putzmeister is present in important tunneling and mining projects worldwide. The development of the New Austrian Tunneling Method (NATM) provided a major boost to the use of shotcrete in rock support, relying on the use of shotcrete to provide immediate active support after each round of advance. Putzmeister's shotcrete manipulators apply concrete in tunnels and mines with rates of up to 39 yd³/h (30 m³/h) and spraying reaches of up to 55 ft (17 m).

GHH Fahrzeuge, headquartered in Germany, has produced load-haul-dump technique machines (LHDs) with articulated steering for the mining industry since 1964. Later on, articulated dump trucks (ADTs) followed. Roof scalers, telescopic trucks, and other special vehicles also belong to the product line. More than 35 years of experience in the development, design, and manufacture of vehicles characterize the quality, reliability, and capability of GHH's products.

Mine Master (formerly Boart Longyear Polish operating division) has manufactured, distributed, and serviced equipment for the underground metal mining and construction industries for the last 35 years. Its principal products are a full range of drilling jumbos (Face Masters), roof bolting machines (Roof Masters), and excavator drilling attachments (Flexi Masters). The product applications are applied to a variety of tunneling and mining environments. The company supplied over 300 drilling and bolting rigs to one of its major customers, KGHM Polish Copper (one of the world's largest primary copper producers).

## Structural Group Becomes STRUCTURAL

Structural Group—a Baltimore-based specialty contracting firm that combines specialty construction and maintenance services with proprietary technology to solve engineering and construction challenges—has announced a name change to STRUCTURAL.

Capitalizing on more than 35 years of service in the commercial, industrial, energy, public, and transportation markets around the world, the new name will establish a platform for a collaborative environment among all locations. Entities known as Structural Group, Structural Preservation Systems, and ElectroTech CP will now be rebranded under the STRUCTURAL name.

"The driving force for our new brand was our customers," said Ken Chodnicki, Chief Sales and Marketing Officer at STRUCTURAL. "We were asked to clarify the multitude of brands and company names we have and deliver our capabilities to them under a single organization." He also added that the name was chosen, in part, because the word STRUCTURAL is already strongly associated with the company and was a natural evolution.

Peter Emmons, STRUCTURAL CEO, added, "Although the name has changed, what our clients have come to know and expect remains the same. Together, all STRUCTURAL resources bring industry-leading expertise and experience, advanced technologies, and the highest commitment to quality and safety."

## Putzmeister America Part of Worldwide Effort to Help Cool Japan's Nuclear Reactors

As the unfathomable tragedy in Japan evolved into a massive effort to contain the damaged nuclear reactors at the country's Fukushima Daiichi plant, Putzmeister America, Inc., was part of a global effort to help. Putzmeister America, Inc., based in Sturtevant, WI, is a division of one of the world's most well-recognized and respected heavy equipment manufacturers, Putzmeister Concrete Pumps GmbH (PCP). Putzmeister affiliates are working together to send four additional boom pumps to join the one already working to cool Fukushima's reactor No. 4. Two of these pumps, the world's largest concrete boom pumps, are coming from Putzmeister America.

The first of the two pumps from the U.S. was prepped for the flight at Putzmeister's West Coast Customer Support Center in Santa Fe Springs, CA, and departed from Los Angeles International Airport (LAX); the other was prepped in North Charleston, SC, and was sent to Atlanta, GA, where it departed from Hartsfield Atlanta International Airport (ATL). Each pump weighs approximately 190,000 lb (86,183 kg) and has a boom reach of over 227 ft (69 m). They were flown to Japan via two Russian Antonov AN-225 Mriya Super Heavy Transport planes, the world's largest aircraft, originally designed to transport the Russian Space Shuttle.

"Like many people all over the world, our thoughts have been with the people of Japan as they deal with this unprecedented crisis," said Dave Adams, President and CEO of Putzmeister America. "Fortunately, we have a piece of equipment that is working to help cool Japan's nuclear reactors…"

The concrete boom pumps—normally used to pour concrete for bridges and high-rise construction projects—are well-suited for the task because of the pinpoint accuracy of the machine's reach. It's able to feed water over the destroyed buildings to the exact place of the hotspots within the reactors. In addition, because the pump is operated via radio remote control, the operator is able to remain in a safe location



Circle #45 on reader response form—page 64

approximately 1.2 miles (1.9 km) away while maneuvering the boom pump.

Two Putzmeister customers—Mike Parigini of Associated Concrete Pumping in Sacramento, CA, and Jerry Ashmore of Ashmore Concrete Contractors, Inc., in Evans, GA—recognized that their 70Z-Meter concrete pumps have the capabilities needed for the cooling operations and without hesitation offered to make the pumps available. The 70Z-Meter pumps are the largest boom pumps in use worldwide.

Putzmeister has previous experience working on nuclear power plants in crisis and other disaster situations. After the Chernobyl disaster in 1986, Putzmeister sent 11 boom pumps to help place the concrete that entombed Reactor Block 4 to prevent additional radiation from being emitted. Also, for more than 25 years, Putzmeister concrete pumps have been used in fire-fighting operations with a spray nozzle retrofit.

### 1 in 9 U.S. Highway Bridges Classified as Structurally Deficient

The Web site for Transportation for America, **www.t4america.org**, reports that 1 in 9 highway bridges in the U.S. are classified as "structurally deficient," requiring significant maintenance, rehabilitation, or replacement. The site features an interactive map that allows viewers to map all the deficient bridges within 10 miles (16 km) of any U.S. address and view a national report, 51 state reports, and a full national ranking of state bridge conditions.

### 4400 U.S. Dams Considered Susceptible to Failure

According to the Association of State Dam Safety Officials, of the nation's 85,000 dams, more than 4400 are considered susceptible to failure. A 2009 report by the state dam safety officials' group estimates the cost of fixing the most critical dams, where failure could cause loss of life, at $16 billion over 12 years, with the total cost of rehabilitating all dams at $51 billion.

### After 3 Straight Months of Decline, March Sees Construction Spending Increase

A Commerce Department report revealed a 1.4% increase in spending on U.S. projects in March of 2011. Total spending in March was a seasonally adjusted rate of $769 billion. The increase was the largest since April of 2010. The spending increase was primarily driven by the construction of factories, hotels, and office buildings. Spending increases were realized in both the public sector (0.1%) and the private sector (2.2%).

### NRMCA Reports Increase in Ready Mixed Concrete Production

According to NRMCA estimates, the preliminary estimate of ready mixed concrete production in February 2011 is 13.4 million $yd^3$ (10.2 million $m^3$), which is 7.2% higher than for February 2010. The estimated year-to-date production through February is 27 million $yd^3$ (20.6 million $m^3$)—6.6% higher than during the same period in 2010.

### Cost of Construction Materials Rising

March saw an annual rise of 6.9% in the producer price index for construction materials largely due to the steep increase in the price of diesel fuel, according to the Associated General Contractors of America. It was the largest increase since 2005 for the index, which tracks the cost of materials and items used in all types of construction.

## Industry Personnel

### Wayne Allen Wins Pioneer Award from ACPA

**Wayne Allen**, Putzmeister America's South Central Regional Sales Manager, was awarded the American Concrete Pumping Association's (ACPA) Pioneer Award on January 18 during World of Concrete 2011 at ACPA's Annual Meeting.

The Pioneer Award is given to those who have been active in the concrete pumping industry for a minimum of 20 years, fostered and advanced the concrete pumping industry in a given area, and improved conditions under which concrete pumping was performed.

With a concrete construction career spanning 30 years, Allen has held various sales positions in the industry, from selling power screeds, power trowels, and concrete buggies to concrete pumps and adjustable scaffolding.

For the past 17 years, Allen has been employed by Putzmeister America and has been an integral part of the company's growth since the beginning. Currently based out of Dallas, TX, Allen provides concrete pump and Telebelt® telescopic belt conveyor sales coverage for Putzmeister America's South Central region.

In addition, Allen has been very active in ACPA throughout his career, including helping to develop and maintain its safety training and certification programs and participating on several ACPA committees.

### New President of Sandvik Materials Technology

**Peter Gossas**, President of Sandvik Materials Technology, will retire at the age of 62. Accordingly, he will leave the Sandvik Group on May 31, 2011.

**Jonas Gustavsson**, currently President of the Wire and Heating Technology product area within Sandvik Materials Technology, has been appointed the new President of the business area effective May 1, 2011. As of the same date, he will be a member of Sandvik's Group Executive Management.

Gustavsson was born in 1967 and holds an MSc in mechanical engineering from Luleå Technical University, Luleå, Sweden. He has solid industry experience from senior positions within and outside Sandvik. He was previously General Manager of the Tube operations within Sandvik Materials Technology in Sweden and also held the position of Vice President Operations at Bombardier Recreational Products in Austria. Prior to this, he occupied several senior positions in ABB.

**Olof Faxander**, President and CEO of Sandvik AB, commented on the change, "With his broad background and proven ability to successfully drive change, Jonas Gustavsson has the right profile to lead Sandvik Materials Technology. He brings with him experience from two different product areas within the business area and has made an exceptional contribution to the development of Wire and Heating Technology over the past 2 years."

## ACI Announces New Officers for 2011

The American Concrete Institute (ACI) introduced its 2011-2012 President, Vice President, and four Board members during the ACI Spring 2011 Convention in Tampa, FL.

**Kenneth C. Hover** was elected to serve as President of the Institute for 2011-2012. After the sudden loss of ACI President Richard D. Stehly in September 2010, Hover was elevated from the position of Senior ACI Vice President to fill the remainder of Stehly's term. Hover's own 1-year term as elected ACI President officially began at the conclusion of the Spring 2011 Convention and will end at the Spring 2012 Convention in Dallas, TX.

**Anne M. Ellis**, Vice President of Government Initiatives at AECOM in Arlington, VA, has been elected ACI Vice President for a 2-year term, and **James K. Wight**, Professor of Civil Engineering at the University of Michigan in Ann Arbor, MI, is now the Institute's Senior Vice President, which is also a 2-year term.

Additionally, four members have been elected to serve on the ACI Board of Direction, each for a 3-year term: **Neal Anderson**, Vice President of Engineering, Concrete Reinforcing Steel Institute; **Khaled Awad**, Chairman and Founder of ACTS, a leading material and geotechnical consulting firm in the Middle East, based in Beirut, Lebanon; **James R. Harris**, Principal of J.R. Harris & Company, Structural Engineers, Denver, CO; and **Cecil L. Jones**, President of Diversified Engineering Services, Inc., located in Raleigh, NC.

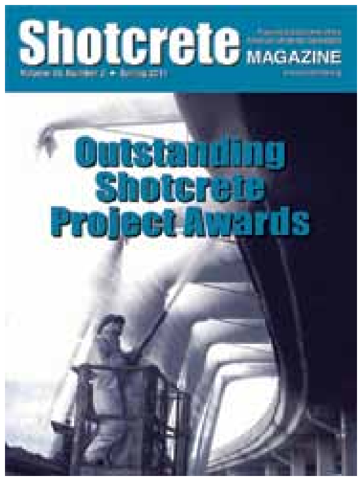
## NRMCA Materials Division Elects Euclid Chemical Executive as Chairman

At its annual meeting in March, the members of the NRMCA Materials Division elected **David Nicholson** to serve as Chairman of the Division's Board of Directors for a 3-year term, concluding in 2014. In his new position, Nicholson will also serve as an ex officio member of the NRMCA Board of Directors. He has been with Euclid Chemical Company (ASA Corporate Member) for 9 years and currently serves as Vice President of Sales. Before his tenure at Euclid, Nicholson held a variety of positions with MasterBuilders. He has served on the Materials Division Board of Directors since 2008.

The NRMCA Materials Division includes companies that supply materials and ingredients for ready mixed concrete, including cement, fly ash, color, admixtures, and fiber.

## Submit your Project for the ASA Outstanding Shotcrete Project Awards

*The 7th Annual ASA Outstanding Shotcrete Project Awards are now open and projects can be submitted until September 1, 2011.*




Pursuing an ASA Outstanding Shotcrete Project Award is not only a smart move for your organization, but also good for the shotcrete industry. The ASA Shotcrete Project Award program offers your organization a unique and unmatched amount of exposure. In addition, the awards program and the annual awards issue of *Shotcrete* magazine are very important tools used to inform and educate the construction world about the many benefits of the shotcrete method of placing concrete.

Use the new streamlined and easy online application form and submit your project today at **www.shotcrete.org/asaoutstandingprojects.htm**.



## ASA Announces Outreach Forum during the International Pool|Spa|Patio Expo in Las Vegas

ASA is pleased to announce an ASA-sponsored Outreach Forum inviting the pool industry to participate in a discussion of what needs/opportunities can be met by ASA.

To be held during the International Pool|Spa|Patio Expo in Las Vegas, NV, the forum will take place in Jasmine E on Level 3 of the Mandalay Bay South Convention Hall on Wednesday, November 2, 2011, at 5:00 p.m. PST. There is no cost to attend the forum and all interested parties are encouraged to attend.

ASA Pool & Recreational Shotcrete Committee Chair Bill Drakeley will lead the discussion and explore topics such as ASA education efforts, nozzleman certification, and other resources that could assist pool building contractors. The meeting will also offer an opportunity to discuss the advantages of shotcrete and different applications regarding watershapes other than pools that shotcrete/gunite contractors can realistically get involved with.

"We are basically going to those in the industry that use the shotcrete/gunite process and asking them what they want ASA to be for them," said Drakeley. "This is a great opportunity for both the industry and ASA to refocus/repurpose a resource that will truly serve the needs of the industry for years to come."

A full agenda will be made available on ASA's Web site in the weeks immediately preceding the ASA Outreach Forum. Those interested in attending the meeting can send an e-mail to info@shotcrete.org, and ASA staff will send an electronic copy of the meeting agenda once it is officially finalized.

## ASA Graduate Scholarship Program Open

ASA is now accepting applications for Graduate Scholarships for the 2011-2012 academic year. The purpose of the ASA Graduate Scholarship Program is to attract, identify, and assist outstanding graduate students pursuing careers in the field of concrete with a significant interest in the shotcrete process.

One scholarship will be awarded to a graduate student attending an accredited college or university in the U.S. and a second scholarship will be awarded to a graduate student attending an accredited college or university in Canada.

Based on essays, submitted data, and references, the ASA Scholarship Committee will select scholarship recipients who appear to have the strongest combination of interest and potential for professional success in the shotcrete industry. Each ASA Graduate Scholarship award consists of a stipend of $3000 (USD) and is paid in one installment of $3000 (USD) directly to the student's educational institution.

Applications and all required documents must be received by 5:00 p.m. EST on November 4, 2011.

All application information and requirements can be found at **www.shotcrete.org/ASAscholarships.htm**.

## ASA's Bimonthly E-Newsletter "What's-in-the-Mix"

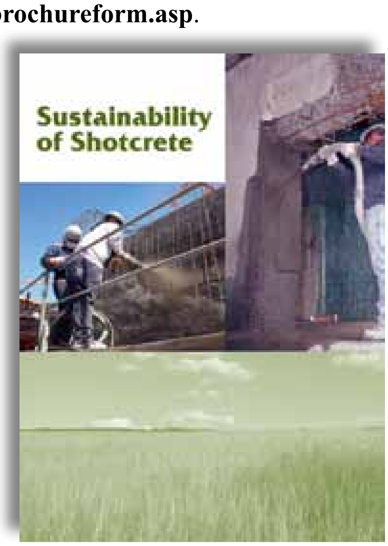
Are you receiving ASA's e-newsletter? If not, forward your e-mail address to info@shotcrete.org and ASA will include you on all future distributions. ASA promises those who provide us with their e-mail address that we will limit the number of e-mails sent to two per month. We also promise not to share or sell e-mail addresses that have been entrusted to ASA.

The "What's-in-the-Mix" e-newsletter is a great way to stay up to date between issues of *Shotcrete* magazine regarding ASA's activities and new products and services available to you. The ASA member edition of the e-newsletter also includes a listing of shotcrete-related federal projects open for bid and a link to the Concrete Joint Sustainability Initiative Industry Trends Report.

## New "Sustainability of Shotcrete" Brochure Well Received

ASA announced the release of this new resource in the Spring issue of *Shotcrete* magazine. Initial reaction to the document has been very positive. "Sustainability of Shotcrete" is proving to be a very important resource to promote and educate the construction world about the exceptional sustainability advantages of the shotcrete process.

Copies of the 10-page brochure can be ordered from the ASA Web site at **www.shotcrete.org /ASA-sustainability brochureform.asp**.




## ASA Fall Committee Meetings in Cincinnati, October 15, 2011

The ASA Fall 2011 committee meetings in Cincinnati, OH, will be held at the Millennium Hotel & Duke Energy Convention Center on October 15, 2011.

The following committees have scheduled working meetings: the ASA Executive Committee, the Publications Committee, the Pool & Recreational Shotcrete Committee, the Education Committee, the Safety Committee, the Sustainability Committee, the Marketing & Membership Committee, and the ASA Board of Direction.

These meetings offer participants the opportunity to network with colleagues, provide input on shotcrete materials and publications, and become a part of ASA's overall mission.

The ASA committee meetings are held in conjunction with the ACI Fall 2011 Convention but do not require registration for the ACI convention. ASA meetings are open and free to anyone who has an interest in the shotcrete process.

Scheduled times for all meetings can be found at **www.shotcrete.org/ASAcalendar.htm**.

A *Shotcrete* feature:

# SAFETY SHOOTER

## Third-Rail Safety

*By Ray Schallom III*

There are a few things you should be aware of when working around the third rail of an electric-powered passenger train. Third rails are generally found in underground portions of the rail line, including subway tunnels and platform stations. When the trains are running above ground, they are commonly connected to electric lines supported by poles above the tracks.

This article only discusses electrified third-rail systems. Every year, we hear about someone getting badly injured or killed when they touch or come in contact with a third rail. The voltage running through the third rail is over 600 volts and is designed for powering the passenger rail cars as they come in contact with it. Cities that have the metro rail service as part of their major transportation system usually depend on electricity to run them. Electricity is a cleaner energy (no pollution) and is safer underground.

The energized third rail has a protective cover over it to keep anyone from directly coming in contact with it. Metro rail cars have two electrical power boxes mounted to the underside and at each end of the passenger car. A flat contact plate is folded down when the train car is in service so that as it comes in contact with the third rail, it will be energized. Power is conducted through these plates to complete the electrical circuit and power the rail car.

When the rail cars are energized, the electricity has a tendency to flow down through the metal wheels, which ride on the steel rails. It's never a problem when both tracks have live traffic running on them at the same time. When the power on one set of tracks is turned off, but the tracks are connected to each other at crossovers, however, this creates a potential problem because electricity travels through connected metal.

Contractors performing work for the Transit Authority (TA) operating the train system in major metropolitan areas are required to send their employees to a safety orientation class conducted by TA field personnel. Depending on the nature of the work, the safety orientation can range from an all-day 8-hour session to an all-week 40-hour session. The safety orientation sessions stress the proper lockout procedures required when turning off sections of the electrical grid that energizes the third rail. This is usually done by a licensed electrician or TA electrician on a daily basis. TA instructors highlight the tools commonly used in rail construction that can conduct electricity when coming in contact with an energized third rail.

During these safety orientation sessions, workers are shown clothing and pictures of victims who contacted an energized third rail. Workers usually ground themselves by touching the third rail and the rail closest to it. It always seems to come down to the injured worker trying to finish up a project and thinking they can complete it without having to go through the steps in tagging out the electrical circuit (procedures for turning off the power and placing a lockout system on the switch to prevent someone from flipping the switch).

After the safety training has been completed, each attendee is given a hard-hat safety sticker by the TA, showing the rail staff that the worker has attended the safety orientation. These stickers are good for a year, which means that a refresher session is required for each additional year working on a particular

*The third rail is located about a foot up from the bottom in this picture*

*Note the horizontal wire at the bottom of this picture—this is the ground wire for one set of tracks. A similar wire was installed for the other set of tracks* transit system. Any worker who does not have that hard-hat safety sticker will not be granted access into the rail work site by any TA personnel. Since 9/11, Homeland Security has been cracking down on security and safety plans by all contractors working on the metro rail systems across the country. No work is conducted until all safety and security plans have been submitted and approved by the TA.

When work begins, the TA representative will go with the contractor to lock out the third-rail power for the shift. Both the TA representative and the contractor will usually put their locks on the rail with the date. This lets other crews know that the power is off and that there is a crew working near or over the third rail. The TA representative verifies that the power is off.

Most of the work is performed on a work train to help prevent construction debris from landing in the ballast rock adjacent to the rails. What most contractors do not realize is that residual electricity can run through the crossover from live tracks outside the lockout area and back down to the work area. The residual electricity will then travel through the metal wheels sitting on the rails up into the cars of the work train. Speaking from experience, you must set up a ground wire system throughout the work area that connects to the cars on the work train. Grounding the cars will prevent the residual electricity from flowing through them. If you do not ground the metal rail cars, any conducting metal you come in contact with (such as wire mesh, lattice girders, or existing reinforcing bar in the structure) will complete the circuit and create an arc.

## In Conclusion

Every worker is responsible for his or her own safety. You have to stay alert to all potential hazards from the beginning to the end of the shift. When working on live tracks to pick up debris or clean up overspray that landed on the rails, be sure to stay well clear of the third rail. If you have to dust off the cover of the third rail, make sure you are not touching one of the rails (if you do, you will ground yourself and the electrical surge can lead to injury or death). Make sure you look both ways when walking close to the live tracks. Also be aware that the suction wind created by a train passing the work area can pull someone into the path of the train. The safety training session will take you down in the subway so you can experience first-hand the wind generated by a live train passing.

Often in construction, we learn from our mistakes. In this case, when dealing with live trains, third rails, and electricity, even the first mistake can kill. Pay attention when you go through your mandatory TA safety training—what they teach you will help keep you safe and alive. Don't take for granted that it won't happen to you; make sure it doesn't by staying alert and practicing the safe procedures this hazardous work requires.

***Ray Schallom III*** *is an Underground Shotcrete Application Specialist and Vice President of RCS Consulting & Construction Co., Inc., Ripley, WV. He has 35 years of experience as a Project Manager, Owner, and Superintendent. He is a Past President of ASA; serves as Chair of the ASA Education Committee; is a member of the Publications, Underground, and Pool & Recreational Shotcrete committees; and is on the ASA Board of Direction. He is also a member of ACI Committees 506, Shotcreting; and C660, Shotcrete Nozzleman Certification. With over 31 years of shotcrete nozzling experience in wet- and dry-mix handheld and robotic applications, Schallom is an ACI Certified Nozzleman in the wet- and dry-mix processes, as well as an ASA-approved shotcrete underground educator and an ACI-approved shotcrete examiner. He is also a member of ASTM Committee C09, Concrete and Concrete Aggregates, and Subcommittee C09.46, Shotcrete.*

# Metro Testing Laboratories Ltd.

Metro Testing Laboratories Ltd. (Metro) is an employee-owned, multi-discipline engineering, testing, and concrete restoration company.

Metro's success has been built on creativity and a "forward-looking" philosophy. This has really paid off for the company. Twenty-four years ago, Metro started testing concrete, soil, and asphalt. About 10 years ago, Metro expanded into materials engineering and consulting, specialty materials testing, geotechnical engineering, environmental testing, and mobile testing.

Metro has handled over 15,000 projects both locally and internationally. International projects have been carried out in Barbados, Bermuda, Mexico, Hawaii, the continental U.S., Australia, and the Philippines.

Metro Testing's facilities meet or exceed the Canadian Council of Independent Laboratories (CCIL) and Canadian Standards Association (CSA) standards for certified concrete testing laboratories.

As a commercial testing company, Metro focuses on the testing of soils, asphalt, and concrete, but also tests other materials such as waterproofing and fireproofing substances, windows, glass fiber-reinforced composite, and many other construction products. The company provides inspection and testing for all phases of construction and conducts the necessary in-house supplemental testing.

In 2005, drawing on expertise acquired through many years of providing quality consulting services, Metro started Concrete Restoration Group. This means client's concerns are expertly addressed on site with "best practice solutions" to concrete restoration problems.

Metro's Concrete Restoration Group employs a number of ACI/ASA certified nozzlemen with extensive hands-on experience applying shotcrete in marine, industrial, and civil applications, both above- and underground.

Company-wide, Metro employs many shotcrete specialists who together bring over 150 years of individual experience to also provide a wide range of shotcrete consulting services, including nozzleman training and certifications, shotcrete mixture designs, troubleshooting, testing, monitoring, and feasibility analysis. Metro's



engineers, technologists, technicians, inspectors, support staff, and nozzlemen have a proven track record for quality work with shotcrete for major local contractors and engineering and architectural firms, as well as with municipal and provincial government agencies.

From repairing concrete ships used to form a breakwater in a harbor and restoring the support structure of major metropolitan bridges, to relining H2S gas-damaged concrete in sewage treatment tanks, Metro has repaired many concrete structures using its proprietary shotcrete material with resounding success.

In addition to the application of shotcrete, Metro's Concrete Restoration Group offers other concrete restoration services, such as hydrodemolition, epoxy injection, expansion joint installation, and specialty grouting.

Combining testing, consulting, and concrete restoration services, as Metro does, is helpful to clients who may have budgetary and/or time constraints. Excessive costs and time losses are minimized by using only one company as opposed to many contractors. Metro's multifaceted offering can also virtually eliminate the possibility of miscommunications that often occur when several different parties are involved in a project. An ideal solution for tight budgets and tighter schedules, Metro Testing continues to earn its position among the best in the industry.

**Metro Testing Laboratories (Concrete Restoration) Ltd.**
6991 Curragh Avenue, Burnaby, BC, Canada V5J 4V6
Phone: 604-436-9109   Fax: 604-436-9103
Web site: **www.metroconcreterestoration.com**
E-mail: info@metroconcreterestoration.com



Circle #52 on reader response form—page 64

# ASA New Members

### CORPORATE MEMBERS

**Abbott Shoring & Foundation Ltd.**
North Vancouver, BC, Canada
Primary contact: Roger Abbott
r_abbott@tolus.net

**Conshot Structures 2010 Ltd.**
Coquitlam, BC, Canada
Primary contact: Carl King
carlking@telus.net
www.conshot.ca

**Getman Corporation**
Bangor, MI
Primary contact: Gene L. Lomboy
glomboy@getman.com
www.getman.com

### CORPORATE ADDITIONAL MEMBERS

**Chris Harkema**
Walker, MI

### INDIVIDUAL MEMBERS

**Kenneth Kempinski**
Allentown, PA

**Russell Ringler**
Gainesville, VA

### NOZZLEMAN MEMBERS

**Michael Junge**
Seattle, WA

**Hart Leelyn**
Seattle, WA

**Craig Matthews**
Kelmscott, Western Australia

**Michael Norton**
Seattle, WA

**Jamie Orona**
Anaheim, CA

### STUDENT MEMBERS

**Christopher de Sousa**
Southport, QLD, Australia

**Aliakbar Mahmoudi Ko**
Kuala Lumpur, Selangor, Malaysia

**Babak Nikbakhtan**
Edmonton, AB, Canada

**Muhammad Nabeel Siddique**
N Karachi, Karashi, Pakistan

### INTERESTED IN BECOMING A MEMBER OF ASA?

Read about the benefits of being a member of ASA on page 62 and find a Membership Application on page 63.

## Putzmeister's Sika-PM 4210

Shotcrete is ideal for early ground support after blasting or excavating in mining, providing early strength development. Putzmeister's mobile shotcrete equipment applies concrete in mines and tunnels all over the world, with concrete output rates of up to 39 yd$^3$/h (30 m$^3$/h) and spraying reaches of up to 55 ft (17 m). The common denominator of all Putzmeister machinery is its high performance and reliability in rough working conditions both above- and underground.

Putzmeister's most advanced model for concrete spraying in mining is the Sika-PM 4210, a further development of the well-known Sika-PM 4207. The first machine of this new series has been allocated to the German Sachtleben Bergbau, who owns and runs the Clara Mine (Grube Clara) in Oberwolfach, situated in the Black Forest in Baden-Württemberg, Germany.

The new proportional remote control of the Sika-PM 4210 responds exactly to customer needs, as it allows the complete regulation of the concrete output and fine adjustments of the preset additive dosage. All other functions of the machine are also available via remote control, including the automatic start of the spraying sequence (air, concrete, and additive).

In addition to this, the reach of the spraying arm has been increased by 4.5 ft (1.4 m) in comparison with the standard model, achieving a maximum vertical spraying reach of 34 ft (10.5 m). The spraying arm is also more agile, with an increase of 25% in the spraying speed at the tip of the arm. The cylinders of all arm extensions are covered for protection but are nevertheless easily accessible for maintenance. Furthermore, new high-intensity xenon working lights have been incorporated into the spraying arm.

Other improvements of the Sika-PM 4210 to respond to the rough working conditions in the Clara Mine are:

- The incorporation of state-of-the-art heavy-duty axles with mining tires;
- A manually released, automatic fire-extinguishing system that comes into action at six critical spots of the machine at once;
- A heavy-duty switchboard made of stainless steel;
- A special low-profile concrete hopper with a discharging height of only 45 in. (1150 mm); and
- A strong stainless steel additive tank with a capacity of 118 gal. (450 L).

## BASF Showcases Sustainable Technology and Concrete Tools

BASF recently showcased four of its proprietary electronic tools that it developed to help concrete producers, architects, engineers, and building owners recognize the benefits of using concrete on their projects.

1. Integrated Durability-Sustainability Wizard—This Wizard is intended to assist engineers, architects, and specifiers in selecting admixture products and technologies to address various durability issues and identify concrete technologies that may potentially contribute to earning LEED credits for a building.
2. Eco-Efficiency Analysis (EEA) Program—The innovative EEA program examines the environmental life cycle of concrete mixtures, beginning with the extraction of raw materials through the production of concrete. This analysis quantifies the economic and ecological benefits of concrete.
3. Macro-Polymetric Fiber Dosage Wizard—This Wizard helps engineers, contractors, and concrete producers determine the amount of macrosynthetic fibers required to replace either welded-wire reinforcement (WWR) or small-diameter bars used as shrinkage and temperature reinforcement and calculate their potential savings.
4. Surface Evaporation Calculator—Based on a few simple inputs, this calculator gives an indication of whether or not the weather conditions on the day of a concrete placement create a higher chance of plastic shrinkage cracking due to an increase in the rate of surface evaporation.

Each of these tools was custom-designed and developed by BASF and is intended to further promote the use of concrete in construction while quantifying its ecological and environmental impact; calculating cost savings for the producer, owner, and architect; increasing durability and service life; and assisting with project planning.

To learn more about these technologies, visit **www.construction.basf.us**.

## ACI 301-10, "Specifications for Structural Concrete"


This document covers general construction requirements for cast-in-place structural concrete and slabs-on-ground. The first five sections cover materials and proportioning of concrete; reinforcement and prestressing steel; production, placing, finishing, and curing of concrete; formwork performance criteria and construction; treatment of joints; embedded items, repair of surface defects; and finishing of formed and unformed surfaces. Provisions governing testing, evaluation, and acceptance of concrete as well as acceptance of the structures are included. The remaining sections are devoted to architectural concrete, lightweight concrete, mass concrete, post-tensioned concrete, shrinkage-compensating concrete, industrial floor slabs, tilt-up construction, precast structural concrete, and precast architectural concrete.

Visit **www.concrete.org** for more information.

---

**Do you have a NEW PRODUCT or PRACTICE that the SHOTCRETE INDUSTRY needs to know about?**

Phone: (248) 848-3780
Fax: (248) 848-3740
E-mail: info@shotcrete.org

AMERICAN SHOTCRETE ASSOCIATION

## Top Ten Sustainability Benefits of Shotcrete

The United States Green Concrete Council's (USGCC) *The Sustainable Concrete Guide—Applications* includes a list of the top 10 sustainability benefits of shotcrete in its chapter on shotcrete. Over the next 10 issues of *Shotcrete* magazine, this Sustainability column will elaborate on each one of the following advantages. Previous discussion of advantages from past issues can be viewed on the ASA Web site at **www.shotcrete.org/sustainability**.

1. Formwork savings of 50 to 100% over conventional cast-in-place construction.
2. **Formwork does not have to be designed for internal pressures** (see below).
3. Complex shapes require very little—if any—formwork.
4. Crane and other equipment savings or elimination.
5. Labor savings of at least 50% in repair applications.
6. New construction speed savings of 33 to 50%.
7. Speed of repair reduces or eliminates downtime.
8. Better bonding to the substrate, which enhances durability.
9. Adaptability to repair surfaces that are not cost-effective with other processes.
10. Ability to access restricted space and difficult-to-reach areas, including overhead and underground.

U.S. GREEN CONCRETE COUNCIL

## Formwork Does Not Have To Be Designed for Internal Pressures

One of the most expensive and labor-intensive parts of traditional cast-in-place concrete construction is the design, fabrication, erection, removal, and transport of forms used to support fresh concrete until it reaches a strength to be self-supporting. Fresh concrete in its liquid state before set exerts a substantial lateral pressure on the formwork trying to contain it. ACI 347, "Guide to Formwork for Concrete," provides formulas to estimate the lateral pressure considering the temperature, casting rate, and type of concrete with a minimum of 4.16 psi (0.03 MPa). Common casting rates and weather conditions can easily double the pressure. If one considers the outward pressure on a 4 x 8 ft (1.2 x 2.4 m) sheet of plywood using just the minimum lateral pressure, nearly 10 tons (9.1 tonnes) of pressure needs to be contained to hold the concrete in place. To put this magnitude of pressure into perspective, think about a parking garage where the design live load is 0.35 psi (0.002 MPa) for car, truck, or bus traffic. The minimum concrete pressure inside a cast-in-place form is well over 10 times greater than cars, trucks, and buses driving in a garage structure.

For formwork to physically hold together in the desired shape during the casting operation and to withstand these massive lateral pressures requires substantial structural strength and rigidity in the forming system. Thus, you will find that properly designed formwork uses a substantial amount of lumber, steel, or aluminum, depending on the form system. Additionally, the formwork needs to be transported to the site, erected, braced, removed, and then trucked off site either for reuse or disposal. This equates to substantial $CO_2$ emissions from transport, as well as labor and cost for a product that isn't even incorporated in the final structure.

With the shotcrete process, the concrete is shot in place, so the weight of concrete is carried by the concrete itself. There is little or no lateral pressure because the shotcrete is essentially self-supporting and doesn't "flow" like fresh concrete does. Forming is reduced by at least 50% of the surface area with the use of one-sided forms. In many cases, no formwork is required at all. In addition to the many benefits of one-sided forms that were discussed in the last issue of this column, when one-sided forms are required, the structural strength requirements of the formwork are substantially reduced because there is no need to design for internal pressure from fluid concrete within the form.

A copy of the USGCC's *The Sustainable Concrete Guide—Applications* can be obtained by visiting the American Concrete Institute's online bookstore at **www.concrete.org**.

*Bay of St. Louis bridge*

*Finishing touches are made to a freshly placed shotcrete wall*

# Shotcrete FAQs

As a service to our readers, each issue of *Shotcrete* will include selected questions and provide answers by ASA. Questions can be submitted to info@shotcrete.org. Selected FAQs can also be found on the ASA Web site at **www.shotcrete.org/ASAfaqs.htm**.

**Question:** I will be placing a large amount of concrete via the shotcreting process onto a river bed. There are minimal forces and the only reason I need reinforcing is for temperature and shrinkage. If I add fibers to the mixture design, what percent of steel will I still need (if any) or, in other words, how much fiber do I need to include so that any other form of mesh or reinforcing bar is not required to meet temperature and shrinkage requirements? In addition, will too much fiber have any unwanted effects?

**Answer:** Fibers are typically added to shotcrete linings for canals, channels, and other water structures in lieu of conventional reinforcing, such as welded wire reinforcement (WWR). For your "large amount of concrete via the shotcreting process," we assume that you are using the wet-mix shotcrete process.

Temperature/shrinkage reinforcement is typically placed in thin sections governed by the structural concrete provisions of ACI 318 at a rate of 0.15 to 0.18%. Please be aware that if the lining is intended to be liquid-tight and has movement joints spaced at greater than 40 ft (12 m) apart, a reinforcement ratio of at least 0.50% is recommended by ACI 350 for concrete liquid-containing structures. Assuming that the section does not need to be liquid-tight and using the ACI 318 requirements, let's consider the tensile capacity of a conventionally reinforced section and provide an equal or greater tensile capacity with fibers. Assuming a 3 in. (75 mm) thick lining with an assumed 28-day compressive strength of 4000 psi (28 MPa), using a WWR of 6 x 6 x W2.9/W2.9 in this section provides a percentage of steel of 0.161% and a tensile capacity of 3770 lb/ft (5610 kg/m). ($A_s f_y$ = 0.058 in.$^2$/ft [0.12 mm] x 65,000 psi [448 MPa] = 3770 lb/ft [5610 kg/m].)

Then, we assume that the direct tensile strength is 75% of the flexural strength (modulus of rupture [MOR]). For 3770 lb/ft (5610 kg/m) in a section 3 x 12 in. (75 x 300 mm), we have 3770/(12 × 3) = 105 psi (0.72 MPa). Then, we need an average residual strength (ARS) (ASTM C1399) of 105/0.75 = 139.6 psi (0.963 MPa) = 140 psi (0.965 MPa).

Using a macrosynthetic fiber, one can achieve these results using 4 to 5 lb/yd$^3$ (2.4 to 3.0 kg/m$^3$) in wet-process shotcrete. Fiber manufacturers will provide exact dosages to meet the ARS requirements.

Using steel fibers, approximately 43 lb/yd$^3$ (25.5 kg/m$^3$) will provide an equivalent area of steel to the WWR of 6 x 6 x W2.9/W2.9 in a 3 in. (75 mm) thick concrete section. Using steel fibers, however, may require a flash coat to cover the fibers that will protrude and rust over time. The corrosion of the fibers will only reach a carbonation depth of 0.05 to 0.10 in. (1 to 2 mm) but may result in staining the lining.

These calculations assume a thickness and strength. You must adjust for your conditions.

**Question:** I am searching for a sample specification that calls for the use of a polymer-modified cement mortar in lieu of one that does not have the polymer additive. My thought is that this material would be more durable. I am also wondering if it would have greater bond to the old substrate.

**Answer:** Most of the industry does not endorse the use of polymer-modified additive in shotcrete. Please refer to ACI RAP Bulletin 12 and ACI 506R for further information and insight from the American Concrete Institute (ACI) at **www.concrete.org**. Shotcrete applied by competent contractors to properly prepared surfaces exhibits excellent bond characteristics to the substrate. Additionally, a good shotcrete mixture that is properly applied will yield a durability equal to or superior to cast concrete. There are many examples discussed in various articles of *Shotcrete* magazine at **www.shotcrete.org/archivesearch/ArchiveSearch.asp**.

**Question:** Are there any guidelines/regulations as to how close in proximity the installer/nozzle person can be to the receiving surface? I have a chimney job (existing chimney repair) that has an opening of 3.5 x 3.5 ft (1.1 x 1.1 m) and the interior is calling for a gunite (dry-mix) liner to be installed. Is there an issue with splash-back or any other concern with using gunite in such a confined space?

**Answer:** When gunning in tight areas, you have to allow for the bend in the hose and the length of the nozzle, which will require at least 2 to 2.5 ft (0.6 to 0.8 m). An area 3.5 ft (1.1 m) wide is a very tight area to gun in, but it can be done. In areas that restricted, it's not possible to always maintain a 90-degree shooting angle, so you will get much more rebound from the deflection when shooting at less than desirable angles. Also, with the dry process, you have to reduce the air pressure and volume to keep from blowing the material off the walls. Ideally, you would like the nozzle to be at least 3.5 to 5 ft (1.1 to 1.5 m) from the receiving surface, depending on the nozzle you use. For a tight area like you are proposing, in addition to reducing the air pressure and running it slowly, we would recommend using a double-bubble nozzle, as it has a wider spray pattern, allowing the nozzleman to be closer to the receiving surface and still get an adequate spray pattern. A double-bubble nozzle is also flexible, which will help in extremely tight areas. You can locate organizations that sell a range of nozzles by visiting the ASA Online Buyers Guide at **www.shotcrete.org/buyersguide**.

**Question:** I would like to add fibers to a shotcrete mixture. Many research articles discuss steel fibers and sometimes synthetic. I'd like to consider glass or synthetic fibers because the exterior wall will be visible and I don't want to see the corroding steel fibers toward the surface of the concrete. What are the pros/cons of glass fibers versus steel fibers and how much should I add to the mixture design to achieve a product that can be submerged in water and experience as few cracks as possible? Is there reference material for these questions?

**Answer:** Refer to ACI 506.1R-08, "Guide to Fiber-Reinforced Shotcrete," at **www.concrete.org** for guidance on fiber types and dosages. Glass fibers are seldom (if ever) used in shotcrete because they tend to break under the high velocity required for shotcrete. Steel or macrosynthetic fibers should be used at about 0.4 to 0.5 volume percent to control hardened shotcrete cracking, 50 to 66 $lb/yd^3$ (30 to 39 $kg/m^3$) for steel (specific gravity (SG) of 7.85), and 6 to 7.5 $lb/yd^3$ (3.6 to 4.5 $kg/m^3$) for macrosynthetic polypropylene (SG of 0.91). Fiber suppliers can provide more technical guidance for their products. You can locate fiber suppliers by visiting the ASA Online Buyers Guide at **www.shotcrete.org/buyersguide**.

**Question:** I have been in the swimming pool industry for 30 years and I deal with a lot of different engineers on my commercial projects who want a wet test to verify water tightness before the finish is applied to the pool. In my experience, air-entrained shotcrete tends to be porous and leak. Are there any engineering specifications that state that air-entrained shotcrete is porous and will leak if the surface is not trowel-finished?

**Answer:** Properly added and mixed air-entraining admixture in concrete will actually reduce the permeability of concrete. This is because the small, well-formed air bubbles from air-entraining admixtures are not interconnected as larger, entrapped air bubbles may be in non-air-entrained concrete. Thus, the reported higher permeability of the air-entrained shotcrete is not a material flaw but must be from poor shotcrete application. Air entraining from 4 to 7% air is advantageous for enhanced resistance to the freezing-and-thawing cycles of saturated concrete and should be specified by the designer in areas subject to significant numbers of freezing-and-thawing cycles annually. The reported high permeability and resultant failure to pass a water-tightness test could be investigated by taking cores of the "porous" material and conducting a petrographic analysis of the core. Based on the reported results, I strongly suspect that the in-place shotcrete has major issues with sand pockets, overspray, and rebound.

**Question:** We recently contracted with a shotcrete company to install a shotcrete structure for a swimming pool. After the pool was completed and filled with water, rust stains began emerging through the plaster surface. When we broke out a section of the pool structure, we found that there was little to no coverage of shotcrete over the steel reinforcement. The shotcrete company's excuse is that they shot the pool to maintain the desired finished depths and widths and there was little to no coverage because the steel was set too high (even if that were the case, they never alerted anyone during the installation). This sounds like an excuse to me. Shouldn't the shotcrete company we hired make sure that the concrete coverage met or exceeded what the structural engineer called for? Is there any credibility to their explanation of why they didn't cover the reinforcing bar enough? What is the standard practice for shotcrete installation?

**Answer:** In short, the shotcrete contractor is responsible for maintaining proper cover over the reinforcing steel. The reinforcing bar installer should set the steel in the proper location for achieving the required cover corresponding to the final desired shape. If the shotcrete contractor finds that he cannot maintain proper cover with the reinforcing as placed, however, he needs to communicate to the designer/owner/general contractor that the reinforcing needs to be fixed before he shoots the section in place. There is no excuse for placing shotcrete with less than the specified cover, as shooting it with reduced cover will obviously create a section that has much less durability than intended by the designer.

**Question:** What is the impact force on formwork resulting from a shotcrete application? I am designing the formwork for a wall to be placed via shotcrete and need to know the forces imposed on the wall forms.

**Answer:** In structural applications, most of the impact force from nozzling shotcrete is directed toward compacting the shotcrete in place rather than against the formwork. This was the subject of a study conducted by Marc Jolin of Laval University, Quebec City, QC, Canada, and reported in the Fall 2008 issue of *Shotcrete* magazine. There is virtually no hydrostatic pressure on the forms from the application using the shotcrete process. A copy of this study can be viewed on the ASA Web site at **www.shotcrete.org/archivesearch/archivesearch.asp**.

# AMERICAN SHOTCRETE ASSOCIATION

## ASA Membership Benefits

| | Corporate | Corporate - *Additional Individual* | Individual | Nozzleman | Employees of Public Authorities / Agencies | Student |
|---|---|---|---|---|---|---|
| Annual Dues | $750 | $100 | $250 | $50 | Free | Free |
| Subscription to quarterly *Shotcrete* magazine (Hard Copy) | X | X | X | X | X | |
| Electronic Subscription to quarterly *Shotcrete* magazine | X | X | X | X | X | X |
| Company & specialty information listed in ASA's online Buyers Guide | X | | | | | |
| Company & specialty information listed in *Shotcrete* magazine's annual Buyers Guide | 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 |
| Discount on ACI Nozzleman Certification, Education and Testing | X | | | | | |
| Free advance general admittance registration to World of Concrete | X | X | X | X | X | X |
| Complimentary ASA shotcrete brochure each year | 25 | | 1 | | 1 | |
| Complimentary ASA reflective hardhat sticker each year | 10 | | 1 | | 1 | |
| Permission to include ASA logo on corporate letterhead and business cards | X | X | X | | X | |
| Permission to display ASA logo on company Web site | X | | | | | |
| Discounted Member pricing on advertising in *Shotcrete* magazine and ASA's e-newsletter | X | X | X | | X | |
| Free logo and link advertising on ASA Web site home page for duration of each issue you advertise in *Shotcrete* magazine | X | | | | | |
| Opportunity to submit items for Industry News and New Products & Practice sections of *Shotcrete* magazine at no charge | X | X | X | | X | |
| Voting privileges at meetings and director/officer elections | X | | X | | | |
| Discounted ASA Member prices on all ASA products | X | X | X | X | X | X |
| Networking and participation opportunities at Annual Membership Meeting and committee meetings | X | X | X | X | X | X |
| All company employees have opportunity to receive discounted Corporate Additional ASA Memberships ($150 off regular membership price for each employee) | X | | | | | |
| Opportunity to submit entries into the annual Outstanding Shotcrete Project Awards Program | X | | | | | |
| Discount on ASA Underground Shotcrete Education Program | X | X | X | | X | |
| ASA promotion of nozzleman certification on a national basis in conjunction with ACI | | | | X | | |
| **Education & promotion of your shotcrete industry to the overall concrete industry** | **X** | **X** | **X** | **X** | **X** | **X** |

# 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

## READER RESPONSE SERVICE

Please send information on the products or services circled below:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
| 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
| 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 |
| 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 |

Name ______________________________

Company ______________________________

Address ______________________________

City ______________________________

State/Province ____________ Zip/Postal Code ____________

Country ______________________________

Phone: ______________________________

Fax: ______________________________

E-mail: ______________________________

Fax or mail to: American Shotcrete Association
38800 Country Club Dr. • Farmington Hills, MI 48331
Phone: (248) 848-3780 • Fax: (248) 848-3740

Summer 2011

## ADVERTISERS IN THIS ISSUE

*Reader Response Numbers in Parentheses* Page

Circle #22 on reader response form—page 64

Circle #11 on reader response form—page 64