Shotcrete MAGAZINE

A quarterly publication of the American Shotcrete Association

Volume 14, Number 1 ◆ Winter 2012

www.shotcrete.org

2012 ASA Buyers Guide Included

Department of Transportation Projects

AMERICAN SHOTCRETE ASSOCIATION

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**

AMERICAN SHOTCRETE ASSOCIATION

Shotcrete MAGAZINE

Volume 14, Number 1
Winter 2012

Features

8 **The Rehabilitation of the Île d'Orléans Bridge**
Philip Sawoszczuk and Daniel Bordeleau

14 **Pineda Causeway Bridge Rehabilitation**
R. Curtis White Jr.

20 **The Morris Street Bridge Rehabilitation**
Dave Sawyer

22 **The Use of Shotcrete as a Repair Process for Ontario Bridge Structures**
Joe Hutter and Mahaish Singh

28 **Ruskin Dam Spillway Shotcrete Assessed**
Lihe (John) Zhang, Mazin Ezzet, Natalya Shanahan, Dudley R. (Rusty) Morgan, and A.P. Sukumar

Departments

2 President's Message — Patrick Bridger
4 Committee Chair Memo — Ray Schallom III
6 Staff Editorial — Chris Darnell
36 Pool & Recreational Shotcrete Corner
38 Safety Shooter — Ted W. Sofis
41 Nozzleman Knowledge
46 Goin' Underground — Warren Harrison
48 Shotcrete Corner — Ted W. Sofis
50 Technical Tip — Lihe (John) Zhang
56 Sustainability
58 Corporate Member Profile — Prestige Concrete Products
60 Industry News
62 Association News
64 New Products & Processes
66 Shotcrete FAQs
68 ASA New Members
71 2012 ASA Buyers Guide
81 Shotcrete Calendar
82 ASA Membership Benefits
83 ASA Membership Application
84 Index of Advertisers

On the cover: Île d'Orléans Bridge, Quebec City, QC, Canada
Photo courtesy of Luc Genest.

The Formula for an Outstanding Association

By Patrick Bridger

The year 2012 marks the 14-year anniversary of ASA. Our Association membership is made up of individuals and corporate leaders who wish to ensure that owners and specifiers have all of the facts regarding the uses and benefits of the shotcrete process. ASA's leadership centers on our Board of Direction, which includes the Executive Committee. Members who serve on the Board are nominated to leadership positions by previous officers of ASA and are then officially elected to their positions by votes from the general ASA membership. ASA's working committees are comprised of ASA members, with a Chair appointed by the President.

As my term as President of ASA comes to a close, I have had the chance to reflect on the incredible amount that has been accomplished over the years at ASA for the good of the shotcrete industry. All of the work performed at the Executive Committee, Board of Direction, and committee levels is done entirely on a volunteer basis. I am so appreciative of and impressed by the individuals and organizations that care deeply enough about our industry and its future to contribute their time, talent, and resources as generously as they do.

Even with the incredible effort of our officers and members, this Association would not function without professional management. From ASA's early days, we have been professionally managed by Creative Association Management (CAM). CAM is a wholly owned subsidiary of the American Concrete Institute (ACI) located in Farmington Hills, MI.

CAM offers executive management and leadership, publication and newsletter development, physical operational space, hardware, software, and financial resources. CAM also offers meeting and event management, marketing and public relations, and Web site design and management for its clients. ASA has taken advantage of all of these services and more over the years.

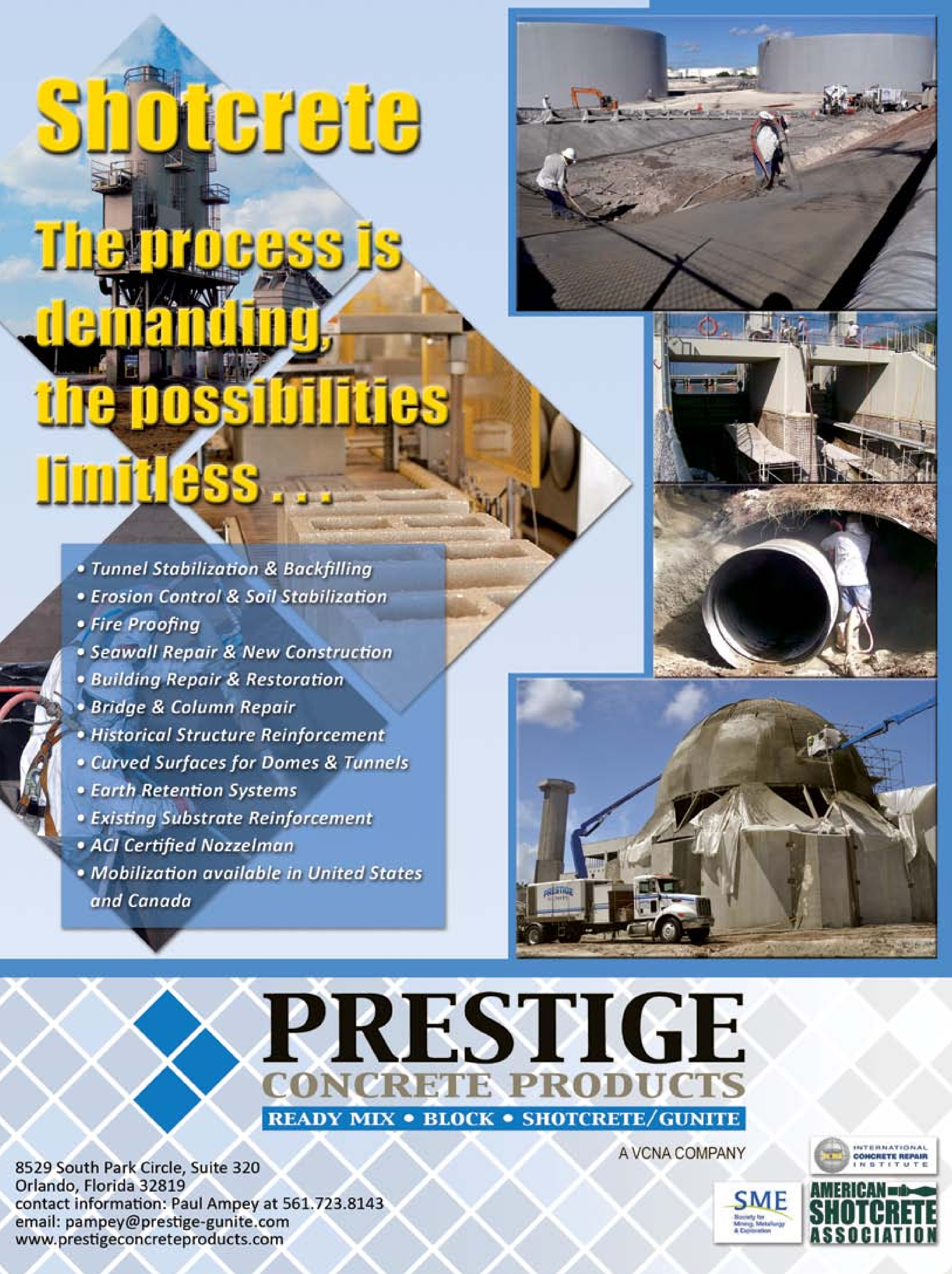
Our Executive Director, Chris Darnell, and Programs Coordinator, Alice McComas, are CAM employees. ASA uses most of Chris's time and 100% of Alice's time, but the list of CAM employees who work to make ASA the best it can be extends far beyond Chris and Alice.

With each of the services mentioned earlier, there are departments with numerous people who work behind the scenes. From the assembly, layout, and editing of the content that goes into *Shotcrete* magazine and the "What's in the Mix" e-newsletter, to event planning and management, to the long list of financial operations, ASA benefits from the efforts of a large and talented team. CAM gives ASA access to resources that would otherwise be beyond our reach.

A prime example of this is the planned redesign of ASA's Web site. ASA will be tapping into CAM expertise and resources to produce a brand-new ASA Web site that is both intuitive and effective in communicating the benefits of shotcrete to the construction world while functioning as a critical tool for our volunteers. Our goal is to introduce the new Web site before the end of 2012.

I want to take this opportunity to recognize and thank the President of CAM, Ron Burg; Chris; Alice; and the numerous others at CAM who have worked so diligently and consistently to provide the many professional services that make ASA a first-class organization.

I also want to extend my personal thanks to the many friends and volunteers who have worked so hard during my term as President and enabled us to accomplish so much. It has been an honor to serve this Association and industry, and I look to the future with great anticipation and confidence in our continued growth and success.


Shotcrete
The process is demanding, the possibilities limitless . . .
• Tunnel Stabilization & Backfilling
• Erosion Control & Soil Stabilization
• Fire Proofing
• Seawall Repair & New Construction
• Building Repair & Restoration
• Bridge & Column Repair
• Historical Structure Reinforcement
• Curved Surfaces for Domes & Tunnels
• Earth Retention Systems
• Existing Substrate Reinforcement
• ACI Certified Nozzelman
• Mobilization available in United States and Canada
PRESTIGE
CONCRETE PRODUCTS
READY MIX • BLOCK • SHOTCRETE/GUNITE
A VCNA COMPANY
8529 South Park Circle, Suite 320
Orlando, Florida 32819
contact information: Paul Ampey at 561.723.8143
email: pampey@prestige-gunite.com
www.prestigeconcreteproducts.com
INTERNATIONAL CONCRETE REPAIR INSTITUTE
SME
Society for Mining, Metallurgy & Exploration
AMERICAN SHOTCRETE ASSOCIATION

Message from the Education Committee Chair

By Ray Schallom III

As Chair of the Education Committee, I wanted to take this opportunity to update you on this important organization within ASA and give you some history of its efforts. Over 10 years ago, in 1999 in Streetsboro, OH, the Education Committee took on its first task: the creation of the Nozzleman Certification Program. This effort included the development of the study material, written exams, performance exams, and approval of the first group of Shotcrete Examiners. In 2001, ASA's Education Committee officially transferred the program to the American Concrete Institute (ACI) and the certification became the ACI Shotcrete Nozzleman Certification Program.

The ASA Education Committee's primary task since 2001 has been overseeing and updating the ASA Education modules used in preparation for ASA-sponsored ACI Nozzleman Certification sessions.

In 2011, the ASA Board of Direction assigned the Education Committee the critical task of implementing the new ASA Nozzleman Certification policies, which are intended to improve the credibility of the certification program by placing ASA's roster of examiners in a position to maximize their objectivity.

The committee's numerous other certification-related tasks include the regular quality review of ASA-conducted ACI Nozzleman Certification sessions, oversight of the selection and performance of ASA's educators/examiners, and the review and enforcement of the ASA Educator/Examiner Policy and Code of Conduct.

Toward this end, the committee will sponsor an Examiners Round Table on Monday, January 23, at World of Concrete (WOC) 2012. This first-ever event is intended to bring all of ASA's ACI-approved examiners up to date with the current policy changes adopted by ASA and ACI and provide a chance to conduct a peer review of examiners and their critical, dual roles as both educators and examiners. We believe that this round table will aid us in the goal of maintaining very high, consistent, and industry-leading Shotcrete Nozzleman Education/Certification sessions. ASA's membership is welcome to attend. Any individual currently serving as, or considering application to become, a member of ASA's roster of examiners is asked to attend.

Other committee tasks include the identification of authors and topics for the Nozzleman Knowledge and Technical Tip features in ASA's *Shotcrete* magazine, management of the ASA Graduate Scholarship Program, and ongoing work on a Shotcrete Inspectors source document to be used as the basis for a future ACI Shotcrete Inspector Certification Program.

ASA was recently approved as a member of The American Institute of Architects (AIA) Provider Program. This means that attendees of ASA presentations/seminars will be eligible to receive AIA-recognized continuing education units. The ASA Marketing Committee is working with the ASA Education Committee to finalize the learning objectives and other steps that will make this arrangement official.

A Shotcrete Inspectors education document is currently being developed and is targeted for review by the ASA Education

Committee at its spring meeting in Dallas, TX. This Shotcrete Inspector document will be used as the source material for a new ACI Certification of Special Inspectors for Shotcrete Projects Program and will be available for sale by ASA. Many thanks go out to the ASA Education Subcommittee that has worked so successfully toward this goal.

Each year, ASA awards two $3000 (USD) scholarships to outstanding graduate students pursuing a career in the concrete industry with a special focus on shotcrete. One scholarship is awarded to a graduate student attending an accredited college or university within the U.S. and the second scholarship is awarded to a graduate student attending an accredited college or university within Canada. The ASA Education Committee is responsible for the review of all applications and the selection of the two individual awardees.

Many thanks go out to the current, semi-retired, and retired members who have volunteered many exhausting hours of their time and shared their years of shotcrete knowledge, time, and resources to help establish the many programs under the management of the ASA Education Committee. The work of the Education Committee is ongoing and critical to ASA's mission. New members interested in continuing the committee's tradition of excellence are encouraged to join this dynamic group. This invitation includes students and both young and seasoned shotcrete industry professionals.

I hope to see you the morning of Monday, January 23, 2012, at WOC for our Examiners Round Table forum and at our next committee meeting this spring in Dallas! Interested members can contact the ASA staff and me at info@shotcrete.org.

ASA Education Committee

Raymond Schallom III, Chair
Marcus von der Hofen, Co-Chair

Edwin Brady
Michael Cotter
Oscar Duckworth
Roberto Guardia
Charles Hanskat
Warren Harrison
Marc Jolin
Ron Lacher
Dan Millette
Dudley R. (Rusty) Morgan
Ryan Poole
Andrea Scott
Ted Sofis
Lihe (John) Zhang
Chris Zynda

Clarifying Nozzleman Certification

By Chris Darnell, ASA Executive Director

What is the cost to get my nozzlemen certified?

How long does it take to get certified?

What is the process for setting up an Education/Certification session?

These were some of the most common questions the ASA staff received over the years at trade shows, through e-mails, and over the phone. Until 2011, these were questions we really could not answer.

Fortunately for the shotcrete industry, we can now give a very precise and definite answer to these and all other certification-related questions!

If you have been reading *Shotcrete* magazine over the last year or so, you are probably aware of the hard work the ASA Board of Direction undertook in 2010 to clarify and level the playing field regarding nozzleman certification for everyone in the shotcrete industry. This was accomplished by carefully reviewing and revising the ASA policy for administering the ACI Shotcrete Nozzleman Certification program. The resulting policy developed by the Board dictates a wide range of improvements and credibility to the program, including fixed and consistent pricing. The shotcrete industry now enjoys a renewed sense of fairness and peace of mind as the policy is applied consistently and evenly to everyone in the industry.

Fixed and Final Pricing

Under the new policy, the final cost for a certification session is provided up front and to the penny, including previously variable costs such as examiner travel and expenses. Pricing for certification is no longer dependent on variables such as your industry contacts and geographic location.

We have also recently eliminated the need for a session deposit for ASA Corporate members.

All pricing, session options, program policies, requirements, and time lines can be found on the ASA Web site under the Certification menu item at **www.shotcrete.org**. Whether you are ready to host a certification session in the near future or you would just simply like to know the cost and time involved in a session for long-term planning, please take a moment to review the information on our Web site. Better yet, complete the online session quote request form for a no-obligation formal quote reflecting the specifics of your session. Of course, you can always contact us with any questions at (248) 848-3780 or info@shotcrete.org.

With the ability to know specific overall final costs up front, as well as the specific time line for a session, everyone can now make well-informed and sound plans for nozzleman certification.

The Rehabilitation of the Île d'Orléans Bridge

By Philip Sawoszczuk and Daniel Bordeleau

The Île d'Orléans Bridge was built between 1931 and 1935. It was inaugurated on July 6, 1935.[1,2] The bridge crosses the mighty St. Lawrence River between the Beauport borough of Québec City and the Island of Orléans. The Island of Orléans, with its six villages, has a population of roughly 7000, with over 600 historical buildings and plentiful agricultural land, making it a prime tourist attraction for locals and travelers alike.[3] Presently, the bridge is owned, operated, and maintained by Transport Québec, Québec's Department of Transportation.[2,4] It is not the intent of this article to cover all the aspects of the concrete/shotcrete rehabilitation specifications of Transport Québec, as this was covered by Dufour et al.[5] in 2006 and the Ministère des Transports du Québec (MTQ) dry-mix shotcrete specification has not changed since.

This 2.8 mile (4.5 km) long, 215 ft (66 m) tall, two-lane structure can be divided into five sections: two concrete beam spans, two steel truss spans, and a steel-suspension span in the center. The bridge pier foundations are all limestone masonry units with mortar. The concrete beam section is supported by nine sets of four concrete columns, which are braced at midheight on either side of the bridge. There are five sets of two concrete columns, with sets braced at the center heights, supporting the steel truss section on either side of the bridge. There are two monolithic piers with large sharply profiled pier foundations to break ice flows and serve as anchor points for the suspension wire. There are two more piers with small steel columns at either end of the suspended span and two steel truss towers holding the suspension wires on two more piers in the center of the bridge. In total, 34 piers with columns of either concrete or steel support the bridge. The deck is made of timber beams placed laterally with asphalt paving. The suspended section is 2370 ft (722 m) long,

The Île d'Orléans Bridge, with 18 of its 34 piers in view, shows how masonry, steel, wood, and concrete can combine into an elegant engineering solution

"The project was complicated, but working with dry-mix shotcrete allowed us to overcome all our obstacles and complete the project on schedule."

–Daniel Bordeleau, Eng, MSc, Groupe Diamantex

The concrete beams and timber deck are clearly visible, showing how various materials can work together. Some salt stains, corrosion, and freezing-and-thawing damages show how materials age

The shotcrete workspace was protected from wind, while also preventing dust and debris from falling into the river

with the center sub-span at 1060 ft (323 m), and the two adjacent sub-spans are 420 ft (127 m) each. The steel suspension cables are a total of 5040 ft (1535 m) and are composed of 37 galvanized steel tendons.[2,4] Although various items in the bridge have been inspected and repaired over the years, the concrete repairs were the focus of the work in 2009 through 2010.

After 75 years, concrete deterioration was significant. Site inspections revealed corrosion of reinforcement, spalling, efflorescence, and freezing-and-thawing damage on many of the concrete columns and beams. Corrosion was likely initiated by deicing salts, but it could also have been aggravated by carbonation. Some map cracking was also present, potentially caused by alkali-aggregate reactivity. The amount of rehabilitation was valued by Transport Québec[6] at 14.9 million (CAD). Stellaire Construction, the general contractor, was faced with some unique challenges. The bridge has only two lanes, which had to remain open during rush-hour periods. Due to high winds and the sensitive fluvial ecosystem below, the work area had to be enclosed in tarps. Another constraint was the rectangular cross section of many of the concrete steel reinforcements, which complicated the application.

With limited space and a tight schedule, the contractor turned to the dry-mix shotcrete process, which is allowed by Transport Québec for concrete repair.[7] One subcontractor, Groupe Diamantex of Québec City, had the experience and the tools to overcome many of the site's challenges. It is worth noting that self-consolidating concrete with a form-and-pump or gravity-fed approach could also have been used. Additional challenges regarding formwork, site mixing, and quality assurance, however, would have to have been resolved.

The work began in 2009 at the Island of Orléans side of the bridge. The majority of the work surrounded the columns of the bridge piers, so scaffolding, catwalks, staircases, platforms, and ladders were erected to improve accessibility. The work was limited to the period between the spring and fall; it started in 2010 on the Québec City side of the bridge. Groupe Diamantex elected to use a barge to move the shotcrete equipment and some of the dry-mix shotcrete materials from shore because lane restrictions made it impossible to locate the equipment on the deck. Material was supplied in 2200 lb (1000 kg) bulk bags and fed through a bulk silo to improve efficiency of the material supply.

Groupe Diamantex elected to use a dry-mix shotcrete material (MS-D1 Shotcrete, supplied by King Packaged Materials Company). The mix is specially formulated with microfibers and an air-entraining admixture and enhanced with silica fume to meet Transport Québec's standards[7] (Table 1). As a silica fume shotcrete, it provided excellent adhesive and cohesive properties and low permeability in its hardened state.[8] The low permeability greatly retards ingress of deleterious agents such as chlorides and water, preventing further corrosion and alkali-aggregate reaction. The aggregate gradation met the requirements of ACI 506R Gradation 2.[8] Some

Scaffolding before chipping has begun. The limestone masonry and map-cracking on the existing concrete is also visible

Silos are loaded with shotcrete material by a forklift on the barge for continuous and efficient material flow. The shotcrete material was lifted to the barge by crane

The column was chipped to 1 in. (50 mm) behind the corroded rectangular steel reinforcements, cleaned, and covered in a welded-wire steel mesh

The air hoses had to travel over 985 ft (300 m) to reach the barge at this point in the project

Table 1: Dry-Mix Shotcrete Performance Requirements

28-day compressive strength, MPa (psi)	Minimal weight of cement, kg/m³ (lb/yd³)		Maximum water-cementitious material ratio (*w/cm*)*	Minimum proportion by weight of 10 mm (3/8 in.) aggregate, %	Air content (plastic and hardened states), %	Minimal weight of synthetic fiber, kg/m³ (lb/yd³)
	Type GUb-SF (Type 1 with silica fume)	Type HE (Type 3)				
35 (5000)	450 (760)	460 (775)	Based on consistency (~0.40)	10	3.5 to 7.0	0.9 (1.5)

*(*w/cm*) is not verified

benefits of coarse aggregates, up to 3/8 in. (10 mm) in size, are optimal compaction and packing density, reduced shrinkage, and cleaner equipment and hoses.[9]

Temporary shoring was necessary during demolition work, as the cross section removed a significant amount of concrete. The surface preparation began by chipping the concrete columns with pneumatic hammers to 1 in. (25 mm) behind the reinforcing steel. Transport Québec specifications limit the pneumatic hammer weights to 35 lb (16 kg) to reduce the possibility of inducing microcracks in the substrate.[6] The corroded reinforcing steel was sand-blasted to remove corrosion and the columns were then cleaned with high-pressure water to remove rust stains, laitance, loose concrete, dust, and any other substances that could potentially weaken

Shotcrete was trowel-finished for aesthetics and also to increase durability

A finished repair is visible, with a support platform in place for final touches and inspection the bond. A welded-wire steel mesh was then fastened tightly to anchors to prevent vibration during shotcrete placement. The substrate was soaked a few hours prior to application to obtain a saturated surface-dry (SSD) condition of the substrate.

ACI-certified nozzlemen were used to place the shotcrete. Working in the tight confines of the enclosed platform and encapsulating the rectangular reinforcements with the welded-wire mesh was a challenge, but the shotcrete crew was able to complete the job with excellent results. The shotcrete was float-finished to create an aesthetic and durable finish and wet-cured using burlap, water, and plastic sheets for a minimum of 7 days, ensuring complete hydration from surface to core of the repair.

The total area repaired was approximately 8000 ft² (750 m²), and the thickness varied from 4 to 8 in. (100 to 200 mm). All repaired areas were sounded after the shotcrete gained sufficient strength. Cores were extracted from test panels daily as a quality control measure.

Using a high-performance dry-mix shotcrete repair material to rehabilitate the pier columns allowed the service life of the bridge to be extended by a couple of decades. The ease of use and flexibility of the dry-mix shotcrete method enabled Stellaire Construction, along with the expertise of Groupe Diamantex, to deliver the rehabilitated bridge on time and on budget to Transport Québec.

References

1. Île d'Orléans Tourism, "The Region," 2003, http://www.tourismeiledorleans.com/introang.html. (last accessed Oct. 22, 2011)

2. Laflamme, J.-F.; Talbot, M.; and Lacoste, M., "Instrumentation des Ouvrages d'Arts au Ministère des Transports du Québec," Association Québecoise du Transport et des Routes, Apr. 26, 2011, http://www.aqtr.qc.ca/congres/pdf/LaflammeJF_MTQ_InstrumentationOuvrages.pdf. (last accessed Oct. 22, 2011)

3. Statistics Canada, "2006 Community Profiles," 2006, http://www12.statcan.ca/census-recensement/2006/dp-pd/prof/92-591/search-recherche/lst/Page.cfm?Lang=E&GeoCode=24&Letter=S. (last accessed Oct. 22, 2011)

4. Talbot, M., "Méthodes Expérimentales et Numériques Utilisées pour l'Evaluation du Pont Suspendu de l'Île d'Orléans," June 8, 2002, Cegep Outaouais: http://pedago.cegepoutaouais.qc.ca/media/0260309/0378334/SCGC BON/Documents/ST031-Talbot.pdf. (last accessed Oct. 22, 2011)

5. Dufour, J.-F.; Reny, S.; and Vézina, D., "State-of-the-Art Specification for Shotcrete Rehabilitation Projects," *Shotcrete*, V. 3, No. 4, Fall 2006, pp. 4-11.

6. Transport Québec, (2008, February 8), "Investissements Routiers 2008-2009," Feb. 8, 2008, http://www.mtq.gouv.qc.ca/portal/page/portal/Librairie/Publications/fr/salle_presse/2008/20080211_investissements2008_2009/investissements_cap_nat.pdf. (last accessed Oct. 22, 2011)

7. "Normes Ouvrages Routiers," Tome VII, Sections 3.2., Éditions 2005—Matériaux, Publications du Québec, Quebec City, QC, Canada.

8. ACI Committee 506, "Guide to Shotcrete (ACI 506R-05)," American Concrete Institute, Farmington Hills, MI, 2005, 40 pp.

9. Reny, S., and Jolin, M., "Technical Tip: Improve Your Shotcrete: Use Coarse Aggregates!" *Shotcrete*, V. 13, No. 1, Winter 2011, pp. 26-28.

Île d'Orléans Bridge

Project Location
Québec City, QC, Canada

Shotcrete Contractor
Groupe Diamantex

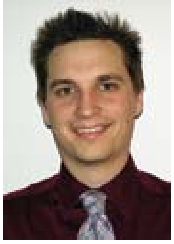
General Contractor
Stellaire Construction

Project Owner
Transport Québec

Engineer
Cima +

Material Supplier
King Packaged Materials Company*

*Corporate Member of the American Shotcrete Association



***Philip Sawoszczuk**, Jr. Eng., is a Technical Services Representative for King Packaged Materials Company. His areas of expertise include rehabilitation and preservation of infrastructure, structural engineering, and durability of concrete. He received his degree in civil engineering from McGill University, Montreal, QC, Canada.*

***Daniel Bordeleau**, Eng, MSc, is Owner and President of Groupe Diamantex, a contractor specializing in the rehabilitation of concrete structures, based in St. Augustin, QC, Canada. Bordeleau received his master's degree in applied science from Laval University, Québec City, QC, Canada, in 1988 and has completed articles on polymer-modified concrete that have been published in the* ACI Materials Journal *and the* ACI Structural Journal. *Bordeleau is a member of Québec Association of Transport and Roads and the Association of Québec Engineers. He has served as President of the Canadian Society of Civil Engineers between 1994 and 1999 and of The 1995 Annual Congress of the Association of Concrete Products; he was Regional Director of the American Concrete Institute from 1997 to 1998.*

GUNITE™
Supply & Equipment
www.gunitesupply.com

Northeast
4141 Airport Rd.
Cincinnati, Ohio
Phone: 513.321.5526
Toll Free: 1.888.321.5526

West
1726 S. Magnolia Ave.
Monrovia, California
Phone: 626.359.9361
Toll Free: 888.393.8635

Southeast
9202 Meadow Vista
Houston, Texas
Phone: 281.469.8097
Toll Free: 800.258.2421

Pineda Causeway Bridge Rehabilitation

By R. Curtis White Jr.

The Pineda Causeway Bridge, located along Florida State Route 404, is one of three similar, high-rise bridges linking mainland Florida's east coast to the barrier islands on the Atlantic Coast, where the Kennedy Space Center and Patrick Air Force Base are located at Cape Canaveral. These bridges provide the only land access to this sensitive area that is home to a thriving tourist destination and important military and NASA facilities.

The Pineda Causeway Bridge also spans the Atlantic Intracoastal Waterway, which is maintained by the U.S. Army Corps of Engineers and administered by the U.S. Coast Guard. The waterway is a vital route for pleasure craft and commercial barge traffic wanting a protected north and south path along the entire east coast of the United States. Disruption to either land or watercraft would be a major issue for the federal agencies that oversee the waterway or the Florida Department of Transportation (FDOT), which is responsible for the highway traffic and maintenance of the bridge structure.

Pineda Causeway over the Indian River

One of the twin spans of the Pineda Causeway

The bridge had experienced significant spalling and delamination of concrete at the waterline of the low-level pile caps since its construction in 1969. An earlier repair of the spalling was attempted using form-and-pump methods. It was a particularly difficult forming job because the piles were not positioned the same on any of the 84 lower pile caps being repaired. This meant that there was no repeatability in forming the repair, so all the forms were custom-built. In addition, the forms needed to be supported under the caps with no clearance from the water—except at low-tide water level—and then only 8 in. (203 mm) could be anticipated. So, in essence, the plan was to support the 84 custom-built forms with skyhooks and hope the repair concrete bonded upside down. This was not a recipe for success.

FDOT let a contract in 2004 to repair these low-water level caps. The repair contractor made a valiant, but ultimately unsuccessful, attempt to complete the repair. His bonding company took over the work and brought in another contractor to complete the contract. This effort, using the same techniques, was no more successful than the first, and the bonding company filed suit against the state to be released from its obligations. Rather than fight the lawsuit, FDOT cancelled the contract and rebid the job in March of 2006, using the same specifications for the work.

The successful bidder was 25% lower than the second bid. The low bidder suggested a value engineering change to the procedure from the beginning. His proposal was to change only the method of placement from form-and-pump to dry-mix shotcrete. Dry-mix shotcrete was proposed because of the access restrictions that required all work be done from watercraft with no highway traffic lane closures allowed. The relatively small quantities and long travel distance from the staging area to the work site precluded the efficient use of wet-mix shotcrete.

Additional "sweeteners" were added to the proposed value engineering change (other than actually being able to **do** the work) in the form of a reduced unit price for the repair work and, innovatively, a "no-crack" warranty. The original repair attempts had produced several caps that were "repaired." These caps exhibited significant cracking and spalling after only 1 year of service. To further entice FDOT to consider shotcrete for this repair (FDOT already has shotcrete specs and a colorful history of use), the contractor proposed a 4-year "no-crack" warranty. After a thorough investigation of the proposed methods, pricing, and past history of application, FDOT approved replacing the form-and-pour method with shotcrete. Standard FDOT specifications for shotcrete were available for reference which added to the ease of changing from one method to another.

Now that means and methods were agreed to by both parties, the daily problems of accomplishing the work had to be addressed. While the Indian River is salt water, normal tides do not affect this portion of the waterway due to its distance from the nearest inlet. Wind direction and strength, however, have a significant effect on high and low water. Because the low water pile caps are submerged during high water, look-ahead schedules had to be created to avoid projected high water and take advantage of low water levels. Prevailing north winds during the winter months usually result in lower water. The contractor was able to take advantage of this effect and complete most of the low-level repairs during this period. When the water came up, efforts were shifted to the required column repairs.

To prove the effectiveness of the shotcrete repairs, FDOT required random bond strength tests. These tests were accomplished using ASTM C1583/1583M-04e1, "Standard Test Method for Tensile Strength of Concrete Surfaces and the Bond Strength or Tensile Strength of Concrete Repair and Overlay Materials by Direct Tension (Pull-off Method)." Pulloff tests of repairs on the footings resulted in failure in the old concrete substrate—generally at values above 200 psi (1 MPa). Any failure in the parent concrete is an indication of the successful bonding between the substrate and the repair material.

The repair material placed on this project was Gunite 7001d, a single-component, modified silica-fume shotcrete material with 1/2 in. (13 mm) polypropylene fibers produced by U.S. Concrete Products of Baltimore, MD. Twenty-eight-day compressive strength test results were in excess of 7000 psi (48 MPa). These tests were conducted in accordance with ASTM C1140-03a, "Standard Practice for Preparing and Testing Specimens from Shotcrete Test Panels" and performed on cores taken from test panels made in

Pullout test showing core failure in substrate

Removal of spalled concrete from pile caps

Pile caps after chipping and ready for shotcreting accordance with ACI 506.2-95, "Specification for Materials, Proportioning, and Application of Shotcrete." The work was accomplished by nozzlemen certified for ACI by ASA Examiners.

Whereas this project was ultimately completed to the satisfaction of the design engineer, the owner, and the contractor, it required all parties be amenable to alternate processes and approaches and concentrate on the **performance** aspects of the specifications and not on prescribing all the steps to be taken during construction. Using this manner of solving problems allowed the project to be completed early and under budget, whereas previous efforts to rehabilitate this bridge had failed miserably. Without the cooperation between parties and innovative thinking by the contractor, this could have been one more project ending in litigation to the benefit of no one.

Shotcrete placement on low water pile caps

Dry-mix shotcrete can be placed slowly to reduce fallouts

***R. Curtis White Jr.** is President of Coastal Gunite Construction Company, a 30-year-old firm specializing in the repair and restoration of concrete structures using the shotcrete process. Coastal Gunite is active east of the Mississippi River and completes shotcrete projects for new basement wall construction, sewer rehabilitation, bridge restoration, building rehabilitation, and seawall reconstruction. Coastal Gunite has won awards from ASA and the International Concrete Repair Institute (ICRI) for bridge repairs in the Florida Keys, tunnel restoration in West Virginia, and cooling tower rehabilitation in northern Florida. White is a long-time member of ACI Committees 506, Shotcreting, and C660, Shotcrete Nozzleman Certification, and ASTM International Committee C09.46, Shotcrete. He is one of the authors of the AASHTOAGC-ARTBA Task Force 37, "Guide Specification for Shotcrete Repair of Highway Bridges." White is a founding member of ASA and ICRI, and has been on the ASA Board of Direction since 2009.*

Pineda Causeway Bridge, State Route 404 over the Indian River (Atlantic Intracoastal Waterway)

Location
Melbourne,
Brevard County, Florida

Shotcrete Contractor
Coastal Gunite Construction Company*

General Contractor
Coastal Gunite Construction Company*

Engineer
Kisinger Campo and Associates Corp.

Material Manufacturer
US Concrete Products, LLC*

Shotcrete Equipment
Allentown Shotcrete Technology, Inc.*
A Putzmeister America company

Project Owner
Florida Department of Transportation, District 5

*Corporate Member of the
American Shotcrete Association


Close-up of reinstalled chamfers


Completed low water pile caps


QUIKRETE
www.quikrete.com
800-282-5828
SHOTCRETE MS
Micro Silica Enhanced
SHOTCRETE MS Mejorado con microsilice
COMMERCIAL GRADE
QUIKRETE

The Morris Street Bridge Rehabilitation

By Dave Sawyer

In 2009, the Indiana Department of Transportation (INDOT) and the city of Indianapolis began planning for the rehabilitation of the Morris Street Bridge, one of the oldest in the city. Located in the central-west area of Indianapolis, the bridge was originally built in 1929 to facilitate vehicular traffic over the White River (part of the Mississippi network of rivers) into and out of the downtown core. Because it handles a flow of approximately 10,000 vehicles daily, its importance to modern-day traffic flow remains high, underlining the urgency for its rehabilitation.

Overview of the Morris Street Bridge project

The project was eventually awarded to Beaty Construction from nearby Boggstown, IN. The concrete rehabilitation portion of the project, accounting for roughly \$1.7 million of the \$7.85 million contract, was then awarded to RAM Construction of Livonia, MI, just west of Detroit.

RAM's scope of work called for rehabilitation of abutment walls, wing walls, arch spans, and piers. They were required to remove and repair damaged areas, re-rodding or applying wire mesh and galvanic anodes before beginning the concrete rehabilitation and fiber-wrap processes. The bridge, measuring 112 ft (34 m) wide and 654 ft (200 m) long, required a significant number of repairs, some of which required up to 14 in. (356 mm) of concrete replacement. The base bid was divided into two options: form and pour a 4 in. (100 mm) encasement over all the arches or repair the arches using shotcrete and install a glass fiber wrap over all the arches. Bids for the shotcrete and fiber-wrap option showed substantial cost savings over the form-and-pour approach. RAM offered pricing for the repair of the arches using their preferred method of concrete placement: shotcrete.

The project began in earnest in the spring of 2011. Although the schedule allowed for completion of the shotcrete by the end of the 2011 calendar year, RAM was determined to finish sooner. The schedule, however, experienced a severe and

Areas repaired using the dry-mix shotcrete process included bridge piers

RAM's scope of work called for rehabilitation of abutment walls, wing walls, arch spans, and piers

Repair access on the underside of the bridge spans using scissor lifts

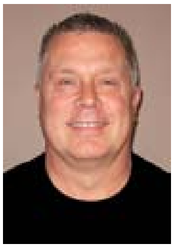
The structure required a significant number of repairs, some of which required up to 14 in. (356 mm) of concrete replacement

RAM used ACI-certified nozzlemen for all shotcrete placement

unavoidable setback in April and May when the White River flooded its banks around the bridge up to 8 ft (2.4 m), completely submerging the floodplain work area and some of the construction equipment, and effectively shutting down all repair operations for a number of days. Despite the delays caused by the flood, RAM shotcrete crews were able to make up for lost time by accelerating their rate of production. Shotcrete placement was completed by late October 2011.

The entire project used approximately 500 bulk bags of King Packaged Materials' MS-D1 and MS-D3 Accelerated Shotcrete, amounting to approximately 305 yd^3 (234 m^3) of concrete replacement. A key factor in RAM's ability to meet the difficult scheduling demands was the company's strategy to use King's MS-D3 Accelerated Shotcrete for the initial part of each repair. The use of this material provided shorter initial and final set times and accelerated strength gain, allowing RAM shotcrete crews to build up areas much more quickly. This material was placed to within an inch of the eventual finished surface. RAM then went back to each repair area and finished shooting with King's MS-D1 Shotcrete, which, because of longer set times, allowed RAM to smooth-finish the repairs much more easily and professionally. After mid-September, cooler weather prompted RAM to shoot exclusively with King's MS-D3 Accelerated Shotcrete. To achieve a satisfactory finish, the concrete finishers were positioned immediately behind the shooting crew.

Despite the delays caused by flooding in the spring, RAM's portion of the contract was completed by the end of October 2011—well ahead of schedule. The accelerated schedule was made possible because of the time savings offered by the shotcrete process, the flexibility offered by different prepackaged shotcrete mixtures, and the experience and dedication of the RAM shotcrete crews. The repairs made the 80-year-old bridge structurally sound while addressing the aesthetic concerns of the local residents. RAM Construction Services is proud of this Morris Street Bridge shotcrete success story and looks forward to many more of the same.



***Dave Sawyer** is a Technical Representative with King Packaged Materials Company and is responsible for the sales and marketing of its line of shotcrete products in the southern Ontario, Canada, and the U.S. Midwest markets. He has over 24 years of experience in the concrete industry and is a member of the ACI Toronto Chapter, ASA, and The Building and Concrete Restoration Association of Ontario.*

The Use of Shotcrete as a Repair Process for Ontario Bridge Structures

By Joe Hutter and Mahaish Singh

For the past 25 years, King Packaged Materials Company has worked closely with the technical personnel at the Ministry of Transportation of Ontario (MTO) to assist in the development of the shotcrete specifications currently used by MTO. This article has been written from the perspective of the shotcrete materials manufacturer and covers the history of the shotcrete process as it has been used for the rehabilitation of Ontario's bridge structures.

MTO is responsible for the maintenance and repair of over 2720 bridges within the highway system of the province of Ontario. This maintenance ranges from snow removal during the winter months to the repair and rehabilitation of those bridges after years of exposure to freezing-and-thawing cycles and the damaging effects of deicing salts. Ontario's winter climate requires the use of significant quantities of road salt to ensure that Ontario's roads are safe all year. Unfortunately, the 550,000 to 660,000 tons (500,000 to 600,000 metric tons) of salt that are used annually take a toll on reinforced concrete structures through corrosion-induced damage.

MTO is responsible for the maintenance and repair of over 2720 bridges in the province of Ontario

The Early Days of Shotcrete

MTO began using shotcrete as a repair method in 1980, preferring to use a latex-modified product for its low permeability values. The specifications in 1980 provided the option of using the dry- or wet-mix process, although local practice usually favored dry-mix because it was generally considered to be more suitable for smaller repairs. There were no requirements for the use of preblended or prepackaged materials, as there were few manufacturers capable of producing these types of mixtures. A typical mixture proportion (by weight) of latex-modified shotcrete was as follows:

- 1 part Type 10 portland cement;
- 3.5 parts fine aggregate;
- 1/3 parts latex (47.5% solids by weight); and
- Water/cement ratio (*w/c*) of 0.35 (approximately).

The MTO specification called for a minimum application thickness of 1 in. (25 mm) and a maximum thickness of 2 in. (50 mm). The decision to limit the maximum thickness of 2 in. (50 mm) was based on the poor cohesive properties of the mixture. Material applied at greater thicknesses would generally sag, separate, and de-bond, leaving the shotcrete contractor with no choice but to reshoot the material. If areas to be shot had thicknesses greater than 2 in. (50 mm), additional layers of shotcrete were placed until the shotcrete repair reached the required thickness. There was no strength requirement before applying a second layer of shotcrete. The specification, however, called for the base material to reach final set. The specification also required that any accumulated rebound or foreign matter be removed.

One of the challenges associated with the use of latex-modified shotcrete was finishing. The "sticky" consistency of the plastic material made it difficult, if not impossible, to finish the surface of the shotcrete patch. In fact, the specification required that hand finishing be minimized so that the surface material would not tear away from the rest of the patch. After reaching initial set, any excess material was cut from around the perimeter of the patch, leaving the remainder of the repair with a gun finish.

As it is today, quality assurance was a key aspect of MTO's shotcrete practice. The contractor was required to shoot two test panels (one vertical and one overhead) using the same equipment and nozzleman used on the project. Cores were taken from the panel at an age of 4 days and tested for compressive strength at 7 and 28 days (the 7-day requirement was 3600 psi [25 MPa] and the 28-day requirement was 4400 psi [30 MPa]). The cores were also checked for voids, as full encapsulation of the steel was required by MTO. If the cores were deemed to be satisfactory and they met the 7-day compressive strength requirement, the contractor was allowed to proceed with the shotcrete placement.

Although there was no provision for taking cores from the repaired area for strength testing, four cores were taken from the repair area after 28 days so that rapid chloride permeability testing could be conducted. A maximum value of 1500 coulombs was specified; however, there was no provision for rejection of the shotcrete for failure to meet the test criteria.

The use of latex-modified shotcrete continued to be used on MTO projects up until the late 1980s, at which time the many problems associated with this material led MTO to look at alternative methods of repair. The key problems related to the use of latex-modified shotcrete were:

1. Finishing—The "sticky" consistency of the latex-modified material prevented traditional finishing, leaving the patch with a rough gun finish. This was believed to be detrimental to the long-term durability of the patch because an "unfinished" surface would have higher absorption potential. Also, the aesthetics of the patch were less than desirable.
2. Mixture consistency—Until 1989, the MTO specification allowed for site mixing, which often led to inconsistencies in the mixture proportions. Mixtures were proportioned volumetrically, usually using shovelfuls of bulk sand and 88 lb (40 kg) bags of Type 10 portland cement. There was no method to ensure that the 1 to 3-1/2 parts ratio specified by MTO was being followed accurately; understanding that compressive strength was the only pass/fail criteria, contractors would often use too much cement, causing higher shrinkage and contributing to cracking. Stockpiling of sand near the mixing station also led to variations in moisture content, especially during periods of wet weather.
3. Surface cracking—Although the bond of most latex-modified shotcrete patches was acceptable, extensive shrinkage cracking was a common concern. Although it was difficult to pinpoint the exact cause of the cracking, potential causes were inconsistencies in the mixture, higher-than-required cement content, less-than-favorable aggregate gradation (stockpiled sand meant no coarse aggregate was used), and difficult curing conditions (especially when repairing bridge soffits).

The specification for latex-modified shotcrete required that hand finishing be minimized, leaving the repair with a gun finish

Until 1989, the MTO specification allowed for site mixing, which often led to inconsistencies in mixture proportions. Inconsistent cement contents would often lead to high shrinkage values, which contributed to cracking and debonding

The Golder Study

In early 1989, MTO enlisted the services of Golder Associates Ltd., a Toronto, ON, Canada, area engineering consulting firm, to conduct a study to determine if their shotcrete repair practices could be improved. The study was carried out in several phases, which included a literature study, limited laboratory evaluations of trial mixtures, and a field evaluation of shotcrete mixtures using test panels in both vertical and overhead orientations.

Eleven different mixtures were chosen for the field trials, all placed using the dry-mix process. The variables included aggregate gradation (mixtures with and without coarse aggregate), surface preparation (with and without bonding agents), and varying dosages of silica fume and the use of latex, steel, and synthetic fibers. A local contractor experienced in the application of dry-mix shotcrete was selected to shoot the test panels, and all mixtures were supplied, pre-bagged, and proportioned under controlled factory conditions to ensure consistency.

Panels were constructed with dimensions of 39 x 39 in. (1 x 1 m) and a 2 in. (50 mm) concrete base was poured to allow for an acceptable substrate on which the shotcrete could be placed. The concrete surface was roughened to produce a surface that would be similar to a typical repaired surface. Six parallel 0.5 in. (13 mm) diameter steel reinforcing bars were placed in one corner of the panel at a distance of 2 in. (50 mm) above the concrete surface. The spacing between the bars ranged from 2 to 6 in. (50 to 150 mm) and an 18 x 18 in. (450 x 450 mm) piece of 2 in. (50 mm) square wire mesh was secured to the reinforcing steel.

All mixtures were shot by the same experienced nozzleman to ensure consistency. Each mixture was shot in a vertical and overhead orientation and then moist-cured for a period of 7 days. Cores were extracted after 10 days and returned to Golder's laboratory for storage in the moist-curing room with a relative humidity of 100% at 73°F (23°C).

Field Trial Observations (Plastic Properties)

The nozzleman reported that the easiest mixtures to shoot were the silica fume mixtures, primarily because they made it easier to fully encapsulate the reinforcing bars and to place thicker passes. By comparison, in some cases, mixtures without silica fume collapsed within several hours of shooting a second lift. Also, rebound values of mixtures produced with silica fume were significantly lower than those produced with latex.

Field Trial Observations (Hardened Properties)

To properly assess the hardened properties of each mixture, testing included compressive strength, bond strength, rapid chloride permeability, and boiled absorption. The test results varied with each mixture with the lowest compressive strength attributed to the plain mixtures (mixtures without silica fume) and the highest to mixtures with silica fume. Results of tensile bond strengths were also lowest with latex mixtures and highest with silica fume mixtures. Rapid chloride permeability tests were lowest (less permeable) with the silica fume mixtures and highest with the plain mixtures. Boiled absorption values were lowest with the latex-modified mixtures and highest with the plain mixtures.

After weighing the value of each set of test results, Golder recommended that a full-scale field trial involving the repair of an MTO structure be undertaken using a shotcrete mixture enhanced with silica fume and with an aggregate gradation closely matching ACI 506 Gradation No. 1. The trial should include sections shot in both overhead and vertical orientations.

Full-Scale Field Trial—Magnetawan River Bridge

Early in 1990, MTO issued a request for bids to repair the Magnetawan River Bridge, located approximately 186 miles (300 km) north of Toronto. Constructed in 1959, it was the last new open-spandrel concrete arch bridge constructed in the King's Highway System. The required repairs included rehabilitating the underside of the bridge deck (soffit) and sections of the concrete arches that spanned the Magnetawan River.

The bidding closed in the spring of 1990 and the contract was awarded to a Toronto-area contractor with experience on MTO structures. For the first time, the MTO specification called for a prepackaged shotcrete mixture following the recommendations in the Golder Associates report. Over 39 yd^3 (30 m^3) of deteriorated concrete was chipped from the structure and replaced with a silica-fume-enhanced, dry-mix shotcrete material with gradation meeting ACI 506 Gradation No. 1. Initial quality control testing produced an average compressive strength of 6800 psi (47 MPa) and an average rapid chloride permeability value of 557 coulombs. Both results were well within the limits set by MTO. Subsequent visits to the site (the latest of which was made at the time this article was authored) showed that there was no evidence of de-bonding or failure in any of the 21-year-old shotcrete patches and no indication of any corrosion or further damage to the repaired areas.

The success of the Magnetawan River Bridge project led to the development of the current MTO specification, which was most recently updated in July of 2009. Since that project was completed, approximately 65 MTO structures have been repaired using the prepackaged silica-fume-enhanced shotcrete mixture.

After 21 years, there was no evidence of debonding or failure in any of the shotcrete patches of the Magnetawan River Bridge structure

The success of the Magnetawan River Bridge project led to the development of the current MTO shotcrete specification

Current MTO Shotcrete Nozzleman Approval System

For the first several years after MTO adopted the new shotcrete specification, contractors were typically required to have their nozzlemen shoot test panels before starting any shotcrete work on a contract. The original specification simply stated that "A nozzle operator approved by the Owner (The MTO) shall be provided for the application of the shotcrete. Approval may require the evaluation by the Owner, of test panels prepared by the nozzle operator doing the work."

In 1994, however, MTO implemented a testing program in which nozzlemen would be "certified" by a program that was administrated by MTO personnel. This program, which continues to operate today, required that nozzlemen shoot both vertical and overhead test panels using the equipment and materials that were to be used on the project. Applicants who fail to meet the acceptance requirements on the first attempt are permitted one additional attempt during the same calendar year.

Nozzlemen approved through this process for the first time are permitted to place shotcrete on any MTO project during the same calendar year in which the approval is granted. If a nozzleman is approved a second time, the nozzleman is approved for a period of two calendar years. After the second approval, a nozzleman is approved for three calendar years, provided their previous approval was for 2 years, the minimum rating for each of the 24 cores is 2, and the minimum compressive strength of each core is 4350 psi (30 MPa) at 7 days.

Two test panels are required by each applicant—one for vertical and the other for overhead orientations. MTO is very specific about the design and construction of the test panels. As stated in the MTO document detailing the requirements for nozzleman approval:

In 1994, MTO implemented a testing program in which nozzlemen were certified by a program that was administered by MTO personnel

- The form shall be made of minimum 0.66 in. (17 mm) thick plywood, 39 x 39 in. (1 x 1 m) in size, on suitable stiffeners to prevent vibration of the form. Alternatively, the form may consist of a 39 x 39 in. (1 x 1 m) bed of precast shotcrete or precast concrete slab;
- Size 15 (No. 5) bars shall be placed 1.5 in. (40 mm) from the form at 6 in. (150 mm) centers;
- Size 15 (No. 5) bars shall be placed on and perpendicular to the first bars at 12 in. (300 mm) centers;
- If the form is constructed of precast shotcrete or concrete, it shall be abrasive blast cleaned within 36 hours and maintained in a wet condition for 1 hour prior to shooting the test panel; and
- Welded galvanized steel wire fabric of MW 5.6 x MW 5.6 (51 x 51 mm) mesh size shall be placed against and tied to the outer layer of Size 15 (No. 5) bars. The wire fabric shall be in two pieces with an overlap of one square near the center of the panel.

The applicant is required to shoot the test panels in the presence of an MTO representative to a minimum thickness of 4.75 in. (120 mm) and leave the panels in place until a designated MTO representative is available on site to witness the coring. Panels should be cured to conform to the current MTO specifications.

Twelve 3.75 in. (95 mm) diameter full-depth cores are extracted from each test panel. Six cores require reinforcing bars (at least one requires the intersection of two bars and one requires the overlap of the mesh). Six cores containing no reinforcing bars are also required.

The evaluation of the applicant is based on three criteria:

- Application;
- Visual examination of cores; and
- Compressive strength test results.

Visual examination of the cores is carried out by MTO to identify defects and the magnitude of defects, including:

- Delaminations;
- Sand pockets or lenses;
- Voids; and
- Shadows or voids behind reinforcing steel.

Each core is rated on a scale of 1 to 5 with 1 being a core with no defects and 5 being a core with one or more serious defects. To pass, the average rating of all cores requires a score of 1.5 or less. If the cores pass the visual examination, cores without steel are tested for compressive strength—two at 7 days and four at 28 days.

The minimum average strengths are 3625 psi (25 MPa) at 7 days (average of two cores) and 4350 psi (30 MPa) at 28 days (average of four cores). If any sets of cores fail to meet the minimum compressive strength requirements, the panels are considered to have failed.

The current MTO shotcrete specification allows for only prepackaged materials with performance test data verifying that the material meets the requirements of the specification

A list of approved nozzlemen is maintained by MTO's Materials Engineering & Research Office, Concrete Section, and copies of the list are provided to the Contract Management Office and the Regional Construction Offices. The list contains the nozzleman's name, date of birth, and is also supplemented with photo identification for use by field staff on MTO contracts.

Current MTO Shotcrete Specification

The current MTO shotcrete specification was originally developed from the Golder Associates Report that was commissioned in 1989. Although a number of updates have been added, much of the current specification is based on the data that was collected in that report. Key components of the specification include:

Shotcrete Material:

Only prepackaged mixtures are accepted. Materials must be supplied from an approved manufacturer—with performance test data supplied by the manufacturer or from another MTO contract—verifying that the material meets the requirements of the specification.

Nozzlemen:

Shotcrete shall be carried out by nozzlemen who have participated in the MTO Shotcrete Nozzleman Certification Program and who are on the list of approved nozzleman operators for the current construction season. Names of the nozzlemen and proof of their MTO qualification must be submitted to Contract Administrators.

Concrete Removal:

Prior to carrying out concrete removal operations, the perimeter of the removal area shall be sawn to a depth of 3/8 in. (10 mm) or to the depth of the reinforcing steel, whichever is less. The perimeter of the removal area shall have a face perpendicular to the original concrete surface for the specified depth of the removal area. Unless otherwise specified on the Contract Drawings, concrete in these areas shall be removed to a uniform depth of 1 in. (25 mm) behind the first layer of reinforcing steel. Concrete surrounding the second layer of reinforcing steel shall also be removed locally to provide a minimum clearance of 1 in. (25 mm) all around the reinforcing steel. Concrete removal beyond the second layer of reinforcing steel shall be carried out only when directed by the Contract Administrator.

Surface Preparation:

All exposed concrete that will be receiving shotcrete shall be uniformly roughened by means of scrabbling, chipping, or bush hammering. A surface profile of 0.2 ± 0.08 in. (5 ± 2 mm) shall be achieved by exposing aggregates across the entire surface. All concrete surfaces, including the reinforcing steel, shall be abrasive blast cleaned prior to the installation of wire mesh. The area to be shotcreted shall be maintained in a wet condition for a period of 2 hours prior to the placement of shotcrete.

Placement of Welded Steel Wire Fabric:

The welded steel wire fabric shall be securely fastened to the exposed reinforcing steel by ties placed no more than 12 in. (300 mm) apart in a grid pattern. The minimum clearance between the existing concrete and the fabric shall be 0.79 in. (20 mm).

Shotcrete Placement:

The MTO shotcrete specification allows for the placement of either dry- or wet-mix process shotcrete. In either case, the shotcrete material must be supplied in a pre-bagged form, maintained in a dry condition up to the time of its use, and stored within a temperature range of 40 to 86°F (5 to 30°C). Continuous-feed pre-dampeners are used only when the dry-mix process is used.

Shotcreting shall not be carried out when the air temperature or existing concrete surface temperature is below 50°F (10°C) or is likely to fall below 50°F (10°C), or is above 86°F (30°C) or likely to rise above 86°F (30°C) throughout the duration of the shotcreting operation, unless protection is provided in accordance with the Contractor's submitted plan. The air in contact with the repaired surfaces shall be maintained at temperatures above 50°F (10°C) for at least 96 hours after the application of shotcrete.

Curing:

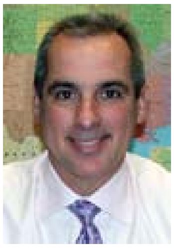
Shotcrete shall be initially moist-cured by continuous fog mist for a minimum of 24 hours. The curing shall commence as soon as the fog mist can be applied without deforming the surface of the shotcrete. After the initial 24-hour fog-misting period, moist-curing shall continue for an additional 72 hours by means of fog mist or wet burlap. Immediately after removal of moist-curing, the shotcrete surface shall be coated with a curing compound according to OPSS 904, MTO's Construction Specification for Concrete Structures.

Conclusions

Continued exposure to freezing-and-thawing cycles and deicing salt make Ontario one of North America's most challenging environments for maintenance of bridge structures. The rehabilitation of concrete structures experiencing deterioration due to corrosion often involves repairs to bridge soffits, curved concrete beams, and columns and other applications that make the use of forms a formidable challenge. The well-proven shotcrete process provides the MTO and Ontario contractors with a reliable, cost-effective option for concrete rehabilitation with a substantial extension of service life and will continue to play a vital role in the cost-effective maintenance of Ontario's highway structures.

References

1. Brown, A. W., and Yuen, C. M. K., "Improved Shotcreting Methods and Materials," Golder Associates Ltd., Toronto, ON, Canada, 1989, 60 pp.
2. Dufour, J.-F.; Reny, S.; and Vezina, D., "State-of-the Art Specifications for Shotcrete Rehabilitation Projects," *Shotcrete*, V. 8, No. 4, Fall 2006, pp. 4-11.
3. "Special Provision No. 931S01," Construction Specification for Structure Rehabilitation—Shotcrete, Ministry of Transportation of Ontario, Toronto, ON, Canada, July 2007, 15 pp.
4. "Special Provision No. 109S50," Construction Special Provision for Structure Rehabilitation—Concrete Patches, Refacing, and Overlays, Ministry of Transportation of Ontario, Toronto, ON, Canada, July 2007, 19 pp.
5. "Special Provision No. 109S49," Construction Specification for Structure Rehabilitation—Concrete Removal, Ministry of Transportation of Ontario, Toronto, ON, Canada, June 2010, 14 pp.
6. "Program for Nozzleman Approval," Ministry of Transportation of Ontario, Toronto, ON, Canada, Mar. 2011, 9 pp.



ACI member ***Joe Hutter*** *is the Vice President, Sales, for King Packaged Materials Company, Burlington, ON, Canada. He has more than 20 years of experience in the cement/shotcrete industry. He is the current Vice President and an active member of ASA and has chaired the ASA Marketing Committee since its inception.*

Mahaish Singh *worked with the Ministry of Transportation (MTO), ON, Canada, for over 43 years, most recently as a Senior Concrete/Materials Engineering Officer. His responsibilities at MTO included working with shotcrete, waterproofing membranes, bearings (laminated and plain), and expansion joint seals. From 1994, Singh worked closely with shotcrete contractors and materials manufacturers to advance the shotcrete process throughout the province of Ontario. His efforts to develop and administer MTO's Shotcrete Nozzleman Certification Program have contributed to the improved quality of shotcrete placed on Ontario bridge structures. Singh's career ended with MTO when he retired at the end of 2011.*

Reprinted from February 2011 issue of Concrete International *with permission of the American Concrete Institute,* ***www.concrete.org***.

Ruskin Dam Spillway Shotcrete Assessed

Study shows that the dam's long service life can be extended by almost 50%

By Lihe (John) Zhang, Mazin Ezzet, Natalya Shanahan, Dudley R. (Rusty) Morgan, and A.P. Sukumar

For more than 4 million residents in British Columbia, Canada, BC Hydro & Power Authority (BC Hydro) is the main producer of electricity. About 90% of the utility's 11,300 megawatt (MW) installed capacity is generated at its 31 hydroelectric facilities. The Ruskin Dam is part of that immense system. Constructed in 1929 and 1930, it is located on the Stave River, about 60 km (37 miles) east of Vancouver, and is the lower facility in the Alouette-Stave-Ruskin Hydroelectric System in the Fraser Valley (Fig. 1).

The dam is a concrete gravity structure composed of eight monoliths situated in a narrow valley and founded predominantly on bedrock. It is 130 m (427 ft) long at the road deck, comprising an 85 m (279 ft) long, seven-bay radial-gated spillway straddled by two 45 m (148 ft) long nonoverflow sections. The dam is 58 m (190 ft) high from its deepest foundation to the road deck on the dam crest.

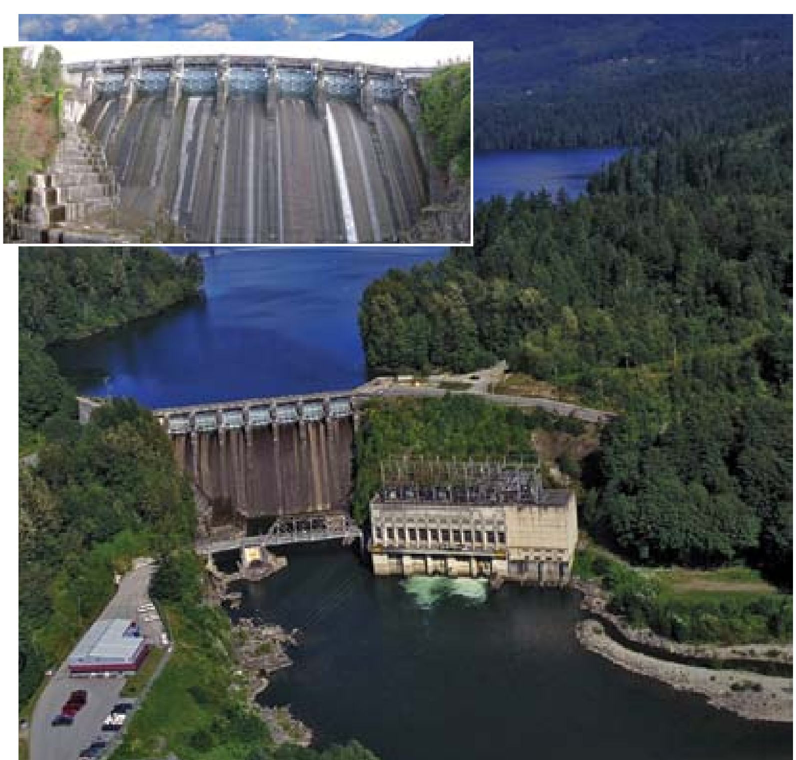


Fig. 1: Ruskin Dam and 105 MW generating station. The spillway (inset) has undergone two renovations in its 80-year life

Ruskin Dam was built long before the development of air entrainment to protect concrete from frost. As a consequence, the concrete in the spillway suffered some frost damage, as well as erosion/abrasion from water and water-borne debris. Some initial repairs were made on the spillway surface in 1954 using shotcrete. But deterioration continued in the concrete spillway and adjacent stepped structure at the right (looking downstream) abutment.

In 1973, a major program was undertaken to completely resurface the spillway and stepped structure. This was done using dry-mix shotcrete reinforced with 5 mm (0.2 in.) diameter welded-wire reinforcement (WWR). The shotcrete thickness on the spillway varied from about 75 to 200 mm (3 to 8 in.), and the thickness on the stepped structure varied from about 75 to 150 mm (3 to 6 in.).

In 1993, an evaluation of parts of one bay in the spillway and the stepped structure demonstrated that the shotcrete in the spillway bay was in good condition generally and well bonded to the substrate concrete.[1,2] There were, however, some localized areas with layering and sand lenses; these had led to spalling in the outer 50 mm (2 in.) of shotcrete. Also, vertical cracking was evident at about 20 m (66 ft) spacing. These were clearly reflection cracks, as they coincided with the locations of construction joints in the dam. Other visible cracking in the shotcrete totaled about 1 m (3.3 ft) of cracks per 10 m^2 (108 ft^2) of shotcrete. In contrast, the stepped structure was in poor condition. The shotcrete had delaminated from the substrate concrete in many places, and it displayed pronounced scaling, erosion, cracking, and spalling. Further, freezing-and-thawing

Fig. 2: Rolling suspended stage

damage to a depth of about 20 to 30 mm (0.8 to 1.2 in.) was found in the substrate concrete beneath the shotcrete.[1,2]

During 2006 and 2007, the BC Hydro project team made a preliminary design of the dam upgrade. Part of this upgrade program included assessing the condition of the Ogee spillway and the stepped right abutment (Fig. 1).

In 2008, AMEC Earth & Environmental was contracted by BC Hydro to provide a detailed condition survey, estimate the remaining service life of the existing shotcrete, and provide recommendations and cost estimates for remedial alternatives to extend the service life of the dam.

Condition Assessment

Access, safety, and environmental protection

Access to the spillway face was a challenge for the inspection team. A rolling suspended stage equipped with adjustable slope brackets was installed and moved from bay to bay (Fig. 2). In addition, a standby high-angle rescue team, a crane with a personnel basket, and a rescue boat were on site throughout the inspection. An environmental management plan was enforced, requiring sampling and testing of water below the spillway to evaluate pH, conductivity, and turbidity prior to and during coring activities, particularly if coring water drip was observed running down the dam face to the Stave River. The investigation was completed with no safety or environmental incidents.

Condition survey and assessment

The condition survey and assessment included:

- Visual examination and photographic documentation of obvious defects, including cracking, erosion, and signs of construction joint delamination; and
- Nondestructive testing (NDT) using impact echo (IE) (Fig. 3(a)), coupled with sounding for delamination using chain drag (Fig. 3(b)) and appropriately weighted hammers (Fig. 3(c)). While chain drag and hammer testing was conducted for the entire shotcrete surface, IE

Fig. 3: Nondestructive testing: (a) IE; (b) sounding using a chain drag; and (c) sounding using a hammer

testing was conducted at a grid of 2 m (6.6 ft) in accessible areas with no water flow. The shotcrete surface at IE test locations was ground smooth within and beyond the zone between the impactor and transducer.

Cores were extracted at locations that appeared to be either delaminated or sound as indicated by NDT. They were used to evaluate compressive strength as well as boiled absorption and volume of permeable voids. A petrographer also examined the cores.

Results and Discussion

Visual inspection

Visual inspection revealed a number of deficiencies, including cracking; erosion; construction joint delamination at what appeared to be feathered edges; efflorescence and leaching from water seepage; and surface irregularities. Results of visual inspections were recorded in the condition survey maps (Fig. 4).

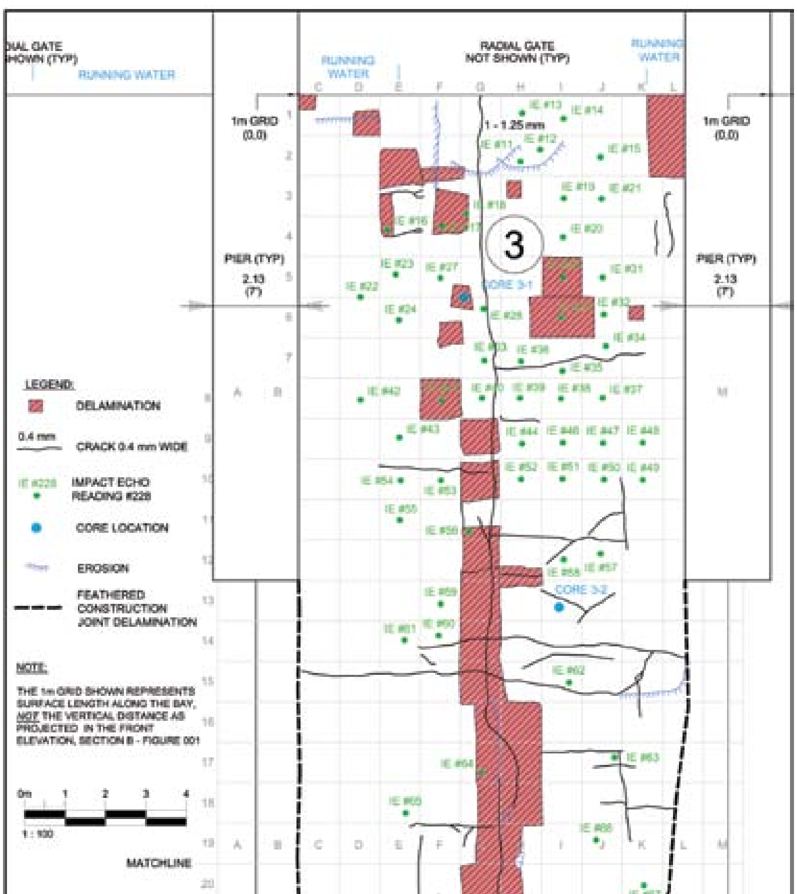


Fig. 4: Example of condition survey map

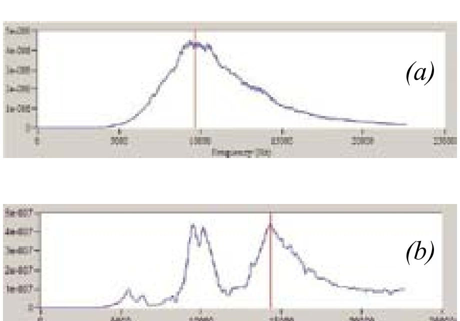


Fig. 5: IE testing results: (a) results indicating sound shotcrete; and (b) results indicating delaminated shotcrete

IE testing and sounding

IE and sounding data were used to categorize the concrete as sound, delaminated, or defective. If IE indicated no defects to a depth of about 300 mm (12 in.), the overlay and substrate were deemed sound (Fig. 5(a)). If a defect was detected using IE and confirmed using sounding, the concrete was deemed delaminated (Fig. 5(b)). If IE indicated a defect that was not confirmed by sounding, the concrete was deemed defective—the defects could be deep delaminations or voids. We also found areas where the IE data could not be interpreted because of poor signals. Although we made attempts to grind rough areas smooth in the majority of test locations, the poor signals could perhaps be attributed to a rough surface.

In total, 217 readings were taken, typically at 2.0 m (6.6 ft) spacing in accessible areas (Fig. 4). Of the total evaluated points, 41% were deemed sound material, about 15% were found to be delaminated, 22% were defective, and 23% of the IE readings provided poor signals that could not be interpreted.

Spillway Bays 1, 2, 3, 5, and 7 were sounded. Table 1 summarizes the total delaminated area detected for each bay.

Bay 3 had the largest percentage of delaminated area (18%), while Bays 5 and 7 had the lowest amount of delamination. The total delaminated area for the entire spillway was calculated to be 99 m^2 (1065 ft^2) or 6%.

Core examination

Cores obtained from the spillway were visually examined prior to preparation for testing and petrographic examination. Detailed information about cores is listed in Table 2.

All cores had delamination planes. Half of the cores had delamination at the shotcrete/concrete interface, and two cores had multiple delamination planes. Cores extracted from locations where delamination was indicated by NDT showed delaminations in the shotcrete layer; cores extracted from locations that appeared sound from the NDT testing showed delaminations in the concrete layer.

The shotcrete thickness was in the 55 to 210 mm (2.2 to 8.3 in.) range in the spillway and 40 to 130 mm (1.6 to 5.1 in.) in the stepped structure. The average depth of delamination below the shotcrete/concrete interface was calculated to be 25 mm (1 in.) in the spillway and 15 mm (0.6 in.) in the stepped structure. Core examination also revealed the presence of porous zones (shadows) in some of the shotcrete cores.

Core testing

Density, absorption, volume of permeable voids, and compressive strength were determined for the spillway shotcrete and concrete (Table 3).

It was determined that the average absorption of the spillway shotcrete was 5.6% and the average volume of permeable voids was 12.7%. These values are well within the limit provided in ACI 506R-05[3]—that is, 6 to 9% typical absorption values and 14 to 17% volume of permeable voids.

Although the average compressive strength of the spillway shotcrete was calculated at 40.0 MPa (5800 psi), the results varied from 20.8 to 69.4 MPa (3016 to 10,063 psi). This is sometimes encountered with dry-mix shotcrete, as the compressive strength is significantly affected by the amount of water added at the nozzle. It should be noted that the specified compressive strength of the shotcrete was 4500 psi (31 MPa).

For the original spillway concrete, the average absorption was 4.6% and the average volume of permeable voids was 11.0%. Much less variation was observed in the concrete compressive strength as compared to the shotcrete compressive strength, although one outlier was excluded from the average based on Chauvenet's criterion. The corrected average strength of the spillway concrete was 28.4 MPa (4118 psi).

Petrographic examination

The petrographic examination indicated that the principal form of distress affecting the concrete is freezing-and-thawing damage. There was evidence of through-core fracturing and cracking,

Table 1: Delamination Summary

Bay no.	Delaminated area, m^2	Total bay area surveyed, m^2	Delaminated area, %
1	11.7	147.5	7.9
2	14.1	316.6	4.5
3	66.3	371.3	17.9
5	3.8	429.3	0.9
7	3.0	336.1	0.9
Total	98.9	1600.8	6.1

Note: 1 m^2 = 10.76 ft^2

Table 2: Shotcrete Thickness and Depth of Delamination in the Spillway Cores

Core no.	Shotcrete thickness, mm	Depth of shotcrete delamination below surface, mm	Depth of concrete delamination below shotcrete/concrete interface, mm	Other observations
1-2	75	10 to 30	110	Delamination is along a large-size aggregate
1-3	200 to 210	140 and 200 (at the interface with base concrete)	No delamination	Porous zones (shadows) in the shotcrete
2-1	190	160 and 190 (at the interface with base concrete)	No delamination	—
2-2	175	175 (at the interface with base concrete)	No delamination	—
3-1	55 to 65	55 (at the interface with base concrete)	0 to 25	—
3-2	130 to 140	No delamination	35	—
5-1	85 to 105	No delamination	350*	—
5-2	170	170 (at the interface with base concrete)	No delamination	—
7-1	85 to 100	No delamination	50 and 305*	—
7-2	85 to 95	No delamination	25 to 45	—
Average	130	—	25	—

*Not included in the average. Only delaminations located near shotcrete/concrete interface are included

Note: 1 mm = 0.03937 in.

both attributable to freezing and thawing. While some minor signs of alkali-silica reaction were observed, the associated expansion would have been insufficient to have caused the observed cracking (Fig. 6).

Assessment

The condition survey established that while the shotcrete-faced spillway appears to be in reasonably good condition overall, there is distress in the forms of cracking, delaminations at construction joints with feathered edges, and more deep-seated delaminations at the shotcrete/concrete interface or in the substrate concrete. There are also localized areas of erosion and seepage through the shotcrete face (Fig. 7).

Based on the findings of the field investigation and subsequent petrographic evaluation and physical testing of shotcrete and concrete components of extracted cores, it is concluded that the prime mechanisms of continuing deterioration of the spillway face and stepped structures were delamination and cracking attributable to ongoing freezing and thawing. This is compounded by the effects of localized seepage and erosion in the shotcrete face and at feathered-edge construction joints.

Therefore, we recommended that the defective and deteriorated areas of the spillway shotcrete be removed and replaced. An overall schematic showing the general areas that have to be removed and replaced is in Fig. 8.

Rehabilitation

For remediation, we recommend the use of wet-mix shotcrete for repairs, as it provides consistent

Table 3: Density, Absorption, Voids, and Compressive Strength of the Spillway Shotcrete and Substrate Concrete

Sample ID	Absorption after immersion and boiling, %	Outlier ID	Bulk density after immersion and boiling, kg/m^3	Outlier ID	Volume of permeable voids, %	Outlier ID	Corrected compressive strength, MPa	Outlier ID
Spillway shotcrete								
1-3-I	7.85	1.27	2.35	–1.22	17.1	1.18	21.7	–1.04
2-2-I	7.04	0.82	2.38	–0.66	15.7	0.80	27.7	–0.70
3-2-I	3.23	–1.33	2.43	0.19	7.6	–1.38	69.4	1.68
5-1-I	4.77	–0.46	2.51	1.48	11.4	–0.35	31.6	–0.48
5-2-I	4.27	–0.74	2.39	–0.54	9.8	–0.80	20.8	0.62
7-1-I	6.37	0.44	2.46	0.75	14.7	0.55	38.7	–0.07
Average	5.59	—	2.42	—	12.7	—	35.0	—
Standard deviation	1.78	—	0.06	—	3.70	—	18.11	—
Critical value for rejection (Chauvenet's criterion)					1.73			
Corrected average	5.59	—	2.42	—	12.7	—	40.0	—
Spillway concrete								
1-3-III	5.34	0.59	2.50	–0.39	12.7	0.62	30.4	0.80
1-2-II	6.59	1.56	2.46	–1.60	15.2	1.52	29.4	0.57
2-1-III	3.27	–1.01	2.56	1.00	8.1	–1.03	27.6	0.18
3-1-II	4.26	–0.25	2.50	–0.40	10.2	–0.27	18.4	–1.77
5-2-II	4.78	0.16	2.53	0.37	11.6	0.22	24.2	–0.54
7-2-II	3.23	–1.05	2.56	1.01	8.0	–1.06	30.2	0.76
Average	4.58	—	2.52	—	11.0	—	26.7	—
Standard deviation	1.29	—	0.04	—	2.78	—	4.69	—
Critical value for rejection (Chauvenet's criterion)					1.73			
Corrected average	4.58	—	2.52	—	11.0	—	28.4	—

Note: 1 kg/m^3 = 1.686 lb/yd^3; 1 MPa = 145 psi performance and will work well to produce the sloped, irregularly shaped patches needed on the spillway. Cast-in-place concrete would be difficult to form, deliver, and consolidate; and it would be difficult to obtain a quality surface finish (air bubbles tend to get trapped under sloped formwork, resulting in numerous voids on the concrete face). With modern wet-mix, steel fiber-reinforced, silica fume modified shotcrete, it's possible to achieve high quality, dense concrete with smooth surface finishes. It is also possible to achieve high compressive strength, excellent resistance to freezing and thawing, and resistance to erosion and abrasion. We recommend removing delaminated zones and placing a full thickness replacement overlay, using mild steel reinforcement to tie the overlay back to the original concrete dam material (Fig. 9).

A complete shotcrete overlay was also proposed as an option. This overlay involves resurfacing approximately 3000 m^2 (32,280 ft^2) of the spillway with a reinforced shotcrete overlay. Although you can use either WWR or steel fibers, we recommend resurfacing the spillway with a steel fiber-reinforced shotcrete overlay to a nominal 150 mm (6 in.) thickness (Fig. 9). This is similar to the approach used in the Littlerock Dam shotcrete overlay seismic retrofit.[4] As in the Littlerock Dam project, it was recommended that a system of shotcrete anchors connected by reinforcing bars be installed to provide mechanical anchorage so that the long-term performance of the bonded overlay is not entirely dependent on bond. Using steel fibers eliminates the complications of installing and achieving good shotcrete

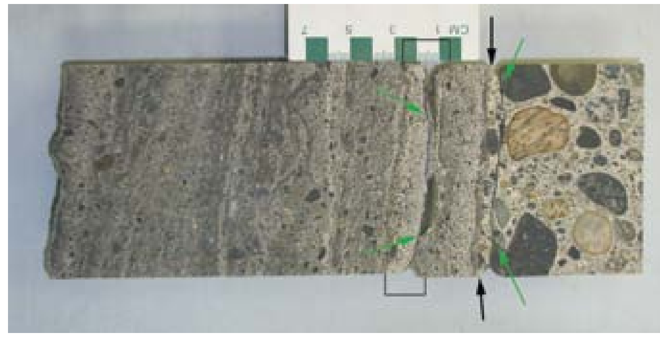


Fig. 6: Example of petrographic examination photo. Polished core surface of Core B2-1 prepared along the long axis of the core. The black arrows indicate the tight shotcrete (gray) parent concrete (at right) contact. The green arrows indicate through core cracking both in the parent concrete and in the shotcrete layer. The black brackets outline a zone of very weak, highly porous shotcrete

Fig. 7: Feathered edge construction joint delamination

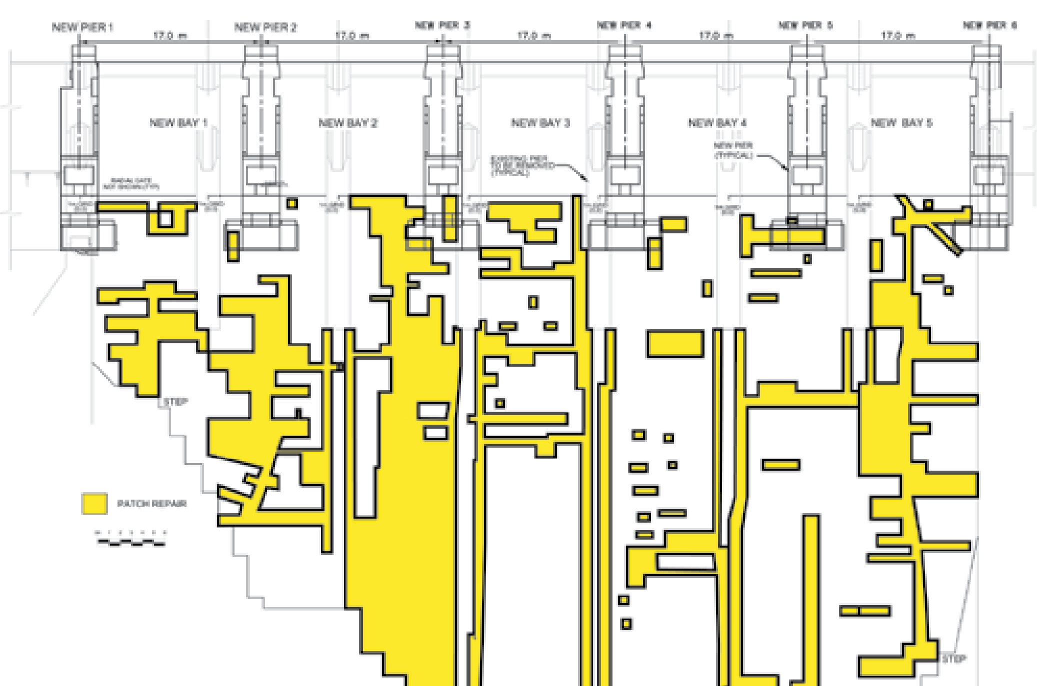


Fig. 8: Sketch of spillway repair maps (yellow represents area to be removed)

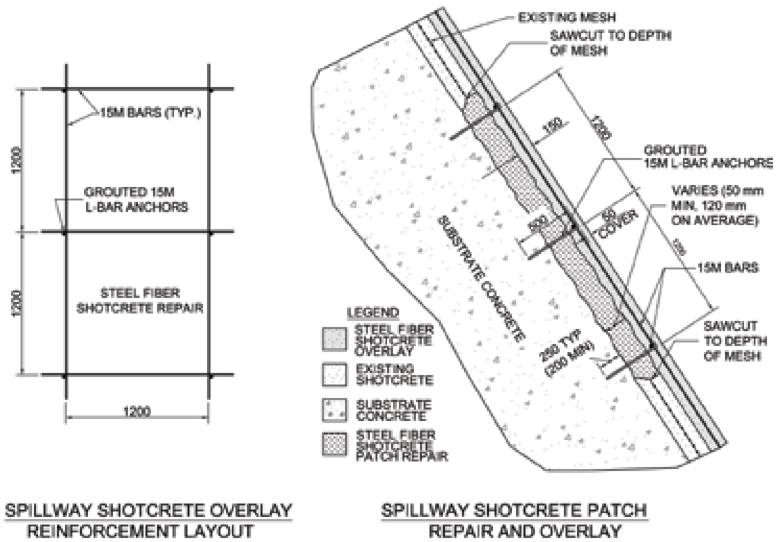


Fig. 9: Steel fiber-reinforced shotcrete repair of spillway surface. All dimensions in mm (1 mm = 0.03937 in.)

consolidation around WWR. When properly cured, steel fiber-reinforced shotcrete has been demonstrated to be very effective in reducing or even eliminating cracking of bonded shotcrete overlays in dams and other hydraulic structures.[4]

Life Extension

The existing WWR reinforced dry-mix shotcrete resurfacing of the Ogee spillway of the Ruskin Dam has extended the serviceability of the dam by nearly 40 years. A major seismic upgrade to the dam is planned, with a view to extending the design life of the dam by at least another 50 years. A detailed condition survey of the shotcrete-faced spillway shows that while the majority of the shotcrete overlay is still in good condition and well bonded to the substrate concrete, there are areas now displaying weathering or deterioration, including cracking, delamination, and erosion. Remedial alternatives involving either patch repair or a full bonded steel fiber-reinforced wet-mix shotcrete to extend the service life of the dam for another 50 years or more have been presented as options.

References

1. Heere, N., "Durability of Shotcrete Rehabilitation Treatments of BC Hydro Dams," MASc thesis, University of British Columbia, Vancouver, BC, Canada, Feb. 1995.

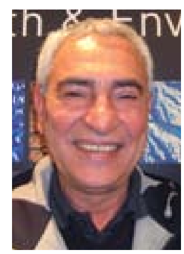
2. Heere, R.; Morgan, D.; Banthia, N.; and Yogendran, Y., "Evaluation of Shotcrete Repaired Dams in British Columbia," *Concrete International*, V. 18, No. 3, Mar. 1996, pp. 24-29.

3. ACI Committee 506, "Guide to Shotcrete (ACI 506R-05)," American Concrete Institute, Farmington Hills, MI, 2005, 40 pp.

4. Forrest, M. P.; Morgan, D. R.; Obermeyer, J. R.; Parker, P. L.; and LaMoreaux, D. D., "Seismic Retrofit of Littlerock Dam," *Concrete International*, V. 17, No. 11, Nov. 1995, pp. 30-36.

Selected for reader interest by the editors.

*ACI member **Lihe (John) Zhang** is a Materials Engineer with AMEC Earth & Environmental. He specializes in concrete technology, fiber-reinforced concrete, shotcrete, evaluation and rehabilitation of infrastructure, and impact resistance. He is a member of ACI Committees 506, Shotcreting; 544, Fiber-Reinforced Concrete; and 370, Blast and Impact Load Effects. He received his PhD in civil engineering from the University of British Columbia.*

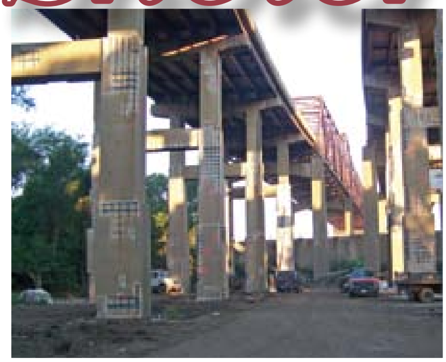


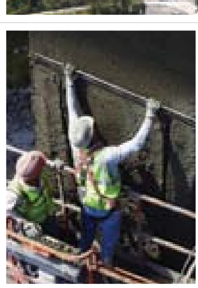
***Mazin Ezzet** is a Senior Materials Engineer with AMEC Earth & Environmental. He has more than 35 years of experience in civil and materials engineering. He has provided consulting services for a wide range of projects, including bridges, dams, tunnels, and marine structures in the Middle East, North Africa, Europe, and North America.*

***Natalya Shanahan** is a Materials Engineer with AMEC Earth & Environmental. She received her BS and MS in civil engineering from the University of South Florida, Tampa, FL. She has worked on concrete structural assessment and evaluation projects and on construction sites.*

***Dudley R. (Rusty) Morgan**, FACI, is a Principal Consultant with AMEC Earth & Environmental, a Division of AMEC Americas Limited. He is a civil engineer with more than 40 years of experience in concrete and shotcrete technology and the evaluation and rehabilitation of infrastructure. Morgan was Secretary of ACI Committee 506, Shotcreting, for 15 years.*

*ACI member **A. P. Sukumar** is Project Engineering Team Lead (Major Projects), Generation Engineering, BC Hydro. He has more than 25 years of experience in engineering and project management. He received his PhD in civil engineering from Dalhousie University, Halifax, NS, Canada, and his MBA from Simon Fraser University, Vancouver, BC, Canada. At present, he leads a team of project engineers involved in major projects upgrading/building hydroelectric dams and power plants.*





On behalf of the Pool and Recreational Shotcrete Committee, I am proud to introduce the establishment of our new position papers regarding the shotcrete process in the pool industry. The concept of these papers originated from all the confusion in our market segment. Correct terminologies, strength, performances, and so on were usually unsubstantiated opinions based on nonfactual science. With these new statements, the committee is establishing reference benchmarks that are vital to builders who use the process. The positions are bottom-line fundamentals of correct shotcrete. I encourage all participants to start building their own library of sanctioned reference information from the American Shotcrete Association (ASA) and the American Concrete Institute (ACI). These types of publications and positions allow pool builders to now have accredited associations supporting their specific pool product. ASA's primary goal is to spread and promote the proper use of shotcrete technology. These position statements do just that. This column features Position Statement #1, "Compressive (Strength) Values of Pool Shotcrete." It can also be found on the ASA Web site at **www.shotcrete.org/poolpositionpaper**. It is a great building block for your new reference library!

William T. Drakeley
Chair, Pool and Recreational Shotcrete Committee

American Shotcrete Association's Pool and Recreational Shotcrete Committee Position Statement #1

Compressive (Strength) Values of Pool Shotcrete

Pool and shotcrete contractors have a responsibility to provide a pool structure that not only meets certain design specifications, but also meets basic durability values expected with shotcrete applications. The American Shotcrete Association's (ASA) Pool and Recreational Shotcrete Committee and ASA Board of Direction have reaffirmed a 4000 psi (27.6 MPa) minimum for in-place compressive strength pool concrete.

Concrete in field installations has a variety of different exposure conditions. Concrete used in water-retaining pool and recreational structures is expected to have a low permeability under any potential exposure. The American Concrete Institute (ACI) 318-08, "Building Code Requirements for Structural Concrete," durability requirement provisions for concrete are covered in Chapter 4. ACI 318-08 specifies concrete "in contact with water where low permeability is required" is a Category P1 exposure. Table 4.3.1, Requirements for Concrete by Exposure Class, requires for a P1 exposure a minimum compressive strength of 4000 psi (27.6 MPa) with water-cementitious material ratios (*w/cm*) no greater than 0.50. These values are ACI 318-08 Building Code required minimums. Consideration of key factors will yield higher strengths when concrete is placed via the shotcrete method.

Normally, good-quality concrete placed by the shotcreting process will substantially exceed the 4000 psi (27.6 MPa) minimum ACI 318-08 Building Code requirement. Key factors that increase the likelihood of the compressive strength significantly exceeding the minimum of 4000 psi (27.6 MPa) have to do with the material itself and the high velocity (350 to 400 ft/s [106 to 122 m/s]) with which the material is applied onto the surface. After being strongly accelerated by high air pressure in the nozzle, the concrete strikes the receiving surface with such force that it is compacted. This results in consolidation of all the concrete rather than the sometimes haphazard consolidation that can occur with cast-in-place concrete. Fully consolidated concrete provides greater strength and lower permeability than poorly consolidated concrete. The compacted, low-permeability concrete created by shotcreting is the ideal concrete for structures intended to hold water.

The resulting structure's concrete porosity and resulting compressive strength will easily exceed 4000 psi (27.6 MPa) using the shotcrete (wet) process. Further, due to cement content and lower *w/cm* inherent in dry-mix (gunite) shotcrete, concrete compressive strengths will normally far exceed the 4000 psi (27.6 MPa) ACI 318-08 Building Code minimum. Barring significant errors in material batching in application of the shotcrete or in curing, one simply cannot avoid producing water-retaining shells with these higher compressive strengths.

To further understand the properties of the shot product, you must also analyze its material matrix on a particle-to-particle basis. Shotcrete mixtures differ from typical concrete mixtures. With shotcrete, the aggregate size is decreased while the surface area of all aggregates/particles is increased. This increase in surface area demands an increase in the binder (cementitious materials such as portland cement, fly ash, and slag), that fills the voids between the aggregate and glues this matrix together. The resulting lower *w/cm* gives shotcrete its increased strength.

Couple this matrix with proper velocity in placement (high velocity = full compaction = strength and low porosity) and you get 28-day compressive strengths ranging from 4500 to 9000 psi (31 to 62 MPa) or more.

In summary, properly designed concrete placed via the shotcrete process with in-place values less than 4000 psi (27.6 MPa) is the result of an unintentional or intentional breakdown in material production or shotcrete application. Though the pool industry has seen shotcrete specified with less than the ACI 318-08 Building Code required 4000 psi (27.6 MPa) minimum 28-day compressive strength, lower strength could only result from significantly reduced material quality or poor application procedures. Specifying a lower compressive strength would result in increased porosity of the in-place shotcrete and thus greatly reduce the pool shell's basic ability to hold water.

Unfortunately, the pool industry often suffers from the distribution of incorrect information on minimum compressive strength values of in-place shotcrete/concrete. ASA continually works to educate all who are in and related to the pool industry regarding proper placement and in-place properties of concrete placed with the shotcrete process. ASA also works to ensure that the shotcrete industry understands and implements the guides, specifications, and codes of ACI and its shotcrete information. Together, ASA and ACI form the primary sources of shotcrete education and documentation. We firmly maintain that the 4000 psi (27.6 MPa) minimum 28-day compressive strength that meets the ACI 318-08 Building Code requirements is necessary to produce durable, water-containing pool shells that our owners deserve and expect. Specifying any lower compressive strength does a disservice to the owner and the pool industry.

References

ACI Committee 318, "Building Code Requirements for Structural Concrete and Commentary (ACI 318-08)," American Concrete Institute, Farmington Hills, MI, 2008, 473 pp.

ACI Committee 506, "Guide to Shotcrete (ACI 506R-05)," American Concrete Institute, Farmington Hills, MI, 2005, 40 pp.

"Board of Directors Letter," American Shotcrete Institute, Farmington Hills, MI, Apr. 28, 2011.

"Craftsman Workbook for ACI Certification of Shotcrete Nozzleman CP-60(09)," American Concrete Institute, Farmington Hills, MI, 2009, 126 pp.

Drakeley, B., "Committee Chair Memo," *Shotcrete*, V. 13, No. 3, Summer 2011, pp. 4-5.

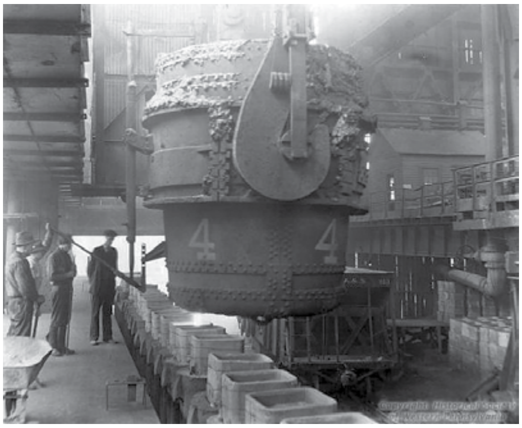
Yoggy, G., "The Elevated Game," *Watershapes*, V. 11, No. 9, Sept. 2009, pp. 44-49.

Static Electricity

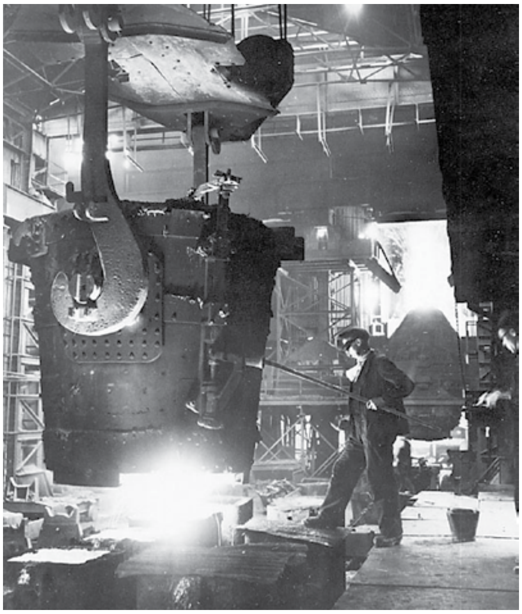
By Ted W. Sofis

Those of us who have been involved in the installation of dry-process shotcrete have at some point experienced problems with static electricity. My first experience with static electricity came while gunning teeming ladles at J&L Steel in Aliquippa, PA.

The brick lining of the ladles would be glowing red as they were put into position to be hot gunned. Hot gunning is a term used in the steel industry for gunning refractory onto glowing hot surfaces in vessels, soaking pits, and ladles. With hot gunning, thin layers of refractory are shot onto the hot surface where it dries on contact. Because of the intense heat of the glowing ladle brick, we would often add a metal or plastic pipe to lengthen and extend the nozzle. Unfortunately, the extending nozzle pipe was not grounded to the gun and the gunning hose. Here is where it gets ugly. While we were gunning a ladle, there was a crackle and a 3 ft (0.9 m) long blue lightning bolt of electricity instantaneously appeared. It electrically (and probably mentally) shocked the nozzleman, who dropped the nozzle like a hot potato. Yes, we had inadvertently discovered the Taser! I immediately shut off the gun and, fortunately, no one was hurt—at least not seriously. I had heard about static electricity with gunning; but until you experience it, you have no idea how powerful it can be.



A steel industry teeming ladle pouring steel in ingot molds. The teeming ladles were lined with refractory brick and often hot gunned in between heats, with thin layers of gunned refractory



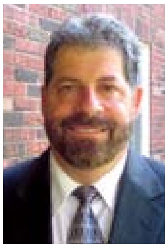
Another teeming ladle pouring molten steel into ingot molds

So when gunning, always make sure you are using static-grounded hose. Everything from the gun to the nozzle should be grounded. Whenever possible, with kiln-dried materials such as refractory gunning mixtures or prepackaged shotcrete materials, consider predampening. Whenever you need to add a pipe or extension to the end of your nozzle to get closer to the gunning surface, make absolutely sure that it is grounded. If possible, it's always safer to stay with conventional manufactured nozzles. The equipment, hoses, and nozzles that are manufactured and marketed for shotcrete have a proven track record; it's better to be safe than sorry.

Over the years, our shotcrete crews have always preferred using the black tube sandblast hose for gunning. It's a stiffer static-grounded gunite hose that does not kink as easily as softer hoses. Whatever hose your crews like to use, whether it is the soft gum rubber refractory hose or the stiffer black tube, it's important to make sure that it is a static-conducting hose. No one on the nozzle needs the surprise shock of a 3 ft (0.9 m) long lightning bolt of static electricity. Let's leave the Taser gun to law enforcement and keep it as far away from construction as possible.

Like all other elements of construction safety, common sense is an important ingredient. So in addition to making sure that gunning hoses are grounded, take an extra 5 minutes to look over everything before you start working. Make sure that everyone on the job wears the proper personal protective equipment, the air lines have safety pins, whip checks are in place, and all other safety procedures are followed.

The use of a static-dissipating gunning hose is recommended in gunning operations and should alleviate many of the problems with static electricity. Pictured is black tube, white stripe refractory hose with dual copper static wire
Photo courtesy Tom Norman, Airplaco Equipment Co.



Ted W. Sofis *and his brother, William J. Sofis Jr., are the Principal Owners of Sofis Company, Inc. After graduating from Muskingum College, New Concord, OH, with a BA in 1975, Ted began working full time as a shotcrete nozzleman and operator servicing the steel industry. He began managing Sofis Company, Inc., in 1984 and has over 34 years of experience in the shotcrete industry. He is the Treasurer for ASA, Chair of the ASA Publications Committee, and a member of multiple ASA committees. Over the years, Sofis Company, Inc., has been involved in bridge, dam, and slope projects using shotcrete and refractory installations in power plants and steel mills. Sofis Company, Inc., is a member of the Pittsburgh Section of the American Society of Highway Engineers (ASHE) and ASA.*

At the ACI Fall 2011 Convention in Cincinnati, OH, the governing policy for the ACI Shotcrete Nozzleman Certification Program was updated and revised. It is reprinted here in its entirety. You can also download and view a copy from **www.concrete.org/Certification/pdf/scn.pdf**.

ACI Certification Policies for Shotcrete Nozzlemen

The statements contained herein are a consolidation of approved policies and procedures. This policy statement supersedes all previous action of the American Concrete Institute (ACI) Board of Direction with respect to Shotcrete Nozzlemen certification and is effective October 18, 2011.

The certification program policies are broken down into eight sections as follows:

Section 1: Certification Criteria
Section 2: Examination Criteria
Section 3: Re-examination Criteria
Section 4: Appeals
Section 5: Sponsoring Group Criteria
Section 6: Examiner/Supplemental Examiner Criteria
Section 7: ACI Responsibilities
Section 8: Recertification Criteria

Section 1.0—Certification Criteria

1.01 The American Concrete Institute (ACI) certification program for Shotcrete Nozzlemen shall require successful completion of both a written examination and a two-part performance examination, all to be completed within a 1-year period.

1.02 No specific education is required as a prerequisite for Shotcrete Nozzleman certification.

1.03 500 hours of verified work experience as a nozzleman is a prerequisite to participate in the performance examination, with at least 100 hours in the process for which certification is sought. Required work experience must be documented on an ACI Work Experience Form and submitted to the Sponsoring Group conducting the certification session prior to the scheduled testing date. The required 500 hours of work experience must be reviewed and verified by the Sponsoring Group and the scheduled examiner prior to certification session.

If an applicant has tested in a past ACI Certification of Shotcrete Nozzleman session, demonstration of the 500 hours of work experience prerequisite is not required, as this has already been met in their original ACI session.

1.04 ACI Certification of Shotcrete Nozzlemen shall be valid for a period of 5 years from the date of completion of all certification requirements.

1.05 Certification may be renewed by satisfying the recertification requirements.

Section 2.0—Examination Criteria

General Requirements

2.01 The content of the written and performance examinations for certification as a Shotcrete Nozzleman is derived from:

- "Craftsman Workbook for ACI Certification of Shotcrete Nozzleman CP-60(09)"

2.02 All written and performance examinations are closed book. Notes or other technical materials shall not be permitted in the examination area.

2.03 The examinations shall be conducted by the examiner, proctors, and/or supplemental examiners as applicable (refer to Section 6).

2.04 The examiners, proctors, supplemental examiners, and/or sponsoring groups do not have any jurisdiction over the content of any examination, or over the grading of the written examination.

Written Examination

2.05 The examinee will be required to pass a written examination for each type of process in which he/she wishes to be certified (wet- and/or dry-mix).

2.06 The entire written examination for either wet- or dry-mix will consist of 60 to 90 questions. The questions may be either true-false or multiple choice.

2.07 A maximum of 90 minutes shall be permitted for completion of either the wet- or dry-mix examination. The examiner may allow additional time for an oral examination.

2.08 Oral administration of the written exam shall be permitted in special cases when conducted in accordance with ACI guidelines.

2.09 A score of 75% or higher constitutes a passing grade on each written exam.

Performance Examination

2.10 The performance examination shall require the examinee to demonstrate all the essential steps involved in proper shotcrete technique, from initial preparation through placing and curing.

2.11 All examinees are required to certify with a test panel in the vertical position. The examinee may choose to also certify in the overhead position. Each shooting position in each process requires a separate performance demonstration test panel.

2.12 The test panel to be shot shall be of the minimum dimensions and edge configuration shown in drawing Sketch A, Appendix I (**www.concrete.org/Certification/pdf/scn.pdf**, page 13). The vertical test panel shall be positioned within ten (10) degrees of vertical and the overhead panel shall be positioned horizontally at approximately 2.5 m (8 ft) from grade.

2.13 Reinforcement shall be incorporated in the test panel per drawing Sketch A, Appendix I (**www.concrete.org/Certification/pdf/scn.pdf**, page 13).

2.14 The shotcrete mixture design used shall be a mixture in common use in the geographic area of the test site. The mixture for the wet-mix process may be a locally supplied ready mix or dry materials wet-mixed at the test site.

Dry mix may be prepackaged materials or bulk materials dry-batched at the test site.

Mixtures may contain accelerators. The Local Sponsoring Group shall make information available to the applicant regarding mixture design/methods and type of equipment to be used at least 1 week before conducting the performance examination.

2.15 The nozzleman is expected to verify the adequacy of the test panel form, reinforcing placement, panel support/bracing, etc., as part of the performance examination.

2.16 The nozzleman shall be supported by an adequate crew consisting of an experienced gunman or pump operator, and a nozzle helper/airlance-blowpipe operator.

2.17 All work shall be done in the direct presence of the examiner or supplemental examiner(s) as applicable in Section 6.07.

Performance Evaluation

2.18 The examinee's performance will be evaluated based on a two-part performance examination: Part I, demonstrating to the examiner or supplemental examiner the examinee's knowledge of all the items covered on the Performance Checklist; and Part II, five (5) cores will be cut from the performance demonstration test panel to evaluate soundness of shotcrete.

2.19 Grading of the Part I performance workmanship will be based on a point system as set forth on the performance checklist, with points deducted for failure to perform, or incorrect performance of various required elements.

2.20 The minimum passing grade for the Part I performance evaluation shall be 75%.

2.21 For Part II, grading of the cores is based on visually examining, measuring defects, and grading each of five (5) cores located, as shown on Sketch A, Appendix I (**www.concrete.org/Certification/pdf/scn.pdf**, page 13); grading considers various defects, such as (but not limited to) sand lenses, porosity pockets, random voids, and especially voids around reinforcing bars.

2.22 A test panel with any single core grade exceeding grade 3, or with more than two (2) of the five (5) cores having a core grade 3 will be declared a failure. Core grades shall not be averaged.

Section 3.0—Reexamination Criteria

3.01 Failure of the written examination by the criteria cited in Section 2.09 shall require reexamination.

3.02 Failure of either Part I or Part II of the performance examination shall require reexamination on the entire performance examination.

3.03 Reexamination of a performance examination on the same day as original examination will only be permitted at the examiner's option and on a time-and-materials-available basis, subject to processing all other scheduled examinees.

In the event of equipment malfunction during shooting of a test panel, the examinee is permitted to wash out said panel and start over.

3.04 The performance exam for the vertical test panel must be passed for certification to be issued (refer to Section 2.11). If an examinee pursues certification in the overhead position as well and fails the performance exam for the vertical test panel, the entire performance exam must be retaken, including (if still desired) the performance exam for the overhead panel.

3.05 Reexamination on the written or the performance examination must be taken within 1 year of the initial examination. Otherwise, both the written and the performance examinations must be retaken in their entirety.

Section 4.0—Appeals Criteria

4.01 All appeals shall be directed initially to the examiner.

4.02 In the event that the examinee is not satisfied with the decision of the examiner regarding an appeal, the examinee may pursue an appeal with ACI according to the following order:

1. Local Sponsoring Group;
2. ACI Director of Certification;
3. The Certification Appeals Committee (consisting of the Director of Certification, the Chair of the Certification Programs Committee, and the Chair of Committee C660);
4. Committee C660, Shotcrete Nozzleman Certification; and
5. The Certification Programs Committee.

4.03 Appeals submitted to ACI for consideration must be received, in writing, within sixty (60) days of the receipt of the examination at ACI Headquarters.

Section 5.0—Sponsoring Group Criteria

Groups desiring to conduct ACI Certification program(s) shall adhere to the current policy on **Sponsoring Groups for Certification**.

Note: The Sponsoring Group Policy was approved by the ACI Board of Direction on March 21, 1991, and revised by the ACI Certification Programs Committee October 18, 2011.

Because of specialized venue and equipment requirements, Shotcrete Nozzleman Certification examination sessions are typically conducted as "in-house" sessions. The business, organization, or individual providing the venue (and equipment) for the session is known as the "host" for the purposes of this Policy.

For the Shotcrete Nozzleman Certification program (both wet and dry processes), Sponsoring Groups shall also be responsible for the following:

5.01 Ensure that the ACI Host Relationship Disclosure form is signed and completed by the scheduled examiner, and that the relationship between the host and examiner does not constitute a conflict of interest.

5.02 Ensure that the required work experience for each applicant is documented on an ACI work experience form, that the examiner has verified the experience, and that all required signatures are present on the form prior to ordering session materials from ACI.

Note: The 500 hours of work experience prerequisite documentation is not required if proof of participation in a previous ACI Shotcrete Nozzleman Certification session is demonstrated.

5.03 Ensure that a copy of all applicants' work experience forms and the ACI Host Relationship Disclosure form is provided to ACI.

Section 6.0—Examiner/Supplemental Examiner Criteria

6.01 The examiner shall be approved by ACI with the assistance of a Task Group under Committee C660 for dry- and/or wet-mix shotcrete. Qualifications shall be submitted on Form D3 for each process.

6.02 The examiner shall be authorized by ACI to conduct Nozzleman Certification examinations for only the shotcrete process for which the examiner is approved.

6.03 In order to be considered for approval as an examiner, the applicant shall meet the following requirements:

a) Be knowledgeable about shotcrete and thoroughly familiar with the current applicable reference documents.

b) Have a total of at least 5 years of documented experience in at least two of the following four categories:
1. Testing, inspection, and quality control of shotcrete;
2. Supervision of shotcrete construction work;
3. Design of shotcrete structures; or
4. Shotcrete nozzling.

c) Have sufficient experience to evaluate and judge the qualifications of shotcrete nozzleman applicants and conduct written and performance examinations. For each process, this experience must be, but is not limited to:
- Knowledge of both vertical and overhead spraying; and
- Knowledge and experience on more than one type of equipment (gun, pump, nozzle).

d) Have, to the satisfaction of the examiners of record, participated in all phases of at least two (2) ACI-sanctioned Nozzleman Certification programs for each process for which approval is sought, with different examiners of record for each session. For the first session, the applicant must serve as proctor and supplemental examiner. For the second session, the applicant shall serve as a proctor and supplemental examiner and conduct all phases of the session, including written examination, performance examination, and core grading, under direct supervision of the examiner of record for both vertical and overhead.

e) Have attained a passing grade on the written exam for each process sought.

6.04 In order to maintain examiner status, an examiner shall meet the following requirements:

a) Have conducted or assisted in at least (3) ACI-sanctioned Nozzleman Certification programs in five (5) years, if not actively participating in Committee C660 activities.

6.05 Examiners, Supplemental Examiners, and Proctors must recuse themselves from any conflict-of-interest situation while acting as agents of ACI in conducting exam sessions. This includes but is not limited to meeting the following conditions:

a) Examiners, supplemental examiners, and proctors shall not be professionally or personally related to the Host, its parent or subsidiaries, or examinees at the time of the exam session.

b) Examiners and supplemental examiners shall not be employed by the same organization (including parent or subsidiaries) as any of the examinees at the time of the exam session.

c) Examiners, supplemental examiners, and their employers shall not be in a business relationship with the Host, its parent, or any subsidiaries at the time of the exam session.

d) Examiners, supplemental examiners, and their employers shall not be in a business relationship on any project that the Host, its parent, or any subsidiaries have a business relationship at the time of, and six (6) months prior to, the exam session.

Note: ACI policies are intended to aid in the identification and remediation of any aspect of the examination process that could result in invalidation of an exam session and sanction of an Examiner. It is not possible to enumerate or even identify all conflict-of-interest situations for listing in this policy; therefore, ACI urges Examiners and Sponsoring Groups to communicate with ACI during the session planning stages and obtain guidance from ACI, leaving enough time for adjustments prior to the exam session if needed to assure policy compliance.

6.06 Supplemental examiners shall have experience in shotcrete work per Paragraph 6.03B, and shall be approved by and perform at the direction of the examiner.

6.07 Supplemental examiners shall be permitted to assist in conducting Part I of the performance examination.

6.08 Proctors shall be permitted to assist the examiner in conducting the written examination.

6.09 Proctors shall satisfy the following requirements:
- a) Be selected by the examiner; and
- b) Be considered trustworthy and conscientious by the examiner.

6.10 The examiner shall be directly responsible to:
- a) Complete and submit to the Sponsoring Group prior to the session a signed and completed ACI Host Relationship Disclosure form.
- b) Review and verify each applicant's work experience. Verification requires the completion of two steps:
  1. Review each applicant's work experience submitted on an ACI form for completeness and feasibility (that is, it is possible for the applicant to have accumulated the required experience within the time frame reflected on the Work Experience Form).
  2. Contact and speak directly with the applicant prior to approving/signing the applicant's Work Experience Form; this may be by phone if the applicant's identity can be verified, or in person. The complete content and length of the Examiner's interview with the applicant is left to the Examiner's judgment and discretion in deciding if, in their opinion, the applicant possesses the required minimum amount of work experience. Every applicant interview must include the following:
     - Verification of the applicant's identity;
     - Discussion of any items on the applicant's Work Experience Form that seems incomplete, questionable, or require clarification; and
     - Discussion of the applicant's nozzleman experience, including how long they have been a nozzleman, the type of work they have been involved in, and the type of equipment they have used.

  Once assured of the accuracy of the information on the applicant's Work Experience submission and that a minimum of hours (as per Section 1.03) as a nozzleman has been demonstrated, the Examiner must sign and date the applicant's ACI-approved work experience form and return a signed copy to the Sponsoring Group prior to the certification session.
- c) Select the supplemental examiners and proctors.
- d) Verify the qualifications of the supplemental examiners and proctors according to the criteria outlined in Sections 6.07 through 6.10.
- e) Communicate examination needs to the Sponsoring Group.
- f) Verify the identity of each examinee at the session (photo ID), and assure that the examinees are aware of the certification criteria. In addition, a photo must be secured of each participant (face shot) at the session.
- g) Verify that the examinees have signed the release statement on the written and performance examinations at the session prior to testing.
- h) Verify that materials, mixture designs, and equipment are suitable for the program.
- i) Verify that the test panel conforms to Appendix I, Sketch A (**www.concrete.org/Certification/pdf/scn.pdf**, page 13), and verify the reinforcing bar location (to ensure accurate locations for later coring).
- j) Verify that test panels are secured to minimize vibration and prevent tipping or collapse.

  Note: Appendix III (***www.concrete.org/Certification/pdf/scn.pdf****, page 15*) *of this Policy contains approximate weight and force parameters and an example of a configuration that has been used successfully. Overhead applications deserve particular attention due to the weights involved and the potential for "dropouts" (in-place shotcrete falling out during or immediately after shooting). All ACI Shotcrete Nozzleman certification sessions shall comply with all applicable Federal, Regional, and Local safety regulations.*
- k) Be present and in full supervision during the examination sessions (written and performance).

  Note: Historical administrative experience indicates that a ratio of 1:5 Examiners/Supplemental Examiners to Examinees is advised to facilitate Examiner control of sessions. Examiners may exceed this ratio if the program policies are maintained throughout the duration of the examination session, and the order, fairness, objectivity, and thoroughness of the process intended by the policies are preserved.
- l) Ensure that neither they nor their examiner candidates and/or supplemental examiners individually observe more than one examinee conducting tests at any one time during the performance examination.
- m) Verify that the performance evaluations were conducted by examiners or by approved supplemental examiners, review and co-sign the performance checklists where appropriate.
- n) Arrange for removal and positive identification of cores from test panels.

  Note: All panels are to be cored, even if the examinee fails other parts of the performance exam.
- o) Perform or direct the layout of core locations.
- p) Be present and in full supervision of panel stripping and coring. Photograph the back of the stripped panel prior to coring.
- q) Visually examine and grade cores. Photograph all extracted cores that reflect the performance of the examinee and take individual photos of cores with failing core grades.
- r) Collect and summarize all test data (complete and sign the Performance Checklist - Part II, Grading Summary, and Checklist Report for each examinee) and collate with written examinations.
- s) Forward all test data to the Sponsoring Group for preparation and shipment to ACI Headquarters, Certification Department.

t) Conduct detailed interviews of examiner applicants assisting in administering sessions, evaluating their abilities in administering examinations, and forwarding the results of their evaluation to ACI Headquarters with the session materials.

Section 7.0—ACI Duties and Responsibilities

7.01 ACI shall approve the local sponsoring group.
7.02 ACI shall approve the examiner. Examiner reapproval is required every five (5) years.
7.03 Examiner approval may be suspended or revoked by ACI at any time.
7.04 ACI shall authorize the sponsoring group to conduct examination sessions for Shotcrete Nozzleman Certification.
7.05 ACI shall grade the written examinations and review the results of the performance examination/evaluations, and notify the examinee and examiner of the final results in writing.
7.06 ACI shall certify the examinees that have satisfied the certification requirements.
7.07 ACI shall issue a certificate, wallet card, and hard-hat decal to successful examinees.

Section 8.0—Recertification

Shotcrete Nozzlemen may recertify for an additional five (5)-year period by successful completion of all the certification requirements outlined in Sections 1.0, 2.0, and 3.0 of this policy or, if eligible, by participating in the alternative recertification process as follows:

8.01 The recertification process described in Sections 8.02 to 8.03 is available only to candidates who meet the following criteria:
- a) Nozzlemen previously certified by ACI who are seeking recertification in the same process (wet- or dry-mix) as their previous ACI-issued certification; and
- b) Nozzlemen participating in recertification within 6 years of their previous ACI-issued certification; and
- c) Nozzlemen possessing at least 1000 hours of work experience as a shotcrete nozzleman within the two (2) years immediately prior to seeking recertification or possessing an average of 500 hours per year within the five (5) years immediately prior to seeking recertification.

8.02 Information described in Sections 8.01a through 8.01c required for determination of candidate eligibility for recertification shall be gathered, evaluated, and verified by the examiner prior to administration of any recertification examination, as described in Sections 8.03a and 8.03b.

8.03 Candidates who meet the criteria listed in Section 8.01 as determined by the Examiner may renew their certification (recertify) by successfully completing:
- a) A structured interview with the Examiner. The interview is in lieu of the written exam requirement imposed for initial certification and is designed to substantiate that the candidate has retained his knowledge of the safe and competent application of shotcrete and is made aware of any new developments in this area of concrete construction; and
- b) A performance examination per the policies described in Sections 2.01 through 2.04, Sections 2.10 through 2.22, and Sections 3.02 through 3.04.

8.04 The oral interview must be conducted within the time frame described in Section 8.01b. If the interview is not conducted within this time frame, the candidate seeking recertification shall be required to take the written examination per the policies described in Sections 2.05 through 2.09, and Sections 3.01 and 3.05.

CALL FOR TOPICS

Shotcrete magazine welcomes topic suggestions for the “Nozzleman Knowledge,” “Technical Tip,” and “Safety Shooter” columns, especially from our **nozzlemen** readers. These columns, in particular, are designed to serve ASA’s nozzlemen members and bring helpful information not readily available in the industry. If you would like to submit a topic or question for an article, please send an e-mail to info@shotcrete.org or call (248) 848-3780. ASA staff and the Publications Committee will do their best to secure an author to address your concerns. Annual compilations of these columns are available as a member benefit for ASA’s nozzlemen members.

Underground Shotcrete Roof Repair of Hanging Lake Tunnel

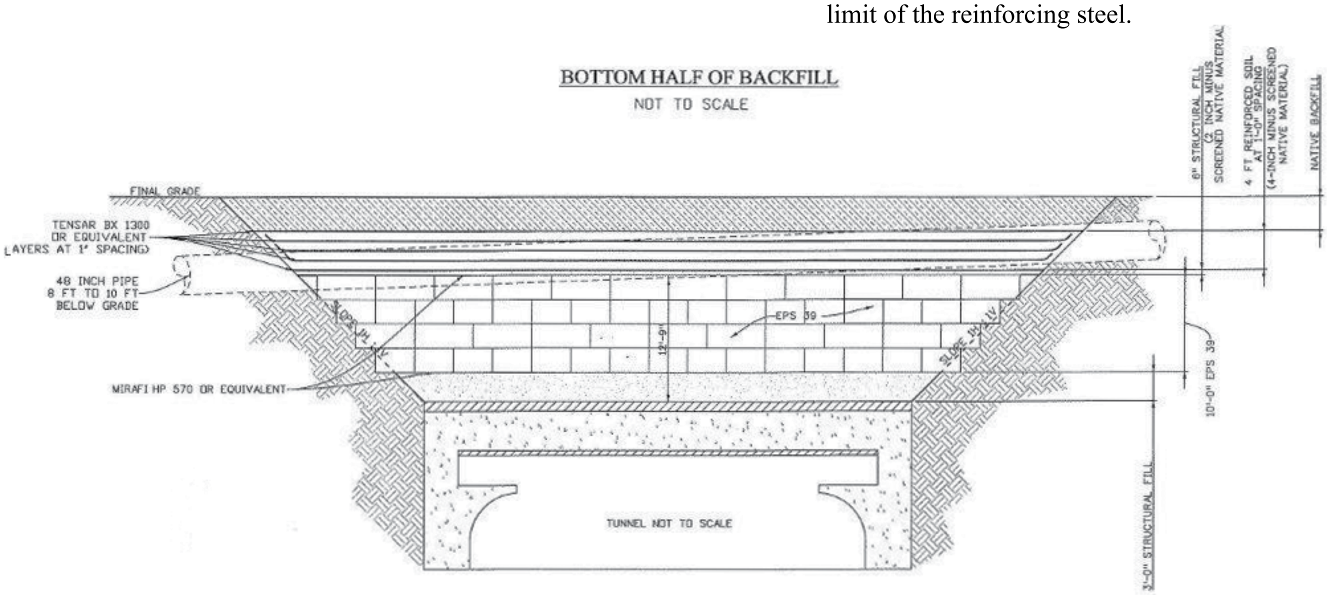
By Warren Harrison

During a Federal Highway Administration annual safety inspection in March 2007, a crack was found in the flat roof portion of the cut and cover section of the Hanging Lake Tunnels along Interstate 70 in Glenwood Springs, CO. The crack—an end shear failure—was discovered in the roof section of the eastbound tunnel only. The total displacement was 2 in. (50 mm) and moving.

The apparent cause of the failure was a rock fall in January 2002 that overstressed the open cut portion of the tunnel, adding 35 ft (10.6 m) of surcharge on top of the existing fill over the tunnel. The eastbound tunnel was immediately shut down after the crack was discovered, and the cracked roof section was temporarily supported with steel columns and heavy steel crossbeams to stop the failure. The roof displacement was monitored and stabilized by the steel sets. The total design, stabilization, excavation, and repair time was 6 months, with the eastbound tunnel reopening in November 2007.

Crack in roof

Dana Christensen, a Colorado Department of Engineering regional engineer, designed the repair. First, the excess rock and soil and the original backfill would be removed. The open cut tunnel portion was not accessible by road but was adjacent to the mainline Union Pacific Railroad track through Glenwood Canyon, making the removal process difficult. Concrete Works of Colorado, the excavation and support contractor, had to bring all equipment in by rail and use railcars to remove all of the material. The removal took several weeks, as there was limited availability of gondola cars to move the debris out due to the railroad's mainline schedules. With the removal of the rock and soil, the crack in the roof closed, as the loading did not exceed the plastic limit of the reinforcing steel.



Tunnel section showing final backfill with expanded polystyrene fill to reduce load

The design fix to the existing 4 x 40 x 105 ft (1.2 x 12 x 32 m) slab included drilling and placing 980 vertical No. 7 (No. 22) hook bars through the slab connecting an upper and lower mat of No. 10 (No. 32) reinforcing bar. The lower mat was encased with overhead shotcrete 6 in. (150 mm) thick and a top slab 18 in. (450 mm) thick poured in place. The overhead shotcrete was shot with no accelerator and encased the No. 10 (No. 32) bars. For convenience and splicing needs, the No. 7 (No. 22) bar was Grade 75 Dywidag threadbar.

The mixture was supplied and delivered by Casey Concrete from Carbondale, CO, with the materials in the design shown in Tables 1 through 4.

The mixture included fly ash to mitigate alkali-silica reactions.

The surface was prepared with sandblasting to a rough surface to aid in the bonding of the shotcrete to the bottom of the existing roof. After sandblasting, the roof was power-washed to predampen and clean the surface. The concrete was pumped with a Reed 4050 pump using a slump of 1 to 2 in. (25 to 50 mm) to aid in the attachment to the roof.

The final backfill over the tunnel included a thick layer of expanded geo foam to reduce the dead loading for the beam.

Table 1: Concrete Mixture Materials

Material	Source
Cement	Holcim Type I/II MA
Fly ash	San Juan Class F
Silica fume	Rheomac SF100
Fine aggregate	Mountain Aggregates, Casey Concrete
Coarse aggregate	Mountain Aggregates, Casey Concrete
Admixtures	BASF Rheobuild 1000, Micro Air, Delvo, Polyheed 997

Table 2: Mixture Proportions per 1.01 yd³ (0.77 m³)

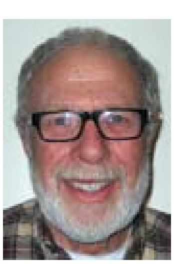
Material	Quantity
Cement, lb (kg)	660 (299)
Fly ash, lb (kg)	60 (27)
Silica fume, lb (kg)	60 (27)
WRA, oz (L)	94 (2.8)
Polyheed, oz (L)	36 (1.1)
AEA (micro air)	As needed
Retarder, oz (L)	30 (0.9)
Fine aggregate, lb (kg)	2040 (925)
Coarse aggregate, lb (kg)	560 (254)
Water, lb (kg)	341 (154)

Table 3: Physical Properties of Concrete

Property	Results
Unit weight of mixed concrete (ASTM C138), lb/ft³ (g/cm³)	136.0 (2.18)
Slump (ASTM C143), in. (mm)	3 (76)
Air content (ASTM C231, pressure method), %	7.20
Water-cementitious material ratio (*w/cm*)	0.44
Temperature (ASTM C1064), °F (°C)	72 (22)
Relative yield, yd³ (m³)	1.02 (0.78)

Table 4: Compressive Strengths in psi (MPa)

7 days	28 days
4700 (32.4)	7520 (51.8)
4810 (33.2)	7680 (53)
4750 (32.8)	7740 (53.4)
Average	
4750 (32.8)	7650 (52.7)



__Warren Harrison__, PE, is the President of WLH Construction Company in Denver, CO, specializing in shotcrete, soil nailing, grouting, and concrete repair. He is currently serving as a member of ACI Committee 506, Shotcrete, and is a previous Board member of ASA. A graduate of the Colorado School of Mines with an MBA from the University of Colorado at Denver, Harrison has worked on projects from Kodiak, Alaska, to Tiberius, Israel, and many places in-between.

Shotcrete: Old Specifications and Misconceptions

By Ted W. Sofis

One of the greatest advantages of using shotcrete is that shotcrete can be placed on vertical and overhead surfaces without the need for forming. In the 1980s, we performed large quantities of spall repair on several bridges where the repairs were specified for cast-in-place concrete. The additional costs of forming cost us approximately 30% more than a shotcrete repair. Unfortunately, the perception (at the time) was that a shotcrete repair was inferior to a cast-in-place repair. Today, we have better shotcrete materials and equipment; an association—ASA—that promotes good practices and education; and a growing acceptance, appreciation, and understanding of shotcrete's advantages.

Many of the old shotcrete specifications called for the material to be placed with multiple layers of 2 x 2 in. (50 x 50 mm) welded-wire reinforcement. Again, the specification was based on inaccurate information. Shotcrete was being treated as merely a cosmetic surface repair and crews were not aware that the material could and should be gunned to the full depth of the repair. The specification itself presented a problem. By specifying multiple layers of 2 x 2 in. (50 x 50 mm) mesh, a situation was created that would cause honeycombing when attempting to gun to the full depth. Such a specification was based on the misconception that shotcrete should be placed in 3 in. (75 mm) lifts, as would be done with hand-troweled repair mortar.

On this slope protection project, the dry-process shotcrete material is gunned to the full necessary depth in one pass

That brings us to the essence of the issue: shotcrete is concrete. It's just placed in different methods—pneumatically in the dry process with water added at the nozzle and by pumping in the wet process with air added at the nozzle. In pouring a cast-in-place repair, no one would require it to be done in layers. Shotcrete is no different. Make sure your specifications are up to date and remember to treat shotcrete as you would treat a conventional cast-in-place concrete repair. Get behind the first layer of reinforcing bar whenever possible, avoid laminations, and gun the repair to full depth, if at all possible. In deep repairs, use reinforcing bars with appropriate spacing and avoid multiple layers of mesh. A monolithic repair will provide a better result. This is especially important in refractory installations, where laminations create points of failure in heatups and cooldowns. The same can be said about infrastructure projects where laminations create the same issues with freezing-and-thawing cycles. In short, a repair gunned to the full depth is desirable whenever possible.

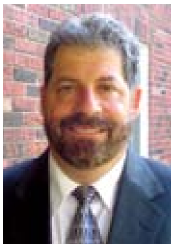
Shotcrete provides many varied solutions to installation problems. We need to take advantage of this placement method and the technology involved to reduce costs, increase productivity, and improve the quality and durability of the installations. The world is rapidly changing and the construction industry is becoming more and more competitive. Therefore, it is imperative that we continue to look for and take advantage of better and more cost-effective ways to perform our work in both repair applications and new construction.

The deteriorated concrete on this bridge pier is removed to behind the first layer of reinforcing bar to allow the shotcrete to fully encapsulate the reinforcing bar

The shotcrete placement on this bridge pier is gunned to the full depth in one continuous pass. It is better to avoid gunning in layers whenever possible

The dry-process shotcrete in this tunnel reline is gunned overhead to the full desired depth without layers

In this power plant ash hopper, the refractory, on the left, is gunned to the full 9 in. (229 mm) depth in one application. The ungunned area with the "V"-type refractory anchors is to the right



__Ted W. Sofis__ and his brother, William J. Sofis Jr., are the Principal Owners of Sofis Company, Inc. After graduating from Muskingum College, New Concord, OH, with a BA in 1975, Ted began working full time as a shotcrete nozzleman and operator servicing the steel industry. He began managing Sofis Company, Inc., in 1984 and has over 34 years of experience in the shotcrete industry. He is the Treasurer for ASA, Chair of the ASA Publications Committee, and a member of multiple ASA committees. Over the years, Sofis Company, Inc., has been involved in bridge, dam, and slope projects using shotcrete and refractory installations in power plants and steel mills. Sofis Company, Inc., is a member of the Pittsburgh Section of the American Society of Highway Engineers (ASHE) and ASA.

Air Content in Shotcrete: As-Shot Versus As-Batched

By Lihe (John) Zhang

Air-entraining admixtures are added to shotcrete primarily for durability considerations. Freezing-and-thawing resistance is improved by air entrainment.[1-3] It is widely recognized in the shotcrete industry that the air content of the as-batched shotcrete will drop during the shooting process. This is due to the fact that the shotcrete process tends to "knock out" air from the mixture and thus reduce the air content of the in-place shotcrete. The air content in the in-place shotcrete is typically below 6%, regardless of how high the as-batched air content was before shooting. Testing for air content in the hardened shotcrete can be conducted by air voids analysis using the ASTM C457 test procedure. This test is time-consuming and expensive, however, and is thus not often used as a quality control test. Thus, the challenge is to establish the basic criteria for the air content in the in-place shotcrete. This article discusses the requirements for the air content in the shotcrete mixture, both before and after being applied, and then tries to answer a simple question: Do we need to test the air content both before and after shooting?

Measuring the Air Content

An air meter is used to measure the air content of the plastic shotcrete or concrete. Air content measured at the point of discharge from the truck or at the end of the pump hose is referred to as **as-batched air content** (Fig. 1). Air content measured by shooting directly into the air meter base or shot against a wall into a wheelbarrow or even into a basket and then scraped out to fill the air meter is called **as-shot air content**. Sometimes, the terminology of "air content at nozzle" is also used (erroneously) for the as-shot air content.

When an accelerator is used, it can be very difficult to measure the as-shot air content. Shotcrete can reach the initial set in as quickly as 5 minutes or less, and it may not be possible to scrape and fill up the air meter base and conduct the air content test while the shotcrete is still plastic. It is, however, possible to shoot into the air meter base and fill it up, then trim the surface and test for air content within a few minutes. After the test, shotcrete will soon set inside the air meter if it is not cleaned immediately. Therefore, only very experienced testing technicians can handle this type of air content testing without damaging the air meter.

Shotcrete Mixture Design Considerations

A typical air-entrained shotcrete mixture design will have an as-batched air content of 7 to 10% and an as-shot air content of about 3 to 5%. Thus, it is important that the yield calculation in the mixture design use the as-shot air content and not the as-batched air content. Otherwise, the shotcrete supplied will under-yield—that is, the shotcrete contractor will effectively get less material than ordered.

High As-Batched Air Content and Slump-Killer Effect

It is well-recognized in the shotcrete industry that high initial air content in the as-batched shotcrete will increase slump.[4] Considering that the cost of an air-entraining agent (AEA) is much lower than that of high-range water-reducing admixtures, it is typically more economical to add more AEA to increase the slump of the mixture while reducing—but not replacing—the quantity of high-range water-reducing admixtures. As the shotcrete impacts on the wall, about half of the air content is lost and the slump on the wall goes down instantaneously because slump is directly related to air content. This so-called "slump-killer" effect is very beneficial to the shotcrete process. Shotcrete has high slump at discharge into the pump, which makes it easier to pump without blockages and facilitates a good uniform accelerator addition at the nozzle. The instantaneous loss of slump on the wall is good for improved adhesion and thickness of shotcrete buildup without sagging and sloughing.

In some situations, however, such as certain underground shotcrete applications, the "slump-killer" effect has to be used with caution. In some underground mines or tunnels, shotcrete is supplied to an underground remixer unit through a vertical drop pipe, which can range in length from a few hundred meters to a few thousand meters. The impact at the bottom of the drop pipe tends to knock out about half of the air content from the mixture. This results in the "slump-killer" effect taking place at the wrong location, resulting in too stiff (low slump) a mixture in the remixer unit. Therefore, when a drop pipe is used, it is not recommended to add an AEA to the mixture.

It is also found that in underground shotcrete applications, if the transmixer transportation and delivery is a long-haul process, this might cause a substantial increase in air content when the shotcrete arrives at the application site. Air content could increase to up to 14% or even higher. This will make it difficult to pump the "spongy" shotcrete. It is the author's experience that removal of the air-entraining admixture from the shotcrete mixture design is desirable for underground shotcrete applications. Admixture suppliers have products that can reduce the microair introduced by the AEA, but it is more economical not to use an AEA. Actually, the data in the following project examples show that even without an AEA—by adding a high-range water-reducing admixture **only**—the air content can increase up to 4 to 6% during transportation.

Project Example 1: Testing Air Content during Shotcrete Operations in an Aboveground Application

In one trial mix shooting project, we examined the combined effects of a high-range water-reducing admixture, hydration control admixture, air-entraining admixture, and accelerator on the air content of wet-mix shotcrete. The shotcrete mixture design had an as-batched air content of 7 to 10% and an as-shot air content of 3 to 5%. The as-batched air content was tested at the point of discharge from the concrete truck and at the end of the pump hose. The as-shot air content was tested by shooting into the air meter base and shooting onto a vertical wall made with plywood. It was then scraped off to fill the air meter. The results are listed in Table 1.

When an AEA was added, the as-batched air content went up to 18%. The test results show that the air content at the end of the pump hose is only slightly lower than the air content at the discharge from the truck.

The as-shot air content ranges from 2.5 to 3.1% for the air content tested by shooting directly into the air meter base and ranges from 4.0 to 4.5% when tested by shooting onto a vertical wall and then scraped off to fill the air meter base. It should be noted that when an AEA was used, the air content at the pump was as high as 18%. The as-shot content was 5% when shooting into the air meter base and 5.4% when shooting to the wall and tested in the air meter. This shows that even the high as-batched air content results in less than 5.5% as-shot air content.

When a nonalkali accelerator is added at 8% by mass of cement, the air content does not vary greatly from mixtures without an accelerator. It should also be noted that the addition of a hydration control admixture does not affect either the as-batched or as-shot air content in the non-air-entrained shotcrete mixtures.

Project Example 2: Testing Air Content for an Underground Shotcrete Application

For underground applications, shotcrete is agitated in a transmixer during transportation. With a hydration control admixture, this process

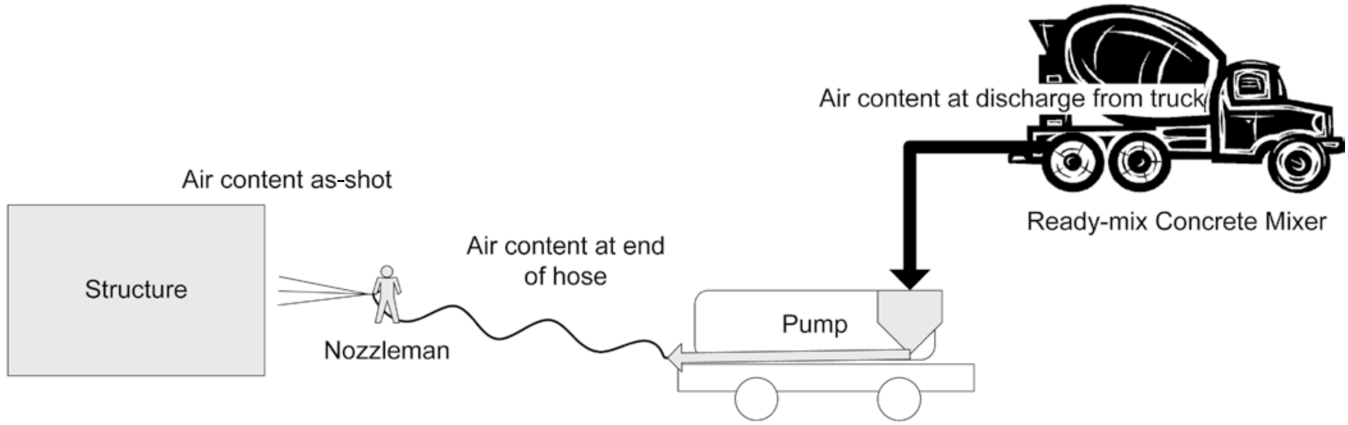


Fig. 1: Sketch of shotcrete process and air content measurement

Table 1: As-Batched Versus As-Shot Air Content for a Trial Shotcrete Project

Material	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Water, L/m^3 (gal./yd^3)	185 (37)	185 (37)	185 (37)	185 (37)	185 (37)
HRWRA, ml	Used as per supplier's recommendation for 175 mm (6.9 in.) slump				
Hydration control admixture, ml	Added to extend set time to 4 hours	None	Added to extend set time to 4 hours	None	None
Air-entraining admixture, ml	None	None	None	Added	None
Accelerator, ml	8% by mass of cement		None	None	None
Slump, mm (in.) at truck	140 (5.5)	90 (3.5)	175 (6.9)	175 (6.9)	220 (8.7)
Slump, mm (in.) at pump hose (no compressed air)	125 (4.9)	75 (3.0)	145 (5.7)	125 (4.9)	220 (8.7)
Air content: before shooting, at truck, %	5.2	5.5	8.0	18.0	9.0
Air content: before shooting, at pump hose discharge, %	4.5	4.6	Not available	18.0	8.5
Air content: after shooting into air meter, %	2.7	3.0	2.5	5.0	3.1
After shooting onto vertical wall, %	4.2	4.0	Not available	5.4	4.5

could last for as long as 72 hours. The air content was tested at discharge from the truck, discharge from the transmixer, and as shot by shooting into the air meter base. Figure 2 shows a sketch of the underground wet-mix shotcrete production, delivery, and application.

Table 2 lists the test results for the as-batched and as-shot air content. It shows that when an AEA is added, the as-batched air content ranges from 9.3 to 12%. After shooting, the as-shot air content ranges from 3.4 to 5.3%. This shows that the as-shot air content is further reduced to less than 5.5%. When no AEA is added, the as-batched air content ranges from 4.1 to 4.3% and the as-shot air content ranges from 1.3 to 3.8%. When a nonalkali accelerator is added at dosages ranging from 4, 6, and 8% by mass of cement, this does not change the as-shot air content significantly.

During the underground shotcrete application, it was noted that when shotcrete was delivered by a transmixer with agitated rotation (for example, 7 rpm agitation for over 2 hours), the air content increased from 11 to 14.5%. This high air content was a concern for pumping, as discussed in the high as-batched air content and slump-killer effect section. Therefore, it is recommended that when long-distance hauling and transportation in a transmixer is required, an AEA should not be used.

Discussion

The two studies reported show that:

1. The as-shot air content is always below 5.5%, regardless of the as-batched air content. Due to the high-velocity impact caused by the shotcreting process, air is driven out of the in-place shotcrete. It should be noted, however, that when an AEA is added, the as-shot air content is always higher than the as-shot air content in a mixture made without an AEA.
2. The as-shot air content tested from the materials scraped from the wall is typically about 1.0 to 1.5% higher than the air content tested from shooting and filling up the air meter base.
3. The use of high as-batched air content with the associated "slump-killer" effect is beneficial to shotcrete pumping and shooting. For underground applications, however, a high as-batched air content might cause pumping problems and the "slump-killer" effect might occur in the wrong place (for example, when a drop line is used). Therefore, it is not recommended to add an AEA for underground appli-

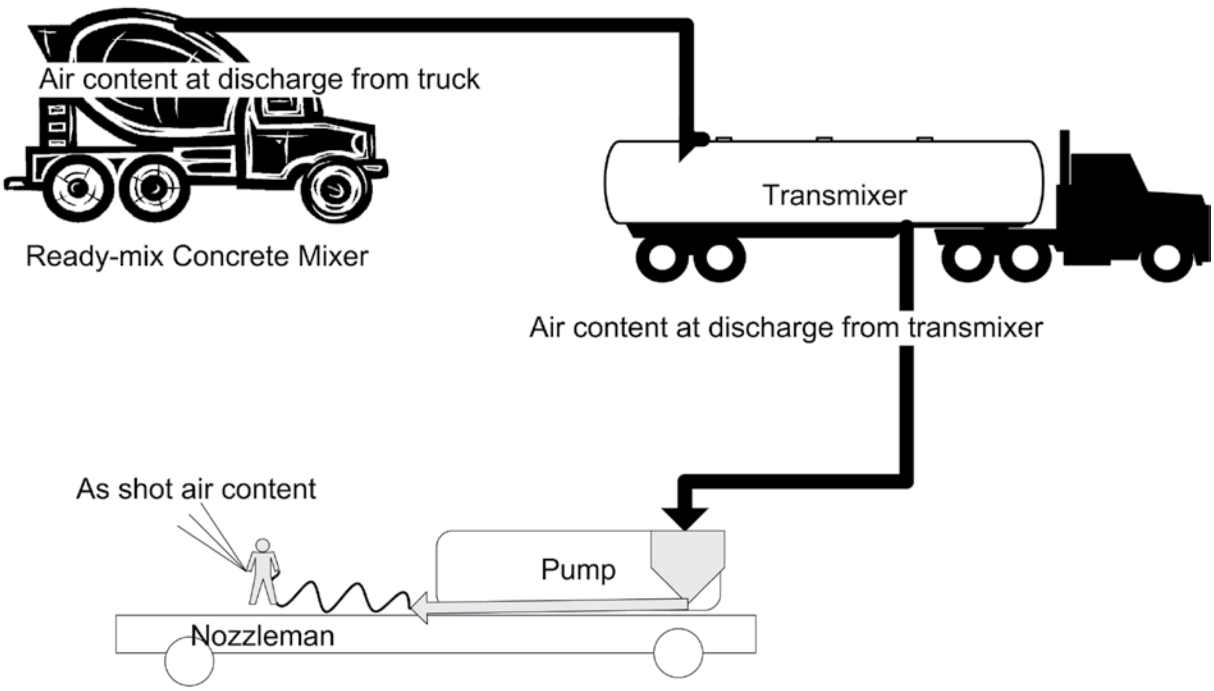


Fig. 2: Sketch of underground shotcrete transportation and application

Table 2: As-Batched Versus As-Shot Air Content for an Underground Shotcrete Project

Material	1	2	3	4	5	6	7	8	9
Water, L/m³ (gal./yd³)	185 (37)	185 (37)	185 (37)	185 (37)	185 (37)	185 (37)	185 (37)	185 (37)	185 (37)
HRWRA, L/m³ (gal./yd³)	1.0 (0.2)	1.0 (0.2)	1.0 (0.2)	1.0 (0.2)	1.0 (0.2)	1.0 (0.2)	1.0 (0.2)	1.0 (0.2)	1.0 (0.2)
Hydration control admixture, L/m³ (gal./yd³)	1.5 (0.3)	1.5 (0.3)	1.5 (0.3)	4.0 (0.81)	4.0 (0.81)	4.0 (0.81)	4.0 (0.81)	4.0 (0.81)	4.0 (0.81)
Air-entraining admixture, L/m³ (gal./yd³)	2 (0.4)	2 (0.4)	2 (0.4)	None					
Accelerator, 0%, 4%, 6% and 8% (by mass of cement)	6	6	6	0	4	6	8	4	6
Slump, mm (in.) at truck	150 (6.0)	275 (10.9)	175 (6.9)	225 (8.9)	225 (8.9)	225 (8.9)	225 (8.9)	125 (4.9)	125 (4.9)
Air content: before shooting, at truck, %	12	11	9.3	4.1	4.1	4.1	4.1	4.3	4.3
Air content: before shooting, at transmixer, %	—	14.5	—	—	—	—	—	—	—
Air content: after shooting to air meter, %	3.4	4.5	5.3	3.0	1.6	1.3	2.3	3.8	3.8

cation, unless there is special consideration (for example, where freezing-and-thawing conditions prevail).

4. The results of the as-batched air content tested at discharge from the truck are very close to the air content tested at the end of the pump hose (before shotcreting). Therefore, it is recommended that the as-batched air content be tested **only** at the point of discharge from the truck.
5. Certain brands of high-range water-reducing admixtures can increase the air content. Depending on the dosage of high-range water-

reducing admixture being added, the as-batched air content can increase by up to 6% or even higher without any AEA being added to the mixture.

6. The addition of a hydration-controlling admixture does not appear to have any significant effect on air content.

Do We Need to Test As-Shot Air Content?

As with conventional concrete, the air content of the as-batched shotcrete at the point of discharge from the truck should be tested as part of the regular quality control operations. In addition, given that a considerable amount of air is "knocked out" of the mixture during the shooting process, it is recommended that for any given mixture and supply/application scenario, a correlation be established between the as-batched and as-shot air contents. If testing shows this correlation to be consistent, testing of the as-shot air contents need only be conducted if there is a change in any of the shotcrete ingredients or proportions or a change in the supply/transportation/application methods or duration.

References

1. Vezina, D., and Bertrand, J., "The Development of Air Entrained Durable Shotcrete for Structural Repairs," *Proceedings, Shotcrete for Underground Support VII*, Telfs, Austria, June 11-15, 1994.

2. Seegebrecht, G. W.; Litvin, A.; and Gebler, S. H., "Durability of Dry-Mix Shotcrete," *Shotcrete*, V. 8, No. 2, Spring 2006, pp. 32-35.

3. Dufour, J. F., "Can Dry-Mix Shotcrete Be Air Entrained?" *Shotcrete*, V. 10, No. 4, Fall 2008, pp. 28-30.

4. Jolin, M., and Beaupre, D., "Temporary Initial High Air Content Wet Process Shotcrete," *Shotcrete*, V. 2, No. 1, Winter 2000, pp. 22-23.

Acknowledgement

This paper was reviewed by Dr. D.R. (Rusty) Morgan, Charles Hanskat, and Scott Rand. Their efforts are highly appreciated.

***Lihe (John) Zhang**, PhD, PEng, LEED AP, recently opened his own firm, LZhang Consulting and Testing Ltd. Zhang has over 10 years of experience in concrete technology and the evaluation and rehabilitation of infrastructure. He received his PhD in civil engineering from the University of British Columbia, where he conducted research on fiber-reinforced concrete. Zhang is a LEED Accredited Professional and has been involved with American Concrete Institute (ACI) Committee 130, Sustainability of Concrete. He is Chair of 506.5R Subcommittee: Underground Shotcrete; a member of ACI Committees 506, Shotcreting, and 544, Fiber-Reinforced Concrete; and ASTM Committee C09, Concrete and Concrete Aggregates. He is also Chair of the ASA Education Subcommittee: Graduate Scholarships, Co-Chair of the ASA Underground Committee, and an ASA Board member.*

Top Ten Sustainability Benefits of Shotcrete

The United States Green Concrete Council's (USGCC) book, *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 listed advantages. Previous discussion of advantages from past issues can be viewed on the ASA Web site at **www.shotcrete.org/sustainability**.

U.S. GREEN CONCRETE COUNCIL

1. Formwork savings of 50 to 100% over conventional cast-in-place construction.
2. Formwork does not have to be designed for internal pressures.
3. Complex shapes require very little—if any—formwork.
4. **Crane and other equipment savings or elimination** (see below).
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.

Crane and Other Equipment Savings or Elimination

An often overlooked sustainability benefit of the shotcrete process is one of the most basic of construction problems: the conveying and handling of materials. Because shotcrete transports material over distances efficiently, it can often eliminate the need for concrete buckets, cranes, hoists, freight elevators, motorized concrete buggies, and other costly methods of transporting cementitious materials to the desired work areas.

Shotcrete is easily conveyed directly to where it is needed, as shown in this shotcrete repair of the upper wall area of this Coke Plant Quench Tower

Shotcrete applications in both the dry- and wet-mix processes convey concrete materials over distances and propel the material directly onto the receiving surface. Shotcrete is placed under high velocity in what is essentially a sprayed installation of concrete material. These methods of transport provide us with several advantages.

On elevated structures or scaffolding, shotcrete hoses or pipe can run directly to the level where the material is needed and completely eliminate the need for cranes, hoists, concrete buckets, or other lifting equipment. The material runs through the shotcrete hose or piping in a continuous manner straight to the work area.

In industrial applications, shotcrete provides an efficient method of transporting material through man-doors or observation ports and up into boilers, vessels, and units, where double handling of materials is often necessary. The same can be said for smokestacks and ductwork, where concrete materials or refractory can be moved with shotcrete equipment, eliminating the need to use hoists or climbers, which often results in double handling of the material. One industrial project in particular, a power plant scrubber, required the contractor to load refractory brick onto a bucket, lift the materials up to a work platform, lower them down to the access door, and then hoist them up into the vessel. The handling of material multiple times could have easily been eliminated by using shotcrete.

In sewers, tunnel inverts, and underground culverts, shotcrete can be placed by feeding hoses through manhole

In boilers and other industrial structures, the only access is often through man-doors and up into the boiler or vessel. Shotcrete provides an efficient method of transporting and placing material

openings and other access points and transported long distances underground, eliminating the need for hoists and concrete buggies. On a past tunnel project some years back, the contractor set up operations on the roadway, where the distance between manholes was 600 ft (183 m). Shotcrete hoses were run horizontally in each direction to transport repair materials to each repair area. Shotcrete eliminated the need for hoists and motorized buggies and provided a more effective method of material placement.

On concrete bridges, the shotcrete material hose can be strung directly to the arch, beam, pier, or abutment where the repair material is needed without using any cranes or hoists. By using shotcrete, the placement process is simplified and, in many cases, eliminates the extra work involved in the double handling of materials.

The need for lifting equipment can be eliminated or substantially reduced anywhere a shotcrete hose can be run or shotcrete can be used for the placement of cement-based materials. Sustainability is about reducing costs in material, energy, and transportation. Moving material on site exactly to where it's needed is just one area where shotcrete always provides an advantage. Remember, shotcrete is not a product—it is a process for placing concrete. It's a method that saves time, money, and in many cases, unnecessary labor.

The shotcrete hose running up into the smokestack conveys the refractory material directly to the areas where it is sprayed in place. This can easily be accomplished without the double handling of materials that would have been necessary with the installation of refractory brick

You Need Mud? We Block It, Mix It, and Shoot It: The Prestige Story

Prestige Concrete Products is a group of leading concrete-related companies united to meet the construction industry's needs for high-quality concrete block, ready mix, and shotcrete/gunite, operating in Florida, North Carolina, Texas, and California.

The VCNA Connection

Prestige Block, Ready Mix, and Shotcrete/Gunite operations were purchased by Votorantim Cement North America (VCNA), Toronto, ON, Canada, in 2007 and became part of a select group of ready mix, cement, and aggregate companies owned by VCNA. Their nationwide affiliates include St. Mary's Cement, a manufacturer of cement, and Canada Building Materials (CBM), a ready-mixed concrete and aggregates company in the Great Lakes region, along with Prairie Material and Aggregates, a ready mix producer in Chicago and the Midwest. VCNA also owns Suwannee American Cement (SAC) in partnership with Anderson Columbia in north Florida. VCNA is a subsidiary of Votorantim Cimentos, one of the top 10 worldwide cement manufacturers, and part of the Votorantim Group, one of South America's largest privately held conglomerates based in São Paulo, Brazil.

Shotcrete application

Brand Recognition

Since the VCNA acquisition, the three Prestige companies have merged to become Prestige Concrete Products. With more than 25 locations in Florida, they also have ready mix operations in North Carolina and shotcrete/gunite crews in Texas and California. They are an emerging company with an experienced staff and dedication to product quality. Their exceptional customer service and innovation have earned them a reputation as the can-do company in every market they serve.

Prestige Concrete Block

Prestige's Concrete Block division provides some of the industry's finest standard and lightweight blocks. A new state-of-the-art plant in Groveland, FL, uses the Columbia Model 1600 Block Machine to consistently manufacture blocks that meet or exceed all ASTM International standards for strength, size, and weight.

Every Prestige-made block has a 2-hour fire rating. They can produce up to 12 million blocks a year, enough to supply the largest jobs in any market they serve. Prestige block is featured in almost every kind of construction project, including residential, commercial, municipal, educational, medical, and industrial buildings.

Prestige Ready Mix Division

As part of the VCNA family of concrete and cement companies, Prestige Ready Mix has access to the technical expertise that built many iconic buildings, such as the Trump International Tower in Chicago, IL, and the RBC Centre in Toronto, ON, Canada, which incorporate the latest in advanced performance concrete. Ownership of SAC ensures a consistent, uninterrupted flow of top-quality material to fulfill customers' needs.

Prestige's Ready Mix division provides high-quality concrete for projects in north and central Florida, as well as Greensboro and Winston-Salem, NC. Certified plant personnel, computer-aided batching, and dispatch services ensure that the customer gets the right product when they

Corporate Member Profile

need it. All Prestige ready mix yards supply concrete, block, and a complete inventory of masonry supplies. Experienced drivers deliver to the job site precisely on time. Prestige works with site managers to place the loads steps away from where masons and finish crews need it, saving valuable time (and workers' backs) over the course of the project.

Two Shotcrete Divisions

Prestige's Shotcrete/Gunite operations have delivered, placed, and finished high-quality materials to contractors throughout Florida, Texas, California, and the Caribbean on an array of construction projects over the past 25-plus years, working in the civil, repair and rehabilitation, and aquatic industries. As shotcrete technology advances in the industry, Prestige has seen its business grow and has found the need to hire and train staff to service specialized areas, thus leading to the emergence of two focused divisions.

Aquatics: Pools and Fountains

Prestige's Shotcrete/Gunite operations have shot over 100,000 pool and fountain installations for hundreds of contractors. Shotcrete/gunite pools are watertight and ideal for pool construction, especially where there are many curves incorporated in the design. The flexibility of placement allows every pool owner to have a uniquely shaped pool, and the elimination of two-sided formwork makes the project more cost-effective.

Construction: Civil, Repair, and Architectural

Shotcrete/gunite is often the best alternative for the repair and restoration of concrete for both reinforced and nonreinforced construction. The flexibility of placement, the limited need for forms, and the excellent bonding characteristics, combined with the speed of placement and finishing, make it an excellent choice for many applications, such as tanks, retaining walls, dams and reservoirs, parking garages, and highway structures. Shotcrete provides an environmental benefit as well; the customer can rehabilitate an existing structure as opposed to demolishing it, preventing it from ending up in a landfill and then having to rebuild the structure from new material. The possibilities are limitless.

The process can be demanding, however. The shotcrete professional must be able to integrate the new materials with in-place construction to form a composite bond that will stand up to exposure and use. Prestige's experienced crews have worked on a number of successful restoration and repair projects, from DOT bridge repairs to wall reinforcement for a university library. They know the material and process for getting the best results.

Prestige's expert crews are led by experienced personnel and when the specification requires, they provide ACI-certified nozzlemen on the project. Their quality control department will test and track the results of their materials to ensure consistent strengths and finishing characteristics. Prestige also offers specialty bagged products, which contain additives that increase strength, reduce cracking, and increase resistance to alkali and chemical attack.

Many architects now incorporate ornate design elements into their structures that meet new creative expectations. When it comes to these architectural elements, shotcrete has become a very viable material. Prestige has had the opportunity to place both wet and dry shotcrete onto dome structures, sculptures, and theme park features.

Whatever a customer's concrete needs require, Prestige can deliver the materials and expertise to ensure success.

Prestige Concrete Products
8529 South Park Circle, Suite 320
Orlando, Florida 32819
Contact: Paul Ampey
Phone: (561) 723-8143
E-mail: pampey@prestige-gunite.com
Web site: **www.prestigeconcreteproducts.com**

Fountainbleau Resort, Miami Beach, FL

Rosen Jewish Community Center, Orlando, FL

AMEC Named One of Canada's Top Employers for 2012

AMEC Americas Limited (**www.amec.com**), an international engineering and project management company and ASA Corporate member, has been named one of Canada's Top 100 Employers by MediaCorp Canada, the nation's largest publisher of employment periodicals and guides.

Now entering its 12th year, the national competition aims to determine which employers lead their industries in offering exceptional workplaces for their employees. This is the third year in succession that AMEC has been awarded this prestigious designation.

"We are delighted to again be recognized as a Top Employer in Canada," said Will Serle, AMEC Group Human Resources Director. "AMEC is a people business and we recognize that an investment in our people is an investment in our future. That is why we have established the AMEC Academy to support the development of both employees and AMEC."

MediaCorp editors grade each winner on nine key areas: physical workplace; work atmosphere and social; health; financial and family benefits; vacation and time off; employee communications; performance management; training and skills development; and community involvement.

Competing against a record number of employer applications, AMEC was required to complete an extensive application process that included a detailed review of operations, communications, HR practices, charitable efforts, and community involvement. Employers were compared to other organizations in their field to determine which offered the most progressive and forward-thinking programs.

In addition to being a fast-growing Canadian company that combines excellent career advancement for its employees with leading-edge employee benefits, AMEC was specifically praised for its extensive AMEC Academy, an impressive in-house training and development program designed to help employees plan their career paths and develop the necessary skills to achieve their long-term goals.

Putzmeister to Partner with GHH and Mine Master

Putzmeister (**www.putzmeister.com**) 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 headquarters of Putzmeister's Underground Concreting Division is located in Madrid, Spain. The cooperation between the companies will start with Putzmeister distributing and marketing GHH and Mine Master machines in the Iberian market (Spain). This initial agreement might be the starting point for a possible global cooperation.

The Putzmeister Underground Concreting Division 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 mutual complementation of the product range, the companies broaden the product offering around the tunneling process, resulting in synergy effects for customers. 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 manufacture 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 1059.4 ft^3 (30 m^3) and spraying reaches of up to 55.8 ft (17 m).

GHH Fahrzeuge, headquartered in Germany, has produced load haul dumpers (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, for the last 35 years, manufactured, distributed, and serviced equipment for the underground metal mining and construction industries. 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 biggest primary copper producers.

SBA Initiative Recognizes Shotcrete Montana

The U.S. Small Business Administration (SBA) Montana District Office recognized 14 small businesses (including ASA Corporate member Shotcrete Montana) in an Emerging 200 (e200) initiative (**www.sba.gov/content/sba-emerging-200-initiative**) graduation ceremony on October 28 at the University of Montana-Helena College of Technology. The goal of the SBA e200 initiative is to provide to inner-city and Native American businesses across the country that show a high potential for growth the network, resources, and motivation required to build a sustainable business.

The CEOs and small business owners who have graduated from the program have produced a 3-year strategic growth plan with benchmarks and performance targets. They were trained further to target their business strategies to accelerate growth, explore financing, diversify markets, and expand their networking.

Joe McClure, District Director of the SBA's Montana District Office, said, "We feel that each one of them will have a brighter future as a result of their participation and that the local and state economy will benefit as well."

The cornerstone of the e200 included an in-depth 100-hour educational program, which ran from April through October 2011, focusing on topics such as organization management, growth strategies and management, market development, and strategic planning.

There were 27 cities nationwide that took part in this initiative.

SubTerra Inc. Celebrates 20th Anniversary

SubTerra Inc. operates as the focal point for a small network of highly qualified independent consultants working in the geotechnical, rock mechanics, civil, mining, and related engineering industries. This unique arrangement facilitates client contact with specialized consultants in these areas and allows them to pursue projects where teamed skills are required. Incorporated in 1991, SubTerra maintains a relatively small permanent staff, which allows them to provide responsive, high-quality technical services at a reasonable cost.

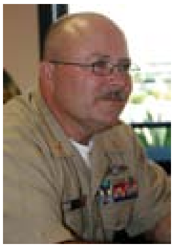
For more information on SubTerra Inc., visit **www.subterra.us**.

CDOT Launches Web Site for Colorado Bridge Enterprise Projects

The Colorado Department of Transportation (CDOT) in Denver officially launched a Web site that will track the status of Colorado's poor bridges as they are being planned, designed, and constructed through the Colorado Bridge Enterprise (CBE). The Web site, **www.coloradodot.info/programs/bridgeenterprise**, consists of current program statistics that are updated on a monthly basis, as well as an interactive map that shows the status of all poor bridges (currently 119). Information about the CBE's bond program and business opportunities for consultants and constructors is also available, along with frequently asked questions.

Industry Personnel

Flagpole to Honor Shotcrete Nozzleman on Third Tour in Middle East



Julio Beatrice

The American Legion is installing a 20 ft (6.1 m) flagpole to honor Julio Beatrice, a longtime employee of Fisher Shotcrete Inc., on his third military tour in the Middle East.

A Legion color guard had previously dedicated a flag to Beatrice, a man known for his dependability and commitment to service.

"He's the person that you call," said Laurel Mellett, Operations Manager for Fisher Shotcrete, where Beatrice has worked for 17 years. "He's always there for you, always willing to help. I think that's probably the military bit in him."

Beatrice is the Lead Estimator for Fisher Shotcrete. The company does concrete and industrial-coating work and has worked on large projects at the Jobing.com Arena and in New York City subways.

The 51-year-old Beatrice also serves as a "Seabee" in the Navy Reserve and is now deployed in Afghanistan. He served two tours in Iraq.

The Seabees are the Navy's construction force, which provides support for combat troops by building hospitals, airfields, and base camps. Although Beatrice couldn't give specifics about his current mission, he said he's involved with constructing jails in Afghanistan, Mellett said.

When home, Beatrice is an active member of the American Legion and rides a motorcycle with the Legion Riders, who organize charitable events to support veterans and others in the community.

Before leaving for Afghanistan, Beatrice asked his fellow riders to look after his motorcycle and ensure that the flag at his employer's office was flying properly, said Marinos Garbis, President of Gilbert's Legion Riders.

Inclement weather had recently damaged the company's existing flag pole, so the Legion decided to replace it with the 20 ft (6.1 m) aluminum pole. Legion members have prepared it as a surprise for Beatrice when he returns in February.

Beatrice's coworkers are looking forward to his return after having to adapt during his military service, Mellett said.

From left to right are coworkers Vicki Avelar; Alberto Medina; Sarah Florman; Julio Beatrice with his niece, Amanda Beatrice; Rich Garland; and Janice Fisher

Errata

In the Industry News section of the Fall 2011 issue, the item titled "Palmetto Gunite Participates in Industry Effort to Assist Laval University Shotcrete Research" confused the identity of the three Snows involved. The pictured "Will Snow" is actually W. L. "Bill" Snow, President and CEO of Palmetto Gunite Construction Company, Inc. His sons Robert and Will Snow were the individuals who delivered the materials and stayed for a week to assist with some of the testing.

Bill Snow

Robert Snow

Will Snow Jr.

ASA Annual Membership Meeting

This year's Annual ASA Membership Meeting will held in Room S225 at the Las Vegas Convention Center on Monday, January 23, 2012, at 12:00 p.m. Election results for open Director and Officer positions will be announced at the meeting. Reports regarding the state of the Association will also be given from the ASA President and ASA Treasurer. All ASA members are encouraged to attend this annual meeting.

ASA Education Committee Examiners Round Table Forum

This first Examiners Round Table is scheduled in Room S225 at the Las Vegas Convention Center from 8:30 to 11:30 a.m. on Monday, January 23, 2012. The forum will focus on a peer review and evaluation of shotcrete cores, a review of the ASA Education Module, and a review of the ASA process and policies for administration of the ACI Shotcrete Nozzleman Certification program.

The forum will center on the ASA roster of ACI-approved nozzleman examiners; however, the meeting is open to all ASA members and visitors.

ASA Committee Meetings at World of Concrete

ASA will feature the following committee meetings in Room S225 at the Las Vegas Convention Center on Monday, January 23, 2012:

12:30 to 1:30 p.m.: ASA Pool & Recreational Shotcrete Committee
1:30 to 3:30 p.m.: ASA Marketing and Membership Committee
3:30 to 5:00 p.m.: ASA Board of Direction

ASA Committee meetings are open and free to all with an interest in the education and promotion of the shotcrete process.

ASA Presence at World of Concrete

Make sure to register for the ASA seminar, "The Diversity of Shotcrete as a Method of Concrete Placement" (Seminar Code WE133), to be held on Wednesday, January 25, 2012, 8:30 a.m. to 10:00 a.m. The seminar will address the following topics:

- Deriving a better understanding of the shotcrete process as a method for placing concrete;
- Explaining the diversity of shotcrete applications;
- Recognizing the importance of training, certification, and the critical role of a qualified shotcrete contractor; and
- Identifying benefits in terms of hardened properties from proper shotcrete mixture design, placement practices, finishing, and curing practices.

ASA will also be exhibiting with a manned booth in the South Convention Hall. Make plans to visit us at Booth #S10749.

WORLD OF CONCRETE®
WORLD OF MASONRY | TECHNOLOGY FOR CONSTRUCTION
hanley wood

Seventh Annual ASA Outstanding Project Awards Banquet

The ASA Seventh Annual Outstanding Shotcrete Project Awards Banquet will be held at 6:00 p.m. on Tuesday, January 24, 2012, in the Versailles Ballroom of the Paris Las Vegas Hotel and Casino. This enjoyable evening will include a reception with cocktails and hors d'oeuvres, a plated dinner, and an awards presentation of the winning project for the following award categories: Architectural, Infrastructure, International Projects, Pool & Recreational, Rehabilitation & Repair, and Underground. If you are not already registered, simply come to the event and register on site.

ASA Lunch & Learn Seminars for Architects, Engineers, Specifiers, and Owners

The shotcrete process offers numerous quality, efficiency, and sustainability advantages; but proper knowledge of the process is critical to the creation of a quality specification and for the success of any specifier/owner employing the process. Maintaining a high level of quality for concrete placed via the shotcrete method is ASA's primary concern, and we have found this type of "Lunch & Learn" on-site presentation to be an excellent tool for all involved.

ASA informational presentations are nonproprietary and free. With a target audience of five or more, presentations are often of the 60-minute "lunch-box"-type format but can be tailored to any format. A typical general presentation would include the following:

1. Introduction to shotcrete;
2. Advantages and benefits using the shotcrete process;
3. Dry- and wet-mix processes;
4. Specifications, material considerations, and typical performance guidelines;
5. Surface preparation;
6. Preconstruction, job-site conditions, and curing methods; and
7. Questions and answers.

ASA presentations can focus on any specific topic a group may be interested in, such as "shotcrete for repair and rehabilitation of concrete structures" and "shotcrete for underground construction."

Contact ASA staff at info@shotcrete.org or (248) 848-3780 to arrange for an on-site informational presentation tailored for your group's needs.

Concrete JSI Sponsorship

ASA's Board of Direction recently pledged ASA's continuing support of the Concrete Joint Sustainability Initiative (Concrete JSI). Concrete JSI is a coalition of industry associations representing companies that make or maintain concrete structures. Concrete JSI associations share a goal of educating about the positive role and responsibilities of concrete in sustainable development.

Formed in the spring of 2009, Concrete JSI represents over 20 associations that, as a group, will concentrate on the sustainable development applications of all concrete structures. It aims to project a unified industry front and present a common message.

For more information on Concrete JSI, visit **www.sustainableconcrete.org**. For more information on the significant sustainability advantages of shotcrete, visit **www.shotcrete.org/sustainability.html**.

Concrete Joint Sustainability Initiative

Like ASA's Facebook Page

ASA's Facebook page (search Facebook for "AmericanShotcrete-Association") was launched last fall and offers followers another easy way to stay up to date on the latest news regarding issues, products, and events of the shotcrete industry's association.

Find us on: facebook®

New Products & Processes

Bekaert First Steel-Fiber Manufacturer to Obtain ICC-ES Certification

In Marietta, GA, August 2011, Bekaert proudly announced that it is the first steel-fiber manufacturer to receive ICC-ES certification for the use of Dramix® in concrete footings, slabs-on-ground, and other elements designed according to ACI 318, Chapter 22.

Bekaert's Dramix steel fibers have been recently reviewed and certified as code-compliant by the International Code Council's Evaluation Service, the United States' leader in evaluating building products for compliance with building codes. Bekaert is proud to follow its partner, Irving Materials Inc., who received its ICC approval for its imix XS brand fibers in 2008.

"The fact that Bekaert's Dramix fibers have been approved by an important third party like ICC-ES is invaluable," said Tom Hautekiet, Global Marketing Manager at Bekaert's building division. "This certification will offer our many customers in the construction industry peace of mind, as well as the confirmation that building with Dramix is reliable and contributes to the quality of their end product."

Dramix has been evaluated according to AC208, "Acceptance Criteria for Steel Fibers in Concrete," for compliance with the International Building Code and International Residential Code. Meeting or exceeding these criteria allows Dramix steel fibers to replace shrinkage and temperature reinforcement in concrete footings, slabs-on-ground, and other structural plain concrete elements. The evaluation procedure includes many different assessments, which are not limited to steel fiber properties (tensile strength, ductility, length, and diameter); concrete compressive and flexural strength; and the average residual strength.

Bekaert's Dramix steel-fiber products are widely used in the construction sector and have given the company a leading position in the market of steel-fiber concrete reinforcement. Dramix is a successful alternative for traditional steel mesh and bar reinforcement and can be applied in a wide range of construction applications, including industrial floors, precast elements, tunneling and mining, residential applications, and public works.

For more information, visit **www.bekaert.com**.

Ultra-Stick Hybrid Shotcrete from Thiessen Team

Ultra-Stick Hybrid Shotcrete is a dried, preblended, cement-based shotcrete that includes carefully selected materials. Ultra-Stick Hybrid Shotcrete has greatly enhanced shooting characteristics and physical properties.

Water is added to the dry shotcrete mixture at the mine site-batching plant and is either transported wet via an underground remixer to the required location or transported dry via an underground hybrid shotcrete carrier to the working heading, where it is batched to the wet mix. The wet application of Ultra-Stick Hybrid Shotcrete is possible through two different processes. The most common process involves the wet material being pumped with a Schwing concrete pump. Air is introduced at the nozzle. The second process involves the wet material being pneumatically conveyed through an Aliva shotcrete machine.

With both processes, the shotcrete impacts at a high velocity, resulting in a well-compacted, high-quality application with excellent bond properties. Ultra-Stick Hybrid Shotcrete may be used with fiber reinforcement (in final batching or super sacks only) to enhance load-carrying capacity. It may also be used with non-caustic and alkali-free accelerators to provide high early strengths. Some common uses include:

- Slope stabilization;
- Initial and secondary tunnel support;
- Structural linings; and
- Concrete rehabilitation.

Ultra-Stick Hybrid Shotcrete has many advantages, including:

- It is a dry, bulk-blended product with an infinite life, as long as it is stored in a dry location;
- It is delivered and stored on site in a dry state for on-demand batching ability;
- It reduces waste with the ability to batch only the amount needed for the project; and
- It reduces the amount of admixtures needed to deliver the material to the job site.

Ultra-Stick Hybrid Shotcrete has vastly improved cohesion characteristics compared to conventional shotcrete. This stickiness saves time and money because:

- Rebound is significantly reduced, resulting in lower product use; and
- Volumes are increased with wet shotcreting.

For more information, visit the Thiessen Team Web site at **www.thiessenteam.com**.

ACI Announces Release of 318-11 Building Code

The American Concrete Institute (ACI) is pleased to announce the release of ACI 318-11, "Building Code Requirements for Structural Concrete and Commentary."

ACI 318-11 is a must-have standard for all concrete design, construction, inspection, repair, and research professionals. It contains the latest code requirements for concrete building design and construction alongside the corresponding commentary and includes many improvements and changes from the 2008 edition. ACI 318-11 will also be available in metric and Spanish versions.

"Engineers, architects, contractors, specifiers, building officials, students, and professors all rely on and regularly use ACI 318," said Ron Burg, Executive Vice President of ACI. "Members of ACI Committee 318 have volunteered thousands of hours to ensure that necessary updates have been made to this 2011 edition, dedicated to enhancing the safety of concrete structures."

The following is a summary of key changes in ACI 318-11:

- Design, installation, and inspection requirements for adhesive anchors are now included. Nominal strengths are defined for adhesive anchors in cracked and uncracked concrete and for adhesive anchors subject to sustained loads. The Code includes criteria for overhead installation of adhesive anchors and requires the certification of adhesive anchor installers for certain installations. The seismic requirements for anchoring to concrete have also been revised.
- Reinforcement detailing for seismic applications has been enhanced. These new requirements include reinforcement detailing for distinct segments of special structural wall systems, detailing of horizontal bars at special boundary elements, and tightened confinement details for flexural hinge regions of large beams.
- Test methods ASTM D516 and D4130 are referenced to determine the concentration of dissolved sulfates in water, brackish water, or seawater, and ASTM C1580 is referenced to determine percent sulfate by mass in soil.
- Newly available deformed bar types are integrated into appropriate provisions. Grade 80 deformed bars conforming to ASTM A615 or A706 are allowed for nonseismic applications. Zinc and epoxy dual-coated reinforcing bars per ASTM A1055 are also now recognized.
- Test records for determining standard deviation for a mixture design may now be up to 24 months old. Also, testing agencies performing acceptance testing of concrete are now required to comply with ASTM C1077.
- Detailing requirements for ties for circular columns are more rigorously defined and minimum reinforcement for deep beams has been added.
- Detailing requirements of temperature and shrinkage reinforcement for post-tensioned slabs have been revised; and
- Factored load combinations now fully conform to ASCE 7-10.

One significant addition to the ACI 318-11 Code addresses the credentialing of individuals who install adhesive anchors. When adhesive anchors are installed overhead and subjected to sustained tension loads, they must be installed by an individual who holds an ACI/CRSI Adhesive Anchor Installer Certification or equivalent.

ACI 318-11 can be ordered by calling (248) 848-3800 or online at **www.concrete.org**.

Shotcrete FAQs

As a service to our readers, each issue of *Shotcrete* includes selected questions submitted to and answered by the American Shotcrete Association (ASA). Questions can be sent to info@shotcrete.org. A searchable archive of FAQs can also be found on the ASA Web site, **www.shotcrete.org/ASAfaqs.htm**.

Question: Is it possible to use a penetrating sealer, such as those used on driveways, to make shotcrete repel moisture? If so, will the sealer improve the shotcrete's freezing-and-thawing performance?

Answer: It is possible to use a penetrating sealer on shotcrete in the same manner as cast-in-place concrete. We are not aware of research on the durability of such a sealer and do not know if it would enhance the freezing-and-thawing characteristics. A high-quality shotcrete mixture that is properly placed will exhibit excellent freezing-and-thawing characteristics with or without a sealer.

Question: Often, steel fiber-reinforced shotcrete (SFRS) linings are applied in underground construction. In some areas of high tensile stresses, it is necessary to use additional ordinary reinforcement (reinforcing bar/mesh). It may be inefficient to switch to non-fibrous shotcrete for these regions. Are the shadowing problems to be expected in that case (SFRS with additional ordinary reinforcement) more severe and how can they be resolved?

Answer: It is not uncommon to encapsulate lattice girders or steel sets in fibrous shotcrete. The skill of the nozzleman, the size and density of the reinforcing, and the characteristics of the mixture and the accelerator are the most important factors in achieving good encapsulation of reinforcing bar or these more complicated applications around lattice girders or steel sets. With welded-wire reinforcement, you should have a 4 x 4 in. (100 x 100 mm) or greater spacing. With reinforcing bar, you should use the minimum diameter possible at a minimum spacing of around 6 in. (150 mm). Preconstruction mockups should be considered to prove the competency of the nozzleman and the mixture. Please note that the best nozzleman cannot succeed without a good, workable mixture.

Question: We are currently working on a tunnel that will cross through a drinking water protection zone in the alluvial aquifer. Do shotcrete technology and materials exist that can be used on groundwater-sensitive areas?

Answer: Shotcrete is the same as concrete when evaluated as a material and its exposure to potable water. In the U.S., many admixtures and cements for concrete have been tested and certified to meet the NSF 61 standards for materials exposed to potable water. In my experience, potable water stored in concrete tanks with direct exposure to the concrete (no coatings) has not exhibited any significant rise in alkalinity. Exposure of a tunnel in a groundwater aquifer would seem to have much less contact area per volume of water contained in the aquifer, such that any rise in alkalinity would be miniscule. Because concrete in the U.S. is universally accepted for the storage and transport of potable water, I'd assume that the use of shotcrete in your tunnel would be perfectly acceptable.

Question: We are considering the use of shotcrete to line a 3600 ft (1097 m) channel that is approximately 15 to 20 ft (4.5 to 6 m) wide. The purpose of the lining is to cap impacted sediments in the channel bottom.

What is the suitability of shotcrete for this type of application, and can you provide a conceptual/budgetary estimate for the implementation of this approach?

Answer: Shotcrete is a method of placing concrete and therefore the material has the same basic characteristics of concrete. Shotcrete is often used for canal, channel, and ditch lining. It is important with shotcrete (concrete) that the subgrade the material is placed over be compacted and stable. The thickness, strength, and reinforcing needs to be designed and specified by a professional engineer familiar with this type of structure or pavement. For budget numbers, you should contact one of our contractor members, who can be found in the **Buyers Guide on the Web site** at **www.shotcrete.org**.

Question: We are currently placing a shotcrete wall in a tunnel. The wall has a minimum thickness of 8.25 in. (210 mm) and is placed against secant piles. Our specs called for a wet cure. To minimize shrinkage cracking, what is the minimum amount of time to allow after shotcrete placement before the wet cure is applied?

Answer: There is a difficult balance between wet curing too early or too late. You should not add water too early (before the material sets), as this would increase the water-cement ratio (w/c) of the material on the surface. You also do not want to add water during the finishing process, as this would also work the water into the surface and increase the w/c at the surface. Good practice would be to use an evaporative retardant, which generally also serves as a finishing aid during the finishing process, and then get the wet cure set up as soon as possible.

Question: We are studying a repair to an existing large-diameter corrugated metal pipe. The owner requires that the repair meet the fifth edition of the *AASHTO LRFD Bridge Design Specifications with 2010 Interim Revisions*. We want the owner to consider shotcrete as opposed to installing a new carrier pipe. I have pipe dimensions, depth, and so on, but need some help deciding if this is practical.

Answer: Shotcrete has been used in many cases to repair, rehabilitate, and strengthen pipes, culverts, and tunnels. It is not uncommon to use shotcrete to strengthen a culvert under a highway or roadway section. Shotcrete is a method of placing concrete at a high velocity. The shotcrete placed inside the existing pipe can be designed for strengths from 4000 to 10,000 psi (27.5 to 69 MPa), depending on the amount you are willing to spend on the shotcrete products. We cannot speak to the acceptance by the governing body, but it has been done successfully and often in the past. It is vitally important that the shotcrete contractor be competent and experienced in installing the lining. Your specification should require evidence of similar previously completed projects with current references.

Question: We are constructing a new custom residence on the Gulf Coast of Texas using a Monolite insulated concrete form (ICF) system. The ICF system is basically a "sandwich" system with an expanded polystyrene (EPS) panel with a wire cage and shotcrete on both sides. Because of the storm surge and high humidity of the region, we are looking for a mixture formula for a waterproof shotcrete for the exterior coating to help prevent moisture migration to the interior. What can you suggest?

Answer: The insulation itself should provide a vapor barrier. Various additives can be used with the shotcrete to improve its permeable properties, such as silica fume or a commercial waterproofing additive. It is also not uncommon to use a plaster coat over the shotcrete to provide improved water resistance and an architectural finish. The density and uniformity of the shotcrete can be influenced by the competency of the shotcrete applicator. It is always advisable to engage a competent and experienced shotcrete contractor to ensure the best possible results. You can search for a contractor with certified shotcrete nozzlemen from our **Buyers Guide** at **www.shotcrete.org/buyersguide** or **submit a bid request** through our **Online Bid Submittal Tool** at **www.shotcrete.org/projectbidrequest.aspx**.

ASA New Members

CORPORATE MEMBERS

Clark Foundations, LLC
Bethesda, MD
Primary contact: Timothy Campbell
timothy.campbell@clarkconstruction.com

Lehigh Cement Company/White Cement Division
Allentown, PA
Primary contact: Larry Rowland
lrowland@lehighcement.com
www.lehighwhitecement.com

Shotcrete Helmet
Paris, ON, Canada
Primary contact: The St. George Company
info@shotcretehelmet.com
www.shotcretehelmet.com

SPB Torkret Ltd.
Siekierki, Wielkie, Poland
Primary contact: Wlodzimierz Czajka
biuro@torkret.com.pl
www.torkret.com.pl

Whiteside Construction Corporation
Richmond, CA
Primary contact: Robert Branstad
bbranstad@whitesideconstruction.com
www.whitesideconstruction.com

CORPORATE ADDITIONAL INDIVIDUAL MEMBERS

Jeffrey Boucher
Drakeley Industries
Bethlehem, CT

Chris Harkema
The Quikrete Company
Walker, MI

Liam Ireland
KPM Industries
Montreal, QC, Canada

NOZZLEMAN MEMBERS

Alvin Johns
Kiewit Pacific Company
Eugene, OR

PUBLIC AUTHORITY AND AGENCY MEMBERS

Dave Amos
Missouri Department of Transportation
Jefferson City, MO

Joe Bianchi
Mass DOT
Boston, MA

James F. Boyer
Alabama DOT
Montgomery, AL

Kenneth D. Clausen
Idaho Transportation Department
Boise, ID

George Franz
New Jersey Department of Transportation
Trenton, NJ

Douglas A. Gosling
The State of New Hampshire DOT
Concord, NH

Samir Halil
Washington Suburban Sanitary Commission
Laurel, MD

Jim Holland
Idaho Transportation Department
Boise, ID

Theodore Hopwood
KY Transportation Center
Lexington, KY

Ivan Lasa
State of Florida DOT
Gainesville, FL

Claude S. Napier Jr.
Virginia DOT
Richmond, VA

Eric Nelson
North Carolina DOT
Raleigh, NC

Hannah Schell
Ministry of Transportation–Concrete Section
Downsview, ON, Canada

Dustin Thomas
MN DOT
Oakdale, MN

David Tipton
KY Transportation Center
Frankfort, KY

ASA New Members

Peter J. Weykamp
DOT State of New York
Albany, NY

David Youkhana
City of Burlington
Burlington, ON, Canada

AMERICAN SHOTCRETE ASSOCIATION

STUDENT MEMBERS

Mickey F. Dial
Marshall University
Huntington, WV

Jane Jordan Gravely
Bloomfield Hills, MI

Mojtaba Vosough Rouhani
Kiarash
Rasht, Guilan, Iran

Aaron Woods
Austin, TX

Xiong Yu
Morgantown, WV

INTERESTED IN BECOMING A MEMBER OF ASA?

Read about the benefits of being a member of ASA on page 82 and find a Membership Application on page 83.

AMERICAN SHOTCRETE ASSOCIATION
ONLINE BUYERS GUIDE

Online tool offers the industry free access to products and services of the leading companies in the shotcrete industry

The American Shotcrete Association (ASA) Buyers Guide is now available free to the concrete industry at **www.shotcrete.org/BuyersGuide**.

The ASA Buyers Guide provides an important tool to locate those companies that continually prove their commitment to the shotcrete process and its quality by supporting ASA through Corporate Membership.

This service enables users to search for companies based on products and/or services related to shotcrete across seven main categories:

- Admixtures
- Cement/Pozzolanic Materials
- Consulting
- Contractors
- Equipment
- Fibers
- Shotcrete Materials/Mixtures

Searches can be further refined using over 100 subcategories and geographic criteria.

AMERICAN SHOTCRETE ASSOCIATION

www.shotcrete.org/BuyersGuide • (248) 848-3780

AMERICAN SHOTCRETE ASSOCIATION 2012 Buyers Guide

The following list of ASA Corporate Members is current as of December 1, 2011. For a current listing, including the ability to search by seven major specialties (as well as over 100 subspecialties) and states/provinces served, visit the online ASA Buyers Guide at **www.Shotcrete.org/BuyersGuide**.

Abbott Shoring & Foundation Ltd. CONTRACTOR
2105 Banbury Rd
North Vancouver, BC V7G 1W7, Canada
Phone: 604-929-7677
E-mail: r_abbott@telus.net
Contact: Roger Abbott

Acme America Inc. EQUIPMENT
PO Box 269
Coopersburg, PA 18036-0269
Phone: 800-458-2263
Web site: www.acmeamerica.com
E-mail: acme@acmeamerica.com
Contact: John Ferraris

Aircrete Systems LP Inc. ADMIXTURES, CONSULTING, CEMENT/POZZOLANIC MATL, CONTRACTOR, EQUIPMENT, SHOTCRETE MATERIALS/MIXES, FIBERS
4 Industry Way SE
Calgary, AB T3S 0A2, Canada
Phone: 403-203-0492
Web site: aircretesystems.com
E-mail: lamanagement@shaw.ca
Contact: Jack Radu

Airplaco Equipment Company CONTRACTOR, EQUIPMENT
4141 Airport Rd
Cincinnati, OH 45226-1643
Phone: 513-321-4511
Web site: www.airplaco.com
E-mail: sales@airplaco.com
Contact: Tom Norman

Allentown Shotcrete Technology Inc. EQUIPMENT
1733 90th St
Sturtevant, WI 53177-1805
Phone: 262-886-3200
Web site: www.allentownshotcrete.com
E-mail: bridgerp@allentownshotcrete.com
Contact: Patrick Bridger

AMEC Environment & Infrastructure CONSULTING
4445 Lougheed Hwy, Ste 600
Burnaby, BC V5C 0E4, Canada
Phone: 604-294-3811
Web site: www.amec.com
E-mail: john.laxdal@amec.com
Contact: John Laxdal, PE

American Concrete Restorations Inc. CONTRACTOR
11S375 Jeans Rd
Lemont, IL 60439-8839
Phone: 630-887-0670
Web site: www.americanconcreterestorations.com
E-mail: cathy@americanconcreterestorations.com
Contact: Cathy Burkert

Azteca Gunite CONTRACTOR
6626 Flintlock Rd
Houston, TX 77040-4319
Phone: 713-462-5566
Web site: www.aztecagunite.com
E-mail: info@aztecagunite.com
Contact: Ozzie Martinez

Baker Concrete Construction, Inc. CONSULTING, CONTRACTOR
900 N Garver Rd
Monroe, OH 45050-1241
Phone: 800-539-2224
Web site: www.bakerconcrete.com
E-mail: gentrys@bakerconcrete.com
Contact: Steven Gentry

BASF Admixtures Inc. ADMIXTURES
23700 Chagrin Blvd
Cleveland, OH 44122-5506
Phone: 216-839-7015
Web site: www.basf-admixtures.com

Bekaert Corporation CONSULTING, CONTRACTOR, EQUIPMENT, FIBERS
1395 S Marietta Pkwy SE, Ste 100
Marietta, GA 30067-4440
Phone: 800-555-1775
Web site: www.bekaert.com
E-mail: michael.hyland@bekaert.com
Contact: Michael Hyland

BelPacific Excavating & Shoring Ltd. CONSULTING, CONTRACTOR
3183 Norland Ave
Burnaby, BC V5B 3A9, Canada
Phone: 604-205-0002
Web site: www.belpacific.com
E-mail: greg@belpacific.com
Contact: Gregory Samcheck

The Blanchard Group SHOTCRETE MATERIALS/MIXES
4586 Route 134
Allardville, NB E8L 1E2, Canada
Phone: 506-725-2132
Web site: www.blanchardgroup.ca
E-mail: rene@blanchardgroup.ca
Contact: Rene Blanchard

Blastcrete Equipment Company ADMIXTURES, CONSULTING, CEMENT/POZZOLANIC MATL, CONTRACTOR, EQUIPMENT, SHOTCRETE MATERIALS/MIXES
PO Box 1964
Anniston, AL 36202-1964
Phone: 256-235-2700
Web site: www.blastcrete.com
E-mail: jim@blastcrete.com
Contact: Jim Farrell

www.Shotcrete.org/BuyersGuide

Buyers Guide, cont.

Boulderscape Inc. CONTRACTOR
33081 Calle Perfecto, Ste A
San Juan Capistrano, CA 92675-4762
Phone: 949-661-5087
Web site: www.boulderscape.com
E-mail: steve@boulderscape.com
Contact: Steve Jimenez

California Skateparks CONSULTING, CONTRACTOR
273 N Benson Ave
Upland, CA 91786-5614
Phone: 909-949-1601
Web site: www.californiaskateparks.com
E-mail: info@californiaskateparks.com
Contact: Joseph M. Ciaqlia Jr.

Carolina Concrete Systems, Inc. CONSULTING, CONTRACTOR, EQUIPMENT
PO Box 13149
Charleston, SC 29422-3149
Phone: 843-588-6721
E-mail: ccsrockdoc@aol.com
Contact: Bob Wiggins

Cementec Industries Inc. ADMIXTURES, CEMENT/POZZOLANIC MATL
159-3953 112 Ave SE
Calgary, AB T2C 0J4, Canada
Phone: 403-720-6699
Web site: www.cementec.ca
E-mail: info@cementec.ca
Contact: Joseph Kiss

Clark Foundations, LLC CONTRACTOR
7500 Old Georgetown Rd
Bethesda, MD 20814-6133
Phone: 301-272-8326
E-mail: timothy.campbell@clarkconstruction.com
Contact: Timothy Campbell

Coastal Gunite Construction Company CONTRACTOR
PO Box 977
Cambridge, MD 21613-0977
Phone: 410-228-8100
Web site: www.coastalgunite.com
E-mail: coastalgunite1@aol.com
Contact: R. Curtis White Jr.

ConCreate USL Ltd. CONTRACTOR, EQUIPMENT, FIBERS
2 Manchester Ct
Bolton, ON L7E 2J3, Canada
Phone: 800-363-7580
Web site: www.usl-1983.com
E-mail: usl@usl-1983.com
Contact: Karen Brigden

Concrete Engineering Group LLC CONSULTING
2840 Sugar Pine Cir
Northbrook, IL 60062-6433
Phone: 847-453-8877
Web site: www.concreteengrs.com
E-mail: charles.hanskat@concreteengrs.com
Contact: Charles Hanskat

Concrete Repairs & Contracting Co. CONTRACTOR
PO Box 45962
Abu Dhabi, United Arab Emirates
Phone: 01197126336128
Web site: www.repcrete.com
E-mail: repcrete@emirates.net.ae
Contact: Khaled Naddeh

Conshot Structures 2010 Ltd.
145 Golden Dr
Coquitlam, BC V3K 6T1, Canada
Phone: 011-6049962219
Web site: www.conshot.ca
E-mail: carlking@telus.net
Contact: Carl King

Construction Forms, Inc. EQUIPMENT
777 Maritime Ave
Port Washington, WI 53074-2801
Phone: 800-223-3676
Web site: www.conforms.com
E-mail: info@constructionforms.com
Contact: Alan J. Kastelic

Contech Services, Inc. CONTRACTOR
PO Box 84886
Seattle, WA 98124-6186
Phone: 206-763-9877
Web site: www.contechservices.com
E-mail: pete@contechserviceswa.com
Contact: Peter Barlow

Cowin & Company Inc. CONTRACTOR
PO Box 19009
Birmingham, AL 35219-9009
Phone: 205-945-1300
Web site: www.cowin-co.com
E-mail: jcowinjr@cowin-co.com
Contact: John J. Cowin Jr.

Craig Olden, Inc. CONSULTING, CONTRACTOR
PO Box 5000
Little Elm, TX 75068-9000
Phone: 972-294-5000
Web site: www.oldeninc.com
E-mail: adpengelly@craigoldeninc.com
Contact: Art D. Pengelly

The Crom Corporation CONTRACTOR
250 SW 36th Ter
Gainesville, FL 32607-2863
Phone: 828-277-2666
Web site: www.cromcorp.com
E-mail: 4lob@cromcorp.com
Contact: Lars Balck Jr., PE

C-TEC, Inc. CONTRACTOR
1928 S Lincoln Ave
York, NE 68467-9467
Phone: 402-362-5951
Web site: www.ctecconcrete.com
E-mail: ctec@ctecconcrete.com
Contact: Greg Wurst

www.Shotcrete.org/BuyersGuide

Custom Crete Inc. CONTRACTOR, EQUIPMENT, SHOTCRETE MATERIALS/MIXES
4433 Terry O Ln
Austin, TX 78745-2039
Phone: 512-443-5787
Web site: www.custom-crete.com
Contact: Bill Heath

Dees Hennessey Inc. CONTRACTOR
200 Industrial Rd
San Carlos, CA 94070-6257
Phone: 650-595-8933
E-mail: deeshenn@pacbell.net
Contact: Daniel M. Evans

Delta Gunite Solano Inc. CONTRACTOR, SHOTCRETE MATERIALS/MIXES
1735 Enterprise Dr, Ste 103
Fairfield, CA 94533-6822
Phone: 707-425-7293
Web site: www.deltagunitesolano.com
E-mail: deltasolano@sbcglobal.net
Contact: Philip Kassis

Delta Industrial Services Inc. SHOTCRETE MATERIALS/MIXES
PO Box 1109
Delta Junction, AK 99737-1109
Phone: 907-895-5053
Web site: www.deltaindustrial.com
E-mail: mike@deltaindustrial.com
Contact: Mike Crouch

Deluxe Shotcrete & Concrete Construction CONSULTING, CONTRACTOR, SHOTCRETE MATERIALS/MIXES
PO Box 385
Santa Rosa, CA 95402-0385
Phone: 707-568-1200
Web site: www.deluxeshotcrete.com
E-mail: cindy@deluxeshotcrete.com
Contact: Cindy Culley

DOMTEC International LLC CONSULTING, CONTRACTOR
4355 N Haroldsen Dr
Idaho Falls, ID 83401-1105
Phone: 208-522-5520
Web site: www.domtec.com
E-mail: domtec@domtec.com
Contact: Ryan Poole

Donald J. Scheffler Construction CONTRACTOR
15815 Amar Rd
City Of Industry, CA 91744-2107
Phone: 626-333-6317
Web site: http://donaldjschefflerconstruction.com
E-mail: mailbox@donaldjscheffler.com
Contact: Donald J. Scheffler

Douglas Aquatics, Inc. CONTRACTOR
1900 E Belt Blvd
Richmond, VA 23224-6304
Phone: 804-232-8027
Web site: www.douglasaquatics.com
E-mail: gabe.crouch@douglasaquatics.com
Contact: Thomas Gabriel Crouch

Drake Inc. CONTRACTOR
1919 Road Q
Waco, NE 68460-8826
Phone: 402-362-1863
Web site: www.drakeinc.net
E-mail: davedrake@windstream.net
Contact: David Drake

Drakeley Industries LLC CONSULTING, CONTRACTOR
74 Hickory Ln
Bethlehem, CT 06751-2308
Phone: 203-263-7919
Web site: www.drakeleypools.com
E-mail: bill@drakeleypools.com
Contact: William T. Drakeley Jr.

Drill Tech Drilling & Shoring, Inc. CONSULTING, CONTRACTOR
2200 Wymore Way
Antioch, CA 94509-8548
Phone: 925-978-2060
Web site: www.drilltechdrilling.com
E-mail: ryan@drilltechdrilling.com
Contact: Ryan Nagle

East Coast Shotcrete, LLC (ECS) CONTRACTOR
86 Washington Ave
Milltown, NJ 08850-1220
Phone: 732-246-2799
Web site: www.eastcoastshotcrete.com
E-mail: tommy@eastcoastshotcrete.com
Contact: Tommy Pirkle

Eastern Gunite Company Inc. CONTRACTOR, EQUIPMENT
PO Box 557
Exton, PA 19341-0557
Phone: 610-524-5590
Web site: www.easterngunite.com
E-mail: egunite@aol.com
Contact: Thomas F. Lyons

Elkin Hi Tech Inc. EQUIPMENT
2879 Oakland Ave
Indiana, PA 15701-3293
Phone: 724-349-6300
Web site: www.elkinhitech.com
E-mail: elkin@elkinhitech.com
Contact: Frank Holuta

Engineering & Construction Innovations Inc.
780 Barge Channel Rd
Saint Paul, MN 55107-2438
Phone: 651-298-9111
Web site: www.eandci.com
E-mail: shane@eandci.co
Contact: Shane McFadden

Epoxy Design Systems Inc. CONTRACTOR
PO Box 19485
Houston, TX 77224-9485
Phone: 713-461-8733
Web site: www.epoxydesign.com
E-mail: hank@epoxydesign.com
Contact: Hank Taylor

www.Shotcrete.org/BuyersGuide

The Euclid Chemical Company ADMIXTURES, FIBERS, CEMENT/POZZOLANIC MATL
19218 Redwood Rd
Cleveland, OH 44110-2736
Phone: 216-225-7383
Web site: www.euclidchemical.com
E-mail: dmillette@euclidchemical.com
Contact: Daniel Millette

Facca Incorporated CONTRACTOR
2097 County Rd 31 RR 1
Ruscom Station, ON N0R 1R0, Canada
Phone: 519-975-0377
Web site: www.facca.com
E-mail: don@facca.com
Contact: Don Gardonio

Fibercon International Inc. CONTRACTOR, EQUIPMENT, FIBERS
100 S 3rd St
Evans City, PA 16033-9264
Phone: 724-538-5006
Web site: www.fiberconfiber.com
E-mail: nick@fiberconfiber.com
Contact: Nicholas Mitchell Jr.

Fisher Shotcrete Inc. CONTRACTOR
PO Box 1360
Higley, AZ 85236-1360
Phone: 480-897-7824
Web site: www.fishershotcrete.com
E-mail: jfisher@fishershotcrete.com
Contact: Janice Fisher

Forta Corporation FIBERS
100 Forta Dr
Grove City, PA 16127-6308
Phone: 800-245-0306
Web site: www.fortacorp.com
E-mail: info@fortacorp.com
Contact: Daniel T. Biddle

Frontier-Kemper Constructors Inc. CONTRACTOR
1695 Allen Rd
Evansville, IN 47710-3394
Phone: 812-426-2741
Web site: www.frontierkemper.com
E-mail: jmcmahon@frontierkemper.com
Contact: Jim McMahon

Getman Corporation
59750 34th Ave
Bangor, MI 49013-1259
Phone: 269-427-5611
Web site: www.getman.com
E-mail: glomboy@getman.com
Contact: Gene L. Lomboy

Grace Construction Products ADMIXTURES
62 Whittemore Ave
Cambridge, MA 02140-1623
Phone: 617-498-4429
Web site: www.na.graceconstruction.com
E-mail: craig.boucher@grace.com
Contact: Craig Boucher

Group Works LLC CONSULTING, CONTRACTOR
PO Box 7269
Wilton, CT 06897-7269
Phone: 203-834-7905
Web site: www.groupworksllc.com
E-mail: jamie@groupworksllc.com
Contact: James Scott

Gunite Supply & Equipment Co. EQUIPMENT
1726 S Magnolia Ave
Monrovia, CA 91016-4511
Phone: 888-393-8635
Web site: www.gunite.us
E-mail: casales@gunitesupply.com
Contact: Chris Marston

Hardcore Shotcrete Skateparks Inc. CONSULTING, CONTRACTOR
601 S McKinley Ave
Joplin, MO 64801-3220
Phone: 888-758-2695
Web site: www.hardcoreskateparks.com
E-mail: info@hardcoreskateparks.com
Contact: Mark Leone

Hardrock Concrete Inc. CONTRACTOR, SHOTCRETE MATERIALS/MIXES
2898 Lakeshore Blvd W
PO Box 46
Etobicoke, ON M8V 1J2, Canada
Phone: 416-710-9930
Web site: www.shotcrete.ca
E-mail: info@shotcrete.ca
Contact: Frank Schwenzer

Hydro Arch CONTRACTOR
1445 American Pacific Dr
Henderson, NV 89074-7402
Phone: 702-566-1700
Web site: www.hydro-arch.com
E-mail: wmichelson@hydro-arch.com
Contact: Wolf Michelson

In Line Concrete Pumping Services
46 Allensville Road
Utterson, ON P0B 1M0, Canada
Phone: 705-788-2326
E-mail: inlineconcrete@hotmail.ca
Contact: Dwayne Parkin

J Tortorella Swimming Pools Inc. ADMIXTURES, CONSULTING, CONTRACTOR, EQUIPMENT, SHOTCRETE MATERIALS/MIXES
1764 County Road 39
Southampton, NY 11968-5204
Phone: 631-283-7373
Web site: www.tortorella.com
E-mail: joey@tortorella.com
Contact: Joe Tortorella

John Rohrer Contracting Company Inc. CONTRACTOR
2820 Roe Ln
Kansas City, KS 66103-1543
Phone: 913-236-5005
Web site: www.johnrohrercontracting.com
E-mail: brandon@johnrohrercontracting.com
Contact: Brandon D. McMullen

www.Shotcrete.org/BuyersGuide

Johnson Western Gunite Company CONTRACTOR, EQUIPMENT
940 Doolittle Dr
San Leandro, CA 94577-1021
Phone: 510-568-8112
Web site: www.jwgunite.net
E-mail: larryt@jwgunite.com
Contact: Larry J. Totten

Joseph J. Albanese Inc. CONSULTING, CONTRACTOR
986 Walsh Ave
Santa Clara, CA 95050-2649
Phone: 408-640-6219
Web site: www.jjalbanese.com
E-mail: czynda@jjalbanese.com
Contact: Chris Zynda

KHM Inc.
PO Box 2672
Binghamton, NY 13902-2672
Phone: 607-773-0076
Web site: www.khminc.ca
E-mail: info@khminc.ca
Contact: Kathleen Hall

King Packaged Materials Company EQUIPMENT, FIBERS SHOTCRETE MATERIALS/MIXES
3385 Harvester Rd
Burlington, ON L7N 3N2, Canada
Phone: 905-639-2993
Web site: www.kingshotcrete.com
E-mail: jhutter@kpmindustries.com
Contact: Joe Hutter

Knowles Industrial Services Corp. CONTRACTOR
295 New Portland Rd
Gorham, ME 04038-1867
Phone: 207-854-1900
Web site: www.knowlesindustrial.com
E-mail: dmaloney@knowlesindustrial.com
Contact: Dan Maloney

Kryton International Inc. ADMIXTURES
1645 Kent Ave North E
Vancouver, BC V5P 2S8, Canada
Phone: 604-324-8280
Web site: www.kryton.com
E-mail: jwork@kryton.com
Contact: Jillian Work

Lafarge North America CEMENT/POZZOLANIC MATL, CONSULTING
30600 Telegraph Rd, Ste 4000
Bingham Farms, MI 48025-5726
Phone: 248-594-1991
Web site: www.lafargenorthamerica.com
E-mail: ken.kazanis@lafarge-na.com
Contact: Ken Kazanis

Lehigh Cement Company/ White Cement Division CEMENT/POZZOLANIC MATL
7660 Imperial Way
Allentown, PA 18195-1016
Phone: 610-366-4600
Web site: www.lehighwhitecement.com
E-mail: lrowland@lehighcement.com
Contact: Larry Rowland

Mar-Allen Concrete Products Inc. CONTRACTOR
490 Millway Rd
Ephrata, PA 17522-9528
Phone: 717-859-4921
E-mail: jlzimmerman@marallen.com
Contact: Jeffrey L. Zimmerman

Mays Construction Specialties Inc. CONTRACTOR
2399 Riverside Parkway
Grand Junction, CO 81505
Phone: 970-245-0834
Web site: www.mays-mcsi.com
E-mail: kvanderberg@mays-mcsi.com
Contact: Kyle R. Vanderberg

Metro Testing Laboratories Ltd. CONSULTING
6991 Curragh Ave
Burnaby, BC V5J 4V6, Canada
Phone: 604-436-9109
Web site: www.metrotesting.ca
E-mail: nmcaskill@metrotesting.ca
Contact: Neil McAskill

Mid American Gunite Pools Inc. CONTRACTOR
1607 Eastern Ave
Covington, KY 41014-1325
Phone: 859-581-8566
Web site: www.midamericanpools.com
E-mail: pool1boss@fuse.net
Contact: Patrick M. Brennan

Morrison Engineers PLLC CONSULTING, CONTRACTOR
7701 Chapel Hill Rd
Raleigh, NC 27607-4988
Phone: 919-851-2021
Web site: www.morrisonengineers.com
E-mail: james@morrisonengineers.com
Contact: James Hoover

Multicrete Systems Inc. ADMIXTURES, CONSULTING, CEMENT/POZZOLANIC MATL, CONTRACTOR, EQUIPMENT, SHOTCRETE MATERIALS/MIXES, FIBERS
106 Devos Rd
Winnipeg, MB R3T 5Y1, Canada
Phone: 204-262-5900
Web site: www.multicretesystems.com
E-mail: gnickel@multicretesystems.com
Contact: Georg B. Nickel, P.Eng.

The Nassal Company CONSULTING, CONTRACTOR
415 W Kaley St
Orlando, FL 32806-3942
Phone: 407-648-0400
Web site: www.nassal.com
E-mail: info@nassal.com
Contact: Matt Brown

Nationwide Shotcrete Inc. CONSULTING, CONTRACTOR
23638 Lyons Ave, Ste 273
Newhall, CA 91321-2513
Phone: 661-799-3750
Web site: http://nationwideshotcrete.com/intro
E-mail: nationwideshotcrete@yahoo.com
Contact: Jordan Harpole

www.Shotcrete.org/BuyersGuide

Normet Americas Inc. ADMIXTURES, CONSULTING, CEMENT/POZZOLANIC MATL, EQUIPMENT
19116 Spring St
Union Grove, WI 53182-9602
Phone: 262-498-9797
Web site: www.normet.fi/contacts/region
E-mail: mike.rispin@normet.fi
Contact: Michael Rispin

North County Gunite Co. Ltd. CONTRACTOR
12562 Highway 67
Lakeside, CA 92040-1159
Phone: 619-561-5510
Web site: www.northcountygunite.com
E-mail: tom@northcountygunite.com
Contact: Thomas E. Wares

Oldcastle APG West, Inc. CEMENT/POZZOLANIC MATL
4150 W Turney Ave
Phoenix, AZ 85019-3327
Phone: 602-390-3240
Web site: www.superliteblock.com
E-mail: dave.endres@oldcastleapg.com
Contact: Dave Endres

Osco Gunite & Mudjacking Ltd. CONTRACTOR
5920 98 St NW
Edmonton, AB T6E 3L5, Canada
Phone: 780-469-1234
Web site: www.shotcreting.com
E-mail: osco@mudjacking.com
Contact: Larry Hnatiuk

Pacific Alloy Casting Company Inc. EQUIPMENT
5900 Firestone Blvd
South Gate, CA 90280-3708
Phone: 562-928-1387
Web site: www.pacificalloy.com
E-mail: mregus@pacificalloy.com
Contact: Mark Regus

Palmetto Gunite Construction Company Inc. CONTRACTOR, EQUIPMENT
PO Box 388
Ravenel, SC 29470-0388
Phone: 843-889-2227
Web site: www.palmettogunite.com
E-mail: thendpalgun@cs.com
Contact: Thomas A. Hendricks

PCI Roads LLC CONTRACTOR, EQUIPMENT
14123 42nd St NE
Saint Michael, MN 55376-9564
Phone: 763-497-6100
Web site: www.pciroads.com
E-mail: jcorley@pciroads.com
Contact: John Corley

Pool Engineering Inc. CONSULTING, CONTRACTOR
1201 N Tustin Ave
Anaheim, CA 92807-1646
Phone: 714-630-6100
Web site: www.pooleng.com
E-mail: ronl@pooleng.com
Contact: Ron Lacher

Preload Inc. CONTRACTOR
60 Commerce Dr
Hauppauge, NY 11788-3929
Phone: 631-231-8100
Web site: www.preload.com
E-mail: dgc@preloadinc.com
Contact: Donald Cameron

Prestige Concrete Products ADMIXTURES, CONSULTING, CEMENT/POZZOLANIC MATL, SHOTCRETE MATERIALS/MIXES, CONTRACTOR
8529 Southpark Cir, Ste 320
Orlando, FL 32819-9064
Phone: 561-478-9980
Web site: www.prestige-gunite.com
E-mail: pxampey@prestige-concrete.com
Contact: Paul Ampey

ProShot Concrete Inc. CONTRACTOR
4158 Musgrove Dr
Florence, AL 35630-6396
Phone: 256-764-5941
Web site: www.proshotconcrete.com
E-mail: patm@proshotconcrete.com
Contact: Patrick A. Mooney

Putzmeister America Inc. CONTRACTOR, EQUIPMENT
1733 90th St
Sturtevant, WI 53177-1805
Phone: 262-886-3200
Web site: www.putzmeister.com
E-mail: blicklek@putzam.com
Contact: Kelly Blickle

Putzmeister Iberica S A EQUIPMENT
Camino De Hormigueras 173
Cornelius, NC 28031, Spain
Phone: 011-34914288100
E-mail: info@putzmeister.es
Contact: Christine Krauss

The Quikrete Companies CEMENT/POZZOLANIC MATL, SHOTCRETE MATERIALS/MIXES
3490 Piedmont Rd NE
Atlanta, GA 30305-1752
Phone: 724-539-6600
Web site: www.quikrete.com
E-mail: dbittner@quikrete.com
Contact: Dennis Bittner

Ram Construction Services CONSULTING, CONTRACTOR
13800 Eckles Rd
Livonia, MI 48150-1041
Phone: 734-464-3800
Web site: www.ramservices.com
E-mail: rmaxwell@ramservices.com
Contact: Richard Maxwell

Ram Jack of Charlotte, LLC CONTRACTOR
PO Box 2991
Huntersville, NC 28070-2991
Phone: 704-892-2900
Web site: www.ramjackcharlotte.com
E-mail: markramjack@bellsouth.net
Contact: Mark Beckham

www.Shotcrete.org/BuyersGuide

RCS Consulting & Construction Company Inc. CONSULTING
PO Box 714
Ripley, WV 25271-0714
Phone: 304-532-2479
Web site: www.rcscoinc.com
E-mail: rschallom@rcscoinc.com
Contact: Raymond Schallom III

REED Shotcrete Equipment EQUIPMENT
13822 Oaks Ave
Chino, CA 91710-7008
Phone: 909-287-2100
Web site: www.reedpumps.com
E-mail: mike.newcomb@reedmfg.com
Contact: Mike Newcomb

Restek Inc. CONTRACTOR
6601 Boucher Dr
Edmond, OK 73034-8582
Phone: 405-330-3950
E-mail: restek@flash.net
Contact: Ellery N. Brown

RG Johnson Company Inc. CONTRACTOR, SHOTCRETE MATERIALS/MIXES
25 S College St
Washington, PA 15301-4821
Phone: 724-222-6810
Web site: www.rgjohnsoninc.com
E-mail: rich@rgjohnsoninc.com
Contact: Richard E. Adasiak

Robert H Ward & Associates CONSULTING, CONTRACTOR, EQUIPMENT
3300 Holeman Ave
South Chicago Heights, IL 60411-5520
Phone: 708-756-0767
Web site: www.rhwardandassociates.com
E-mail: shotcreterjr@hotmail.com
Contact: Blake Rago

Schnabel Foundation Company CONTRACTOR
2950 S Jamaica Ct, Ste 107
Aurora, CO 80014-2686
Phone: 303-696-7268
Web site: www.schnabel.com
E-mail: todd@schnabel.com
Contact: Todd Duncan

Serafina Industries Ltd. ADMIXTURES, CONSULTING, CEMENT/POZZOLANIC MATL, CONTRACTOR, EQUIPMENT, SHOTCRETE MATERIALS/MIXES
286 West Montauk Highway, Unit G
Hampton Bays, NY 11946
Phone: 631-259-2760
Web site: www.serafinaconcrete.com
E-mail: info@serafinaconcrete.com
Contact: Joseph Tortorella

Shotcrete Montana ADMIXTURES, CONTRACTOR, CEMENT/POZZOLANIC MATL, EQUIPMENT, FIBERS
PO Box 685
19 S Woodard
Absarokee, MT 59001-0685
Phone: 406-328-7344
Web site: www.shotcretemt.com
E-mail: larry@shotcretemt.com
Contact: Larry Mooney

Shotcrete Technologies Inc. ADMIXTURES, CONSULTING, CEMENT/POZZOLANIC MATL, CONTRACTOR
PO Box 3274
Idaho Springs, CO 80452-3274
Phone: 303-567-4871
Web site: www.shotcretetechnologies.com
E-mail: info@shotcretetechnologies.com
Contact: Kristian Loevlie

Sika Corporation ADMIXTURES, CEMENT/POZZOLANIC MATL
201 Polito Ave
Lyndhurst, NJ 07071-3601
Phone: 201-508-6698
Web site: www.sikaconstruction.com
E-mail: sompura.ketan@sika-corp.com
Contact: Ketan Sompura

Sofis Company Inc. CONTRACTOR
554 Bocktown Cork Rd
Clinton, PA 15026-1142
Phone: 724-378-2670 x2
Web site: http://sofiscompany.com
E-mail: tsofis@sofiscompany.com
Contact: Ted W. Sofis

South Shore Gunite Pool & Spa, Inc. CONSULTING, CONTRACTOR
7 Progress Ave
Chelmsford, MA 01824-3606
Phone: 800-649-8080
Web site: www.ssgpools.com
E-mail: rguarino@southshoregunitepools.com
Contact: Robert E. Guarino

Southwest V-Ditch Inc. CONTRACTOR
3625 Placentia Ln
Riverside, CA 92501-1119
Phone: 951-781-4303
Web site: www.swvditch.com
E-mail: mail@swvditch.com
Contact: Bob Shepherd

Spec Mix Inc. EQUIPMENT, SHOTCRETE MATERIALS/MIXES
PO Box 930134
Atlanta, GA 31193-0134
Phone: 651-994-7120
Web site: www.specmix.com
E-mail: nblohowiak@specmix.com
Contact: Nick Blohowiak

Stone Valley Construction Inc. CONSULTING, CONTRACTOR, CEMENT/POZZOLANIC MATL, EQUIPMENT, FIBERS, SHOTCRETE MATERIALS/MIXES
132 Coaldale Rd
Philipsburg, PA 16866-2333
Phone: 814-342-7151
Web site: www.stone-valley.com
E-mail: kknepp@stone-valley.com
Contact: Ken Knepp

Structural Shotcrete Systems Inc. CONTRACTOR
12645 Clark St
Santa Fe Springs, CA 90670-3951
Phone: 562-941-9916
Web site: www.structuralshotcrete.com
E-mail: jason1@structuralshotcrete.com
Contact: Jason Weinstein

www.Shotcrete.org/BuyersGuide

StructureWerks CEMENT/POZZOLANIC MATL, CONSULTING, CONTRACTOR, SHOTCRETE MATERIALS/MIXES
12600 Robin Ln, Ste 100
Brookfield, WI 53005-3124
Phone: 262-781-4329
Web site: www.structurewerks.com
E-mail: rpreschat@structurewerks.com
Contact: Ross Preschat

Sunwest Gunite Co. ADMIXTURES, CONSULTING, CONTRACTOR, FIBERS
7045 Luella Anne Dr NE
Albuquerque, NM 87109-3907
Phone: 505-821-2549
Web site: www.sunwestguniteco.com
E-mail: garyocanna@gmail.com
Contact: Gary O'Canna

TBH & Associates LLC CONSULTING, CONTRACTOR
5211 NE 88th St
Vancouver, WA 98665-0931
Phone: 360-546-1600
Web site: www.tbhdrill.com
E-mail: ptapio@tbhdrill.com
Contact: Peter Tapio

Testing, Engineering & Consulting Services Inc. CONSULTING, CONTRACTOR
235 Buford Dr
Lawrenceville, GA 30046-4945
Phone: 770-995-8000
Web site: www.tecservices.com
E-mail: tmccants@tecservices.com
Contact: James Glenn McCants III

Thiessen Team USA Inc. ADMIXTURES, CONSULTING, CONTRACTOR, EQUIPMENT, FIBERS, SHOTCRETE MATERIALS/MIXES
PO Box 40
Elko, NV 89803-0040
Phone: 775-777-1205
Web site: www.thiessenteam.com
E-mail: solutions@thiessenteam.com
Contact: James Schumacher/Jessica Florence

Top Gun of Virginia Inc. CONTRACTOR
10017 Richmond Hwy
Lorton, VA 22079-2421
Phone: 703-550-9207
Web site: www.topgungunite.com
E-mail: info@topgungunite.com
Contact: Jon Slaunwhite

Topcor Services Inc. ADMIXTURES, CONSULTING, CEMENT/POZZOLANIC MATL, CONTRACTOR, EQUIPMENT, FIBERS
12025 Industriplex Blvd
Baton Rouge, LA 70809-5131
Phone: 225-753-7067
Web site: www.topcor.com
E-mail: jbaker@topcor.com
Contact: James M. Baker

Torkret Ltd. CONSULTING, CONTRACTOR
Ul Grabowa 8
Siekierki Wielkie
Wielkopolska 62025, Poland
Phone: 486-189-7810 x2
Web site: www.torkret.com.pl
E-mail: biuro@torkret.com.pl
Contact: Wlodzimierz Czajka

Traylor Bros., Inc. CONTRACTOR
835 N Congress Ave
Evansville, IN 47715-2452
Phone: 812-477-1542
Web site: www.traylor.com
E-mail: mburdick@traylor.com

Truesdell Corporation
1310 W 23rd St
Tempe, AZ 85282-1837
Phone: 602-437-1711
Web site: www.truesdellcorp.com
E-mail: kclink@truesdellcorp.com
Contact: Kurt Clink

Val-Mar Inc. ADMIXTURES, CONSULTING, CEMENT/POZZOLANIC MATL, CONTRACTOR, EQUIPMENT, SHOTCRETE MATERIALS/MIXES
12775 Rue Brault
Mirabel, QC J7J 0C4, Canada
Phone: 514-832-0550
Web site: www.val-mar.ca
E-mail: mhudon@val-mar.ca
Contact: Matthieu Hudon

Vancouver Shotcrete & Shoring Inc. CONSULTING, CEMENT/POZZOLANIC MATL, CONTRACTOR, EQUIPMENT, SHOTCRETE MATERIALS/MIXES
9314 182 St
Surrey, BC V4N 3V9, Canada
Phone: 604-881-4898
E-mail: vancrete@shawcable.com
Contact: Rabi Gill

Western Shotcrete Equipment Inc. EQUIPMENT
HC 1 Box 193
Fairdealing, MO 63939-9708
Phone: 573-857-2085
Web site: www.wseshotcrete.com
E-mail: josephharpole@wseshotcrete.com
Contact: Joe Harpole

Whiteside Construction Corporation CONTRACTOR
1151 Hensley St
Richmond, CA 94801-2162
Phone: 510-774-1224
Web site: www.whitesideconstruction.com
E-mail: bbranstad@whitesideconstruction.com
Contact: Robert Branstad

WLH Construction Company CONTRACTOR
2000 W 60th Ave
Denver, CO 80221-6631
Phone: 303-347-8655
Web site: www.wlhconstruction.com
E-mail: wharrison@wlhconstruction.com
Contact: Warren Harrison

Wurster Engineering & Construction CONSULTING, CONTRACTOR
34 Carrie Dr
Greenville, SC 29615-5611
Phone: 964-627-7751
Web site: www.wursterinc.com
Contact: Daryl Wurster

www.Shotcrete.org/BuyersGuide

SPECIALTIES

The following list of ASA Corporate Members is current as of December 1, 2011.
For a current listing, including the ability to search by seven major specialties (as well as over 100 subspecialties) and states/provinces served, visit the online ASA Buyers Guide at **www.Shotcrete.org/BuyersGuide**.

Admixtures

Aircrete Systems LP Inc.	Calgary, AB, Canada
BASF Admixtures Inc.	Cleveland, OH
Blastcrete Equipment Company	Anniston, AL
Cementec Industries Inc.	Calgary, AB, Canada
The Euclid Chemical Company	Cleveland, OH
Grace Construction Products	Cambridge, MA
J Tortorella Swimming Pools Inc.	Southampton, NY
Kryton International Inc.	Vancouver, BC, Canada
Multicrete Systems Inc.	Winnipeg, MB, Canada
Normet Americas Inc.	Union Grove, WI
Prestige Concrete Products	Orlando, FL
Serafina Industries Ltd.	Hampton Bays, NY
Shotcrete Montana	Absarokee, MT
Shotcrete Technologies Inc.	Idaho Springs, CO
Sika Corporation	Lyndhurst, NJ
Sunwest Gunite Co.	Albuquerque, NM
Thiessen Team USA Inc.	Elko, NV
Topcor Services Inc.	Baton Rouge, LA
Val-Mar Inc.	Mirabel, QC, Canada

Cement/Pozzolanic Matl

Aircrete Systems LP Inc.	Calgary, AB, Canada
Blastcrete Equipment Company	Anniston, AL
Cementec Industries Inc.	Calgary, AB, Canada
The Euclid Chemical Company	Cleveland, OH
Lafarge North America	Bingham Farms, MI
Lehigh Cement Company/White Cement Division	Allentown, PA
Multicrete Systems Inc.	Winnipeg, MB, Canada
Normet Americas Inc.	Union Grove, WI
Oldcastle APG West, Inc.	Phoenix, AZ
Prestige Concrete Products	Orlando, FL
The Quikrete Companies	Atlanta, GA
Serafina Industries Ltd.	Hampton Bays, NY
Shotcrete Montana	Absarokee, MT
Shotcrete Technologies Inc.	Idaho Springs, CO
Sika Corporation	Lyndhurst, NJ
Stone Valley Construction Inc.	Philipsburg, PA
StructureWerks	Brookfield, WI
Topcor Services Inc.	Baton Rouge, LA
Val-Mar Inc.	Mirabel, QC, Canada
Vancouver Shotcrete & Shoring Inc.	Surrey, BC, Canada

Consulting

Aircrete Systems LP Inc.	Calgary, AB, Canada
AMEC Environment & Infrastructure	Burnaby, BC, Canada
Baker Concrete Construction, Inc.	Monroe, OH
Bekaert Corporation	Marietta, GA
BelPacific Excavating & Shoring Ltd.	Burnaby, BC, Canada
Blastcrete Equipment Company	Anniston, AL
California Skateparks	Upland, CA
Carolina Concrete Systems, Inc.	Charleston, SC
Concrete Engineering Group LLC	Northbrook, IL
Craig Olden, Inc.	Little Elm, TX
Deluxe Shotcrete & Concrete Construction	Santa Rosa, CA
DOMTEC International LLC	Idaho Falls, ID
Drakeley Industries LLC	Bethlehem, CT
Drill Tech Drilling & Shoring, Inc.	Antioch, CA
Group Works LLC	Wilton, CT
Hardcore Shotcrete Skateparks Inc.	Joplin, MO
J Tortorella Swimming Pools Inc.	Southampton, NY
Joseph J. Albanese Inc.	Santa Clara, CA
Lafarge North America	Bingham Farms, MI
Metro Testing Laboratories Ltd.	Burnaby, BC, Canada
Morrison Engineers PLLC	Raleigh, NC
Multicrete Systems Inc.	Winnipeg, MB, Canada
The Nassal Company	Orlando, FL
Nationwide Shotcrete Inc.	Newhall, CA
Normet Americas Inc.	Union Grove, WI
Pool Engineering Inc.	Anaheim, CA
Prestige Concrete Products	Orlando, FL
Ram Construction Services	Livonia, MI
RCS Consulting & Construction Company Inc.	Ripley, WV
Robert H. Ward & Associates	South Chicago Heights, IL
Serafina Industries Ltd.	Hampton Bays, NY
Shotcrete Technologies Inc.	Idaho Springs, CO
South Shore Gunite Pool & Spa, Inc.	Chelmsford, MA
Stone Valley Construction Inc.	Philipsburg, PA
StructureWerks	Brookfield, WI
Sunwest Gunite Co.	Albuquerque, NM
TBH & Associates LLC	Vancouver, WA
Testing, Engineering & Consulting Services Inc.	Lawrenceville, GA
Thiessen Team USA Inc.	Elko, NV
Topcor Services Inc.	Baton Rouge, LA
Torkret Ltd.	Siekierki Wielkie, Wielkopolska, Poland
Val-Mar Inc.	Mirabel, QC, Canada
Vancouver Shotcrete & Shoring Inc.	Surrey, BC, Canada
Wurster Engineering & Construction	Greenville, SC

Contractors

Abbott Shoring & Foundation Ltd.	North Vancouver, BC, Canada
Aircrete Systems LP Inc.	Calgary, AB, Canada
Airplaco Equipment Company	Cincinnati, OH
American Concrete Restorations Inc.	Lemont, IL
Azteca Gunite	Houston, TX
Baker Concrete Construction, Inc.	Monroe, OH
Bekaert Corporation	Marietta, GA
BelPacific Excavating & Shoring Ltd.	Burnaby, BC, Canada
Blastcrete Equipment Company	Anniston, AL
Boulderscape Inc.	San Juan Capistrano, CA
California Skateparks	Upland, CA
Carolina Concrete Systems, Inc.	Charleston, SC
Clark Foundations, LLC	Bethesda, MD
Coastal Gunite Construction Company	Cambridge, MD
ConCreate USL Ltd.	Bolton, ON, Canada
Concrete Repairs & Contracting Co.	Abu Dhabi, United Arab Emirates
Contech Services, Inc.	Seattle, WA
Cowin & Company Inc.	Birmingham, AL
Craig Olden, Inc.	Little Elm, TX
The Crom Corporation	Gainesville, FL
C-TEC, Inc.	York, NE
Custom Crete Inc.	Austin, TX
Dees Hennessey Inc.	San Carlos, CA
Delta Gunite Solano Inc.	Fairfield, CA
Deluxe Shotcrete & Concrete Construction	Santa Rosa, CA
DOMTEC International LLC	Idaho Falls, ID
Donald J. Scheffler Construction	City Of Industry, CA
Douglas Aquatics, Inc.	Richmond, VA
Drake Inc.	Waco, NE
Drakeley Industries LLC	Bethlehem, CT
Drill Tech Drilling & Shoring, Inc.	Antioch, CA
East Coast Shotcrete, LLC (ECS)	Milltown, NJ
Eastern Gunite Company Inc.	Exton, PA
Epoxy Design Systems Inc.	Houston, TX
Facca Incorporated	Ruscom Station, ON, Canada
Fibercon International Inc.	Evans City, PA
Fisher Shotcrete Inc.	Higley, AZ
Frontier-Kemper Constructors Inc.	Evansville, IN
Group Works LLC	Wilton, CT
Hardcore Shotcrete Skateparks Inc.	Joplin, MO

www.Shotcrete.org/BuyersGuide

SPECIALTIES

The following list of ASA Corporate Members is current as of December 1, 2011. For a current listing, including the ability to search by seven major specialties (as well as over 100 subspecialties) and states/provinces served, visit the online ASA Buyers Guide at **www.Shotcrete.org/BuyersGuide**.

Contractors, cont.

Hardrock Concrete Inc.	Etobicoke, ON, Canada
Hydro Arch	Henderson, NV
J Tortorella Swimming Pools Inc.	Southampton, NY
John Rohrer Contracting Company Inc.	Kansas City, KS
Johnson Western Gunite Company	San Leandro, CA
Joseph J. Albanese Inc.	Santa Clara, CA
Knowles Industrial Services Corp.	Gorham, ME
Mar-Allen Concrete Products Inc.	Ephrata, PA
Mays Construction Specialties Inc.	Grand Junction, CO
Mid American Gunite Pools Inc.	Covington, KY
Morrison Engineers PLLC	Raleigh, NC
Multicrete Systems Inc.	Winnipeg, MB, Canada
The Nassal Company	Orlando, FL
Nationwide Shotcrete Inc.	Newhall, CA
North County Gunite Co. Ltd.	Lakeside, CA
Osco Gunite & Mudjacking Ltd.	Edmonton, AB, Canada
Palmetto Gunite Construction Company Inc.	Ravenel, SC
PCI Roads LLC	Saint Michael, MN
Pool Engineering Inc.	Anaheim, CA
Preload Inc.	Hauppauge, NY
Prestige Concrete Products	Orlando, FL
ProShot Concrete Inc.	Florence, AL
Putzmeister America Inc.	Sturtevant, WI
Ram Construction Services	Livonia, MI
Ram Jack of Charlotte, LLC	Huntersville, NC
Restek Inc.	Edmond, OK
RG Johnson Company Inc.	Washington, PA
Robert H Ward & Associates	South Chicago Heights, IL
Schnabel Foundation Company	Aurora, CO
Serafina Industries Ltd.	Hampton Bays, NY
Shotcrete Montana	Absarokee, MT
Shotcrete Technologies Inc.	Idaho Springs, CO
Sofis Company Inc.	Clinton, PA
South Shore Gunite Pool & Spa, Inc.	Chelmsford, MA
Southwest V-Ditch Inc.	Riverside, CA
Stone Valley Construction Inc.	Philipsburg, PA
Structural Shotcrete Systems Inc.	Santa Fe Springs, CA
StructureWerks	Brookfield, WI
Sunwest Gunite Co.	Albuquerque, NM
TBH & Associates LLC	Vancouver, WA
Testing, Engineering & Consulting Services Inc.	Lawrenceville, GA
Thiessen Team USA Inc.	Elko, NV
Top Gun of Virginia Inc.	Lorton, VA
Topcor Services Inc.	Baton Rouge, LA
Torkret Ltd.	Siekierki Wielkie, Wielkopolska, Poland
Traylor Bros., Inc.	Evansville, IN
Val-Mar Inc.	Mirabel, QC, Canada
Vancouver Shotcrete & Shoring Inc.	Surrey, BC, Canada
Whiteside Construction Corporation	Richmond, CA
WLH Construction Company	Denver, CO
Wurster Engineering & Construction	Greenville, SC

Equipment

Acme America Inc.	Coopersburg, PA
Aircrete Systems LP Inc.	Calgary, AB, Canada
Airplaco Equipment Company	Cincinnati, OH
Allentown Shotcrete Technology Inc.	Sturtevant, WI
Bekaert Corporation	Marietta, GA
Blastcrete Equipment Company	Anniston, AL
Carolina Concrete Systems, Inc.	Charleston, SC
ConCreate USL Ltd.	Bolton, ON, Canada
Construction Forms, Inc.	Port Washington, WI
Custom Crete Inc.	Austin, TX
Eastern Gunite Company Inc.	Exton, PA
Elkin Hi Tech Inc.	Indiana, PA
Fibercon International Inc.	Evans City, PA
Gunite Supply & Equipment Co.	Monrovia, CA
J Tortorella Swimming Pools Inc.	Southampton, NY
Johnson Western Gunite Company	San Leandro, CA
King Packaged Materials Company	Burlington, ON, Canada
Multicrete Systems Inc.	Winnipeg, MB, Canada
Normet Americas Inc.	Union Grove, WI
Pacific Alloy Casting Company Inc.	South Gate, CA
Palmetto Gunite Construction Company Inc.	Ravenel, SC
PCI Roads LLC	St. Michael, MN
Putzmeister America Inc.	Sturtevant, WI
Putzmeister Iberica S A	Cornelius, NC, Spain
REED Shotcrete Equipment	Chino, CA
Robert H Ward & Associates	South Chicago Heights, IL
Serafina Industries Ltd.	Hampton Bays, NY
Shotcrete Montana	Absarokee, MT
Spec Mix Inc.	Atlanta, GA
Stone Valley Construction Inc.	Philipsburg, PA
Thiessen Team USA Inc.	Elko, NV
Topcor Services Inc.	Baton Rouge, LA
Val-Mar Inc.	Mirabel, QC, Canada
Vancouver Shotcrete & Shoring Inc.	Surrey, BC, Canada
Western Shotcrete Equipment Inc.	Fairdealing, MO

Fibers

Aircrete Systems LP Inc.	Calgary, AB, Canada
Bekaert Corporation	Marietta, GA
ConCreate USL Ltd.	Bolton, ON, Canada
The Euclid Chemical Company	Cleveland, OH
Fibercon International Inc.	Evans City, PA
Forta Corporation	Grove City, PA
King Packaged Materials Company	Burlington, ON, Canada
Multicrete Systems Inc.	Winnipeg, MB, Canada
Shotcrete Montana	Absarokee, MT
Stone Valley Construction Inc.	Philipsburg, PA
Sunwest Gunite Co.	Albuquerque, NM
Thiessen Team USA Inc.	Elko, NV
Topcor Services Inc.	Baton Rouge, LA

Shotcrete Materials/Mixes

Aircrete Systems LP Inc.	Calgary, AB, Canada
The Blanchard Group	Allardville, NB, Canada
Blastcrete Equipment Company	Anniston, AL
Custom Crete Inc.	Austin, TX
Delta Gunite Solano Inc.	Fairfield, CA
Delta Industrial Services Inc.	Delta Junction, AK
Deluxe Shotcrete & Concrete Construction	Santa Rosa, CA
Hardrock Concrete Inc.	Etobicoke, ON, Canada
J Tortorella Swimming Pools Inc.	Southampton, NY
King Packaged Materials Company	Burlington, ON, Canada
Multicrete Systems Inc.	Winnipeg, MB, Canada
Prestige Concrete Products	Orlando, FL
The Quikrete Companies	Atlanta, GA
RG Johnson Company Inc.	Washington, PA
Serafina Industries Ltd.	Hampton Bays, NY
Spec Mix Inc.	Atlanta, GA
Stone Valley Construction Inc.	Philipsburg, PA
StructureWerks	Brookfield, WI
Thiessen Team USA Inc.	Elko, NV
Val-Mar Inc.	Mirabel, QC, Canada
Vancouver Shotcrete & Shoring Inc.	Surrey, BC, Canada

www.Shotcrete.org/BuyersGuide

Shotcrete Calendar

JANUARY 12-13, 2012
Shotcrete 2012 Conference and Exhibition
Conference language: German; English summaries of all presentations will be available. Some presentations will be in English.
Alpbach, Tyrol, Austria
Web site: **www.spritzbeton-tagung.com**

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

Scheduled in Room S225:

8:30 a.m.-11:30 a.m.	Examiners Round Table
12:00 p.m.-12:30 p.m.	ASA Annual Meeting
12:30 p.m.-1:30 p.m.	ASA Pool & Recreational Shotcrete Committee
1:30 p.m.-3:30 p.m.	ASA Marketing & Membership Committee
3:30 p.m.-5:00 p.m.	ASA Board of Direction

JANUARY 23-27, 2012
World of Concrete
Seminars: January 23-27
Exhibits: January 24-27
Visit ASA at booth #S10749
Las Vegas Convention Center
Las Vegas, NV
Web site: **www.worldofconcrete.com**

JANUARY 24, 2012
ASA Outstanding Shotcrete Project Awards Banquet
Paris Las Vegas Hotel & Casino
Las Vegas, NV
6:00 p.m.-11:00 p.m.

JANUARY 25, 2012
WOC Seminar: The Diversity of Shotcrete as a Method of Concrete Placement
8:30 a.m.-10:00 a.m.
Las Vegas Convention Center
Las Vegas, NV
Web site: **www.worldofconcrete.com**

FEBRUARY 19-22, 2012
2012 SME Annual Meeting and Exhibit
Society for Mining, Metallurgy & Exploration
Washington State Convention and Trade Center
Seattle, WA
Web site: **www.smenet.org**

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

MARCH 18-22, 2012
ACI Spring 2012 Convention
Theme: "The Art of Concrete"
Hyatt Regency, Dallas
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**

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**

NOVEMBER 7-9, 2012
ICRI 2012 Fall Convention
Rancho Las Palmas Resort & Spa
Ranchero Mirage, CA
Web site: **www.icri.org**

DECEMBER 2-5, 2012
ASTM International Committee C09, Concrete and Concrete Aggregates
Hyatt Regency Atlanta
Atlanta, GA
Web site: **www.astm.org**

ASA Membership Benefits

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

* Student members outside North America will only receive electronic copies

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

All ASA members and subscribers now have access to the NEW electronic version of *Shotcrete* magazine. A link to this e-magazine is sent as an item in the "What's in the Mix" e-newsletter. To ensure that you receive access to all future issues of the electronic version of the magazine, send your e-mail information to info@shotcrete.org.

ADVERTISERS IN THIS ISSUE

Reader Response Numbers in Parentheses — Page

Airplaco Equipment Company 13
Allentown Shotcrete Technology .... Outside Back Cover
AMEC Environment & Infrastructure 2
American Concrete Restorations, Inc. 35
Coastal Gunite Construction Company 63
Epoxy Design Systems, Inc. 5
Fisher Shotcrete Inc. 62
King Packaged Materials Company .... Inside Front Cover
Prestige Concrete Products....3
The Quikrete Companies 19
RCS Consulting & Construction Co., Inc. 47
REED Shotcrete Equipment .... Inside Back Cover
Shotcrete Helmet 4
Structural Shotcrete Systems, Inc. 49
Superior Gunite/Johnson Western Gunite 6
Western Shotcrete Equipment, Inc. 39