Shotcrete MAGAZINE

A quarterly publication of the American Shotcrete Association

Volume 17, Number 1 ◆ Winter 2015

www.shotcrete.org

Outstanding Shotcrete Project Awards

AMERICAN SHOTCRETE ASSOCIATION

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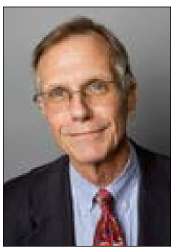
Features

Departments

On the cover: Acoustic Shells, Littlehampton, UK.
Photo courtesy of Flanagan Lawrence.

A Great Year for ASA, and a Very Bright Future Ahead

By Charles S. Hanskat



Wow…just WOW. It's hard to believe my year serving as President is coming to a close. It seems like just a few months ago I stood up at our Annual Outstanding Shotcrete Project Awards Banquet and shared with you my vision for ASA in 2014. It's been a year with a flurry of activity on multiple fronts with major accomplishments.

Some of the highlights of this year:

- Strong growth in membership
- Increased demand for our ASA/ACI Nozzleman Certification sessions
- Rollout of an updated Nozzleman Education session
- ASA published its new "Safety Guidelines for Shotcrete"
- Significant increase in our financial stability
- Substantial funding for critical shotcrete research
- Continued development and publication of Board Position Statements on Best Practices for Shotcrete Placement
- Reorganization of committee structure to maximize their effectiveness
- Continued strong growth in the Outstanding Shotcrete Project Awards Program and Banquet

Perhaps the most important achievement in 2014 is the ASA Strategic Plan. The Plan gives us focus. It sets achievable targets. But, most importantly, it allows our association, composed of members in a variety of different roles across the shotcrete industry, to know where we're headed. What is ASA going to do for you? What is ASA going to do for the craftsmen, project managers, business owners, suppliers, educators, and engineers that are the heart of our industry? Look at the Plan and you'll find the answer to what ASA intends to do for you, your company, and the shotcrete industry.

Of course, any plan is only words on paper until there is buy-in from the members, which leads to their active efforts to accomplish the tasks to reach the goals. The Board recognized that to fuel the intended growth in programs and services ASA provides to the members and the industry, we needed to consider providing more staff resources. In December, the Board voted unanimously to fund in our budget an upgraded full-time Executive Director position, and further to have an Executive Director who is experienced in shotcrete, can actively promote shotcrete to outside groups, is a team builder, and has good connections within the concrete industry.

With the increased support of a full-time Executive Director, and the direction of our Strategic Plan, we will see more rapid progress in many of the areas of growth and service I identified a year ago at the annual Banquet and in my first President's Message:

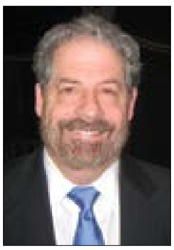
- Enhance and increase membership;
- Evaluate methods to increase funding;
- Engage more members to become active in ASA; and
- Continue to develop strong liaisons with specifiers, owners, and general contractors.

So as the sun sets on my term, it in turn rises for our incoming President, Marcus von der Hofen. I'm confident Marcus will take the lead in moving ASA forward to achieve our strategic goals. I have enjoyed tremendous support from Marcus and indeed the entire Executive Committee (Michael Cotter, Bill Drakeley, and Oscar Duckworth) throughout my term. Our Board of Directors and Committee Chairs have provided great support, and shown a high level of involvement in furthering ASA's goals. Also, two of our Past Presidents, Joe Hutter and Patrick Bridger, have gone above and beyond, continuing to actively serve on our committees and graciously accepting assignments on task groups that benefited from their long experience with ASA. Without a doubt, Alice McComas and Mark Campo deserve my thanks and admiration for routinely and expertly tackling all those day-to-day association operations that we as volunteers could never fill, and always being available to help when needed.

Finally, I'd like to thank all the members of ASA. Without you there would be no ASA, and I would never have been able to experience the exhilaration of leading ASA forward, and helping to establish a long-term vision of where we, ASA, will be as future presidents, officers, Board members, and committee members take the reins, and move ASA onward and upward.

ASA Publications Committee

By Ted Sofis



We've come a long way since ASA was first formed in 1998. Today, *Shotcrete* magazine has a circulation that is read by engineers, contractors, and manufacturers, not just in North America but around the world. We have a distribution of 17,000 and there are over 100 countries where the electronic version of the magazine is received. *Shotcrete* magazine provides a valuable resource to the industry, providing insight and information on the various aspects of the shotcrete process.

There is a lot to be excited about. The ASA Board of Direction has approved a new Strategic Plan that identifies the Association's most important initiatives. ASA is actively promoting the safe and beneficial use of shotcrete in the construction industry. This includes contributions to fund research on the durability of shotcrete, comparing the properties and service life of cast-in-place concrete to those of dry- and wet-mix shotcrete. Both our Pool & Recreational Shotcrete Committee as well as our Board of Direction have begun to issue position papers that were first published in the magazine and now available on our "Resources" page online. You will be able to read about this and other developments in *Shotcrete* magazine.

The Publications Committee takes great care to select relevant themes for each issue of the magazine to address the wide scope of applications where shotcrete work is performed. In addition to our featured theme articles, we cover topics of interest to our readers with regular features, including "Technical Tip," "Nozzleman Knowledge," "Safety Shooter," "Goin' Underground," "Pool & Recreational Shotcrete Corner," and "Shotcrete Corner."

Our recently launched, renovated ASA website provides a forum where shotcrete-related questions can be submitted and answered by the members of our technical team. Many of these are printed in our magazine. Our technical team is made up of shotcrete professionals with extensive experience in the many different segments of the shotcrete industry. I would like to personally thank all the members of our technical team for the time they give responding to all the questions submitted by our readers. I believe the strength of ASA comes from the cross section of our membership. All articles are now searchable online in our "Archives" search.

Each year, the Publications Committee awards the Carl Akeley Award at our annual ASA Shotcrete Project Awards Banquet to recognize the top technical paper published in *Shotcrete* magazine over the previous year. ASA also awards scholarships for graduate students in both the United States and Canada. In recent years, various ASA task groups and committees have put together documents on safety, inspector training, and certification education. ASA members also continue to have active involvement within the ACI Committee C660, Shotcrete Nozzleman Certification.

Our Awards issue of *Shotcrete* magazine features the Outstanding Shotcrete Project awards that highlight project winners in

Committee Chair Memo

various categories. The Fall issue carries the Buyers Guide, which has a bonus distribution via ASA's booth at World of Concrete in Las Vegas, NV. The magazine has a section for New Products and Processes as well as Industry News. These are an added benefit for our Corporate Members, who can submit information, announcements, or news items at any time. We encourage our Corporate Members to take advantage of this wonderful opportunity to share your news with our readership! Corporate members can also sign up to submit their Corporate Member Profile for publication—each issue, another Company Profile is featured. These are some of the many things that go into making *Shotcrete* magazine the outstanding trade magazine that it is.

None of this would be possible without the dedicated work of our Technical Editor Charles Hanskat and our Program Coordinator Alice McComas. I would also like to thank our committee chairs who, in addition to their other duties, volunteer their time to spearhead issues and secure content. Last but not least, a thank-you is extended to our authors, who take the time and effort to write about and share their insights on the wide range of shotcrete projects, techniques, and innovations that you read about on the pages of *Shotcrete* magazine. If you have a topic you would like to hear about or a subject you would like to write about, please submit your ideas to us at info@shotcrete.org.

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ASA's Outstanding Shotcrete Project Awards:

Benefitting the Shotcrete Industry

By Mark A. Campo, ASA Executive Director

This February marks the 10th occasion that ASA members have gathered to celebrate the year's most outstanding shotcrete projects. This 10th Annual Outstanding Shotcrete Project Awards Banquet was held for its second year at the Staten Island Ballroom in the New York, New York Hotel & Casino, Las Vegas, NV, a private yet large gathering space that appropriately fits the level of excitement and enthusiasm contained within. With a record number of attendees preregistered for the event, it was wonderful to witness such strong commitment from everyone in the shotcrete industry.

Ten years has seen an increase in quantity and quality of projects submitted. Ten years has seen greater creativity and innovation in overcoming obstacles and time constraints to deliver amazing results. Ten years of notable, impressive growth in banquet attendance and sponsorships!

ASA's Outstanding Shotcrete Project Awards program benefits the shotcrete industry in a number of ways, from ensuring that the shotcrete method of concrete placement receives the exposure and credibility it deserves, to recognizing excellence in design and execution where it is deserved. These truly outstanding projects often provide reference points for Technical Inquiries; at complimentary Onsite Seminars given to architects, engineers, and specifiers; and at tradeshows and other classes given by ASA speakers, thus strengthening ASA's abilities to provide tangible examples of successful shotcrete placement and furthering the promotion of the safe and beneficial aspects of shotcrete placement in the construction industry.

Exposure

Each year, the ASA Outstanding Shotcrete Project Awards program continues to receive more and more exposure. And as technology and news outlets throughout the construction industry continue to see ASA press releases and publications, these award-winning projects continue to open the eyes of specifiers to the tremendous benefits of shotcrete placement. This exposure can only help members of ASA grow our industry, which is acknowledged to have some of the construction industry's most innovative contractors, designers, engineers, and suppliers.

Credibility

Witnessing the success of these award-winning shotcrete projects directly reinforces the ultimate vision of ASA—that structures built or repaired with the shotcrete process are accepted as equal or superior to cast-in-place concrete. Gaining stature as a versatile and sustainable placement method for concrete satisfies the core reason for the very existence of this association.

Financial Health of the Association

Special thanks are in order to ASA's banquet sponsors, without whose generous donations this event would not be possible. This year, 34 sponsors contributed a total of $41,000, marking ASA's most successful fundraising effort to date. These sponsorships help to subsidize the cost of individuals' attendance to the banquet, as well as support the programs that embody the mission of ASA: providing training, qualification, certification, education, networking, and leadership to increase the acceptance, quality, and safe practices of the shotcrete process. All of this ultimately serves to promote you and what you do to maintain these high standards of excellence in the industry and grow shotcrete's reputation as a cost-effective, versatile, efficient, and sustainable method for concrete placement.

2014 Outstanding Shotcrete Project Award Winners

International
Acoustic Shells

Underground
Robinson Creek Tunnel Fire

Pool & Recreational
A Natural Look, an Exact Science

Repair & Rehabilitation
The 606-Bloomingdale Trail | Viaduct Repairs

Infrastructure
McCormick Dam & Power Station: Submerged Concrete Repairs

Architecture
Bing Concert Hall

Honorable Mention
Long Prairie Digester Rehabilitation Project
Liberty Tunnel Arch Restoration
Alameda Square

As we begin a new journey into 2015, we hope that all ASA members will begin thinking about current and upcoming shotcrete projects that may be worthy of consideration for next year's ASA Outstanding Shotcrete Project Awards. To facilitate more entries, and to make it easier to submit your projects as they are completed and fresh in mind, ASA is opening up the project award submittal web page immediately after this year's banquet in February. Any project completed between January 1, 2013, and September 1, 2015, will be considered, and multiple projects may be submitted from the same company. We hope that you will submit your outstanding projects NOW, in hopes of being celebrated as an ASA award winner at our next annual banquet.

Recognition of Excellence

Being recognized for excellence and innovation in projects in which your company has been involved could do wonders for your future! Winners receive their award and present an overview of their winning project in front of the entire shotcrete industry at the annual ASA banquet. Winning projects for each category are also published in *Shotcrete* magazine's annual Awards issue, and are also noted in key news and press releases throughout the beginning of the year and featured on our Awards page of the ASA website throughout the year. What could be better than free advertising of your outstanding work?

Many Thanks to President Hanskat

As this magazine goes to print, Charles Hanskat is completing his 1-year term as ASA President. Having served on the Executive Committee since January 2012, he has been a strong factor in the successes of ASA over the last several years.

Charles has been a pleasure to work with—always willing to step up to serve as Examiner for a certification session, review an article, or respond to a technical matter in a way that only a well-seasoned professional engineer knows how. There is no doubt that Charles's thorough knowledge of the entire shotcrete process—and concrete structures in general—has lent great credibility to ASA's publications over the years.

I wish Charles all the best as he continues his work with ASA in 2015 and beyond. Additionally, I wish a successful year to incoming ASA President Marcus von der Hofen, and to the entire Executive Committee, Board of Directors, and committee members who make this association come to life with its member programs and services. ASA's strong position and successful programs are a direct result of all of your hard work!

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2014 Outstanding International Project

Acoustic Shells

By Jason Flanagan

Sited in a sunken garden beside the beach in Littlehampton, West Sussex, UK, these Acoustic Shells act as a stage and shelter for the local community. Designed by Flanagan Lawrence, a London-based architectural practice, the shells were prompted by a desire to reinvigorate Littlehampton with its gentility of the early twentieth century, the shells materially enhance the public open space of the adjacent greensward and satisfy an essential social need that is not provided elsewhere in the area.

The concept for the shells is derived from the notion of a traditional bandstand. Following the Industrial Revolution and worsening conditions in urban areas, bandstands were conceived as a response by local authorities to an increased need for green open spaces where the general public could relax. Following the first bandstand in Britain in the Royal Horticultural Society Gardens in South Kensington in 1861, bandstands became very popular, and were subsequently installed in parks across the country. Competing with new media in the twentieth century, such as cinema and television, bandstands lost their appeal and fell into disuse.

However, the new world of social media has further democratized the production and distribution of music. No longer the preserve of elite musicians, popular music is again made by anyone, and played anywhere—whether online or in public. The Acoustic Shells are a response to this context, bringing back an old ideal—an architecture that can represent sound and the people that made it.

One shell faces the town and forms the principal bandstand. The acoustic design of the interior creates a reflective surface to project the sound of the performers to the audience in the

Stage and shelter (Photo courtesy Flanagan Lawrence)

Shelter (Photo courtesy Flanagan Lawrence) sunken garden. The other shell faces the beach and forms a more intimate structure as a shelter for listening to the sounds of the sea or for entertainers to perform facing the promenade.

The £100,000 budget for the Acoustic Shells prohibited the form of a more traditional bandstand: a large elevated platform, open sides, and an acoustically reflective soffit and roof. This project chose to unify the architectural components of the brief—floor, walls, structure, roof—into a single entity that would reduce materials, complexity, and cost. A traditional timber structure

Stage (Photo courtesy Flanagan Lawrence)

Shelter (Photo courtesy Flanagan Lawrence)

Shelter (Photo courtesy Flanagan Lawrence)

Detail (Photo courtesy Flanagan Lawrence) was ruled out due to the harsh marine environment and the threat of anti-social behavior such as graffiti and arson. It was decided that a robust material was required that could withstand all possible eventualities. Concrete was chosen as a material that could be dense enough to meet an acoustic brief and be robust enough to be a match for the environmental conditions.

An all-concrete structure had its own problems and would have to use innovative construction techniques to limit the wastage inherent in shuttering and forming processes. Research was undertaken in the development of thin shell structures. These can be self-supporting and have structure integrated into the form of the shell. The most efficient technique that would suit was that of sprayed concrete. With care, this process can produce the complexity required by the Acoustic Shells project, and be carried out in a short time frame, thus reducing the site costs further.

Stage (Photo courtesy Flanagan Lawrence)

The project was built in two distinct stages: the construction of the shells by the Shotcrete Group, the specialist sprayed concrete contractor, followed by the integration into the landscaping, which was by Landbuild.

The development of the scheme in three dimensions was very complex and involved considerable input from the contractor. After having developed the form of the building in specialized software, a digital model of the scheme was handed to the Shotcrete Group to drive the development the form. Following the ordering and delivery of the reinforcement bars, a grid of scaffolding 3.3 x 3.3 x 3.3 ft (1 x 1 x 1 m) was set up on the site. A corresponding digital version was set up in the architect's office. Points were taken on the digital model where the form of the shells touched the grid. These were then marked on the scaffold. These points were then checked by digital survey and sent back to the model in the office for review. Once all parties were content with the spatial coordinates, the reinforcing bar mesh could be assembled within the constraints of the marked scaffold, with the confidence that the form of the shells will conform exactly to the shape and specification of the digital version.

Following the reinforcing bar assembly, an expanded metal mesh was threaded into the structure. This acted as stay-in-place formwork and enabled the spraying process to take place from both sides. The thickness of the shell was on average 4 in. (100 mm), with the leading edge thickening to 6 in. (150 mm) for structural stability.

Once sprayed, the structure was hand-finished with metal trowels, creating a perfectly smooth finish. This was then painted and given an anti-graffiti seal.

Since the project's completion in April 2014, the Acoustic Shells have gone on to become a celebrated local landmark for the Littlehampton community. Available for event hire through the local town council, the stage and shelter are also used on a daily basis for play and rest by passers-by. On a wider scale, the project has

Stage (Photo courtesy Flanagan Lawrence)

Stage and shelter (Photo courtesy Flanagan Lawrence)

received global recognition, having been shortlisted for two World Architecture Festival awards and winning the practice the BD Award for Small Project Architect of the Year 2014.

About the Company

Flanagan Lawrence is an award-winning, design-led architectural practice based in London. The practice has an impressive collective expertise across a broad range of sectors and building typology, including large-scale commercial projects and high-end residential schemes, as well as cultural, hotel and leisure, education, infrastructure, logistics, business parks, and major master planning projects both in the United Kingdom and internationally.

Flanagan Lawrence has worked with a diverse body of clients in both the private and public sectors. Private clients include ASK Property, Athos, BAA Lynton, British Land, Brookfield Europe, Candy & Candy, Chelsfield, Development Securities, Espalier, Finchatton, Grainger, Great Portland Estates, Grosvenor, Herby Holdings, Land Securities, Londonewcastle, Muse Developments, Quintain Estates and Developments, Segro, and the Sellar Property Group.

Public sector work has included performance and office spaces, as well as regeneration schemes. Clients have included the Royal Welsh College of Music & Drama, Live Theatre, Riverside Studios, Sadler's Wells Theatre Trust, Soundforms plc, The Sage Gateshead, as well as Imperial College, Oxford, Manchester City Council, and Littehampton Council.

Visit www.flanaganlawrence.com.

The Outstanding International Project

Project Name
Acoustic Shells

Project Location
Littlehampton, West Sussex, UK

Shotcrete Contractor
Shotcrete Group UK

General Contractor
Shotcrete Group UK

Architect/Engineer
Flanagan Lawrence (Architect)
Expedition (Engineer)

Material Supplier/Manufacturer
Shotcrete Group UK

Project Owner
Littlehampton Town Council/
Arun District Council

*Corporate Member of the American Shotcrete Association

"The one thing that unifies our approach is the search for clarity. We are very analytical and don't bring preconceived ideas to the table. We get chosen because we bring freshness and innovation to the process. The overriding unifying feature is the search for the clear, elegant solution." As Design Director, ***Jason Flanagan*** *has been involved in all of Flanagan Lawrence's residential projects. These vary from a residentially led mixed-use scheme in Southwark including private apartments, affordable housing, and a homeless shelter; to individual houses in a village in Cornwall; to high-end residential projects for Candy and Candy, Sellar, and the Grosvenor Estate in London. Flanagan also has an extensive track record of working on public buildings for the performing arts, leading the team on the newly completed, competition-winning scheme for the Royal Welsh College of Music & Drama in Cardiff comprising a concert hall, theatre, and gallery space. Flanagan studied architecture at the Bartlett School of Architecture at London University and at the Royal College of Art. During his studies, he worked for Conran Roche Ltd and Armstrong Associates. He joined Foster + Partners in 1991 and was made Partner at Foster + Partners in 2004. Flanagan joined Flanagan Lawrence in 2006 and has a special interest in acoustics and sound. Amongst his most innovative projects is Soundforms, the first ever mobile acoustic shell with the capacity for a full orchestra.*

2014 Outstanding Underground Project

Robinson Creek Tunnel Fire

By Randy Zeiger, Gabrielle Cadieux, Denis Laviolette, Nick Laviolette, Justin Laviolette, and Edward D. Sparks II

On the eve of Saturday, April 26, 2014, an arson fire engulfed a CSX Transportation railroad tunnel near Robinson Creek, KY, cutting off service to two active coal mines in the area. The biggest and most productive mine is TECO Coal in Myra, KY, which employs approximately 500 personnel, and produces around 2 million tons (1.8 million metric tonnes) of coal per year. Normal track speed for this branch line is 25 mph (40 kph), and train traffic consists of two to three coal trains per week. The tunnel is 742 ft (226 m) in length, most of which was timber lined.

When ignited, the coal seams that outcropped in the tunnel roof and walls, along with the creosote-laden timbers and ties that lined the tunnel, effectively turned the tunnel into an oven, causing much of the walls and roof to collapse. The timber lining system burned for several days before both of the portals were able to be plugged with fill material to suffocate the fire and to address community air quality concerns (refer to Fig. 1).

Fig. 1: Scene of the fire at the west portal on April 26, 2014
(Photo credit: Pike County, KY, newspaper)

CSX Transportation responded to this emergency, focusing on safely restoring service to their customers. This task was wrought with various technical, environmental, and health and safety challenges, including firefighting, managing air quality, and reducing personnel risks while working in a hazardous work environment. AMEC was asked by CSX Transportation to respond to this emergency. AMEC worked with CSXT's Engineering and Environmental departments, HAZMAT, local Division personnel, and LRL Construction Company to manage the incident, address environmental concerns, evaluate the tunnel, and restore rail traffic. HEPACO provided environmental remediation and firefighting expertise. LRL Construction Company performed tunnel exploration and remedial repairs.

The AMEC tunnel engineering design team concluded that an "exploratory investigation" was needed once the fire was brought under control to assess tunnel conditions and determine what was needed to return the tunnel to full service.

Originally, the plan was to remove the earthen plugs at the portals and advance back through the tunnel using a "top heading" approach with hand scaling and rock bolting of the tunnel roof and arches to assess the condition of the tunnel interior. However, the extent of the damage and air quality issues caused by the fire did not permit this type of advance. Temperatures upwards of 3000°F (1650°C) were recorded in the debris pile along the invert of the tunnel, which was up to 15 ft (4.6 m) thick in some places. The debris had to be "mucked" out of the invert to safely advance. This presented a significant challenge due to the extreme temperatures and dangerous atmospheric conditions. With coal seams continuing to burn, it was difficult to create the proper ventilation needed in the tunnel for workers to progress. Fresh air was forced into the tunnel from one portal and withdrawn from the other. The exhaust smoke was routed through a field-fabricated "scrubber" to remove particulate matter before discharge to the environment.

As crews advanced into the tunnel, shotcrete was used to establish the initial structural support and safely assess the condition of the tunnel interior (refer to Fig. 2).

LRL advanced through the tunnel in about 30 ft (9 m) long reaches. This was done by pulling invert muck back toward the open portal with a trackhoe and removing it with a front loader (refer to Fig. 3). Crews then moved forward safely scaling the roof and sidewalls. When ground temperatures and air quality conditions allowed, ACI Certified Nozzlemen placed shotcrete on the ceiling/walls with hand nozzles and a robot to establish initial support. When applied to the coal seams, the shotcrete effectively halted degassing and extinguished visible flare-ups. The high temperatures and CO levels within the tunnel diminished as the shotcrete was applied. As workers cooled down the muck pile and hydroscaled the ceiling and walls, the ground kept "popping" due to rapid cooling. The shotcrete significantly slowed down the cooling process of the rock, and enabled workers to safely press on. LRL workers used an offtrack rubber tire shotcrete operation for the exploration phase because the rail inside the tunnel was deformed. Equipment included a robot tractor mounted arm manufactured by Shotcrete Technologies, a batch plant, and a concrete pump. LRL and the balance of the project team worked 24 hours a day for 24 days to complete this exploration. In this time, LRL installed three-hundred thirty-two 8 ft (2.4 m) long CT-bolts supplied by DSI Underground and placed 100 yd^3 (76 m^3) of shotcrete.

Based on the findings from the exploration, the tunnel engineering design team developed a final liner solution that involved additional rock bolts and shotcrete. Once initial roof support was installed, CSXT crews replaced the track through the tunnel and resumed revenue rail service to the mines on June 10, 2014. Then LRL worked around rail traffic using its rail-mounted shotcrete operation for final liner construction.

LRL was able to place 100 yd^3 (76 m^3) of shotcrete per 12-hour shift. LRL loaded 50 yd^3 (38 m^3) of shotcrete onto their shotcrete train, mobilized 1/4 mile (1/2 km) to the tunnel, placed 50 yd^3 (38 m^3) of shotcrete, flushed hoses, cleaned out the pump, and then cleared the track for a coal train to pass. This process was repeated two times per shift. Final liner construction took approximately 2 weeks. A total of one-hundred seventy-five 13 ft (4 m) and three-hundred seventeen 8 ft (2.4 m) long CT-bolts and 1270 yd^3 (970 m^3) of shotcrete were installed in the tunnel. The shotcrete included 80 lb/yd^3 (47 kg/m^3) of steel fiber reinforcement and yielded a 28-day unconfined compressive strength of 6000 psi (41 MPa).

Fig. 2: Initial shotcrete roof support

Fig. 3: Muck removal with loader

Fig. 4: ACI Certified Nozzleman applying shotcrete to east portal

Fig. 5: Fifty bulk bags loaded on a flat car for final liner installation

Fig. 6: View of final liner from west portal

The QUIKRETE Companies supplied premixed 3000 lb (1360 kg) bulk bags for this project. A total of 1370 bulk bags were used to complete both phases of this project. Using the premixed bulk bags for a job of this caliber guaranteed the materials were uniform and to contract specifications.

Use of the aforementioned construction techniques and materials resulted in rail service restoration 45 days after the fire and full project completion 10 days later. The final product is a reliable, sound tunnel that will support vital railroad service for many years to come (refer to Fig. 4 through 8).

The Outstanding Underground Project

Project Name
Robinson Creek Tunnel Fire

Project Location
Robinson Creek, KY

Shotcrete Contractor
LRL Construction Co. Inc.*

General Contractor
LRL Construction Co. Inc.*

Architect/Engineer
AMEC*

Material Supplier/Manufacturer
The QUIKRETE Companies,*
Shotcrete Technologies*

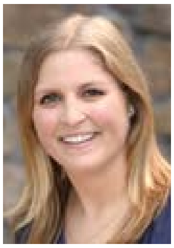
Project Owner
CSX Transportation

*Corporate Member of the American Shotcrete Association

Fig. 7: West portal—final liner

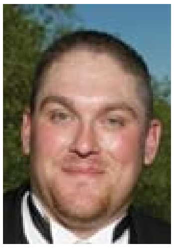
Fig. 8: East portal—final liner

Randy Zeiger *has over 23 years of engineering design and consulting experience on a wide variety of projects for Class 1 Railroads, local and state government agencies, and mining industries. He currently serves as a Senior Project Engineer for AMEC Environment & Infrastructure, Inc. For the past 10 years, he has been focused on railroad services primarily related to tunnel construction, rehabilitation, and monitoring; emergency tunnel and landslide response; roadbed stabilization; and capital improvements such as siding extensions and intermodal yards. For local and state government agencies, Zeiger has experience in the design and permitting for bridges and FEMA Regulated Rivers. For the mining industry, he has experience in the design and permitting for coal refuse impoundments and has investigated, evaluated, and designed many small and large freshwater dams.*



Gabrielle Cadieux *is a Civil Engineer with approximately 2-1/2 years of relative field engineering, design, and consulting experience on a wide variety of projects for Class 1 Railroads, and the U.S. Army Corps of Engineers. She currently serves as a Geotechnical Professional for AMEC Environment & Infrastructure, Inc. For the past year, Cadieux has been focused on railroad services primarily related to roadbed stabilization, slope stability, sinkholes, soft soil improvements, tunnel construction, rehabilitation and monitoring, emergency tunnel and landslide response, and capital improvements such as siding extensions and intermodal yards. Previous experience was with Bauer Foundation Corporation, where she was a Field Engineer at the Center Hill Dam Rehabilitation project in Silver Point, TN, for approximately 11 months.*

Denis 'Dan' Laviolette *is the sole owner of LRL Construction Co., Inc. and has over 40 years of tunneling experience. Laviolette started his company along with two business partners in 1996 and has since taken a small family-owned company into an empire. He takes pride in the specialized work that his company has come to master and is known for fast, safe results when needed most. His extensive knowledge and expertise in tunnel repair, shaft development, tunnel fires, and emergency collapse repair stems back to his mining days and have evolved over the years from working all over the world.*



Nick Laviolette *is LRL Construction's Senior Project Manager and the son of the remaining founder of LRL Construction Co., Denis Laviolette. With over 18 years of experience in tunnel construction for both highways and railways, Laviolette has led his team to complete several large railway clearance projects for multiple rail line owners, as well as various other emergency and reconstruction projects. Laviolette is also responsible in part for LRL's Micro Tunnel and Jack and Bore division.*

Justin Laviolette *is a Project Manager for LRL Construction and has over 15 years of experience in tunnel construction for highway and railways. Laviolette is the son of the remaining LRL Construction founder, Denis Laviolette, and has learned his vast array of experience in mining and tunneling from him. Laviolette has managed and worked many large scaled projects for LRL throughout the United States.*

Edward D. Sparks II *has over 20 years of railroad engineering and maintenance experience on a wide variety of projects in roles of increasing responsibility for CSX Transportation. He currently serves as Assistant Chief Engineer of Structures, responsible for inspection, maintenance, design, and construction of bridges, culverts, and tunnels across the CSX network, which spans 21 states, two provinces, and 21,000 route miles.*

2014 Outstanding Pool & Recreational Project

A Natural Look, an Exact Science

By William T. Drakeley Jr.

This article is based on the article "Country Comfort" by Bill Drakeley in the January 2015 issue of AQUA *magazine. Special thanks to Eric Herman,* AQUA *Senior Editor, for his contributions.*

This project is located in Duchess County, NY, an area defined by its horse and farm country. In particular, the region is full of weekend homes for affluent professionals who work in New York City but escape to the comfort of the countryside on weekends and vacations.

In this case, the clients were equestrian enthusiasts who wanted to make the most of their approximately 100 acre (41 hm^2) property, which features all sorts of jumping gates and horse trails scattered throughout.

Drakeley Pool Company got involved at the suggestion of Eric Groft, a landscape architect with the firm Oehme Von Sweden (Washington, DC). Groft was working with John B. Murray Architects out of New York, who were both familiar with the company's work and thought it would be a good fit for the project team. In addition to Groft and the architect, lighting designers, a sound designer, soils scientists, and a structural engineer were involved. That group also included Dave Peterson of Watershape Consulting (Escondido, CA), who took care of the hydraulic and system design.

Design

In many ways, the design is a terrific example of form meeting function.

The pool is big: 73 ft (22 m) long and 40 ft (12 m) wide with a 9 ft (3 m) deep end. It features a large step treatment on the side adjacent to a pool cabana that echoes the undulating lines of the pool's overall shape. The steps are 2 ft (0.6 m) wide, large enough for entry and egress purposes as well as lounging, and are fitted with LED lights for safe use after dark.

The pool has a perimeter overflow detail that brings the water surface level with the deck, which augments the reflective qualities generated by the dark interior surface.

The original design called for 260 gpm (59 m^3/h) over the edge to achieve complete coverage. The edge detail was so precise, however, that the flow rate was ultimately cut in half and still wet the entire edge. The 1/2 in. (13 mm) slot is set back from the edge 14 in. (355 mm), creating a wet edge detail that visually blends the deck with the pool's interior.

The gutter itself is relatively small—6 in. (150 mm) wide by 10 in. (250 mm) deep. Bather surge capacity is therefore handled by a large below-grade surge tank located downslope of the vessel. A continuous plumbing loop surrounding the pool is fed by gravity, which in turn flows into the surge tank. A secondary circulation system pulls water from the surge tank and pumps it back to the pool to run the edge.

Excavation and Forming

The pool area is on a gentle slope of mostly old fill—lots of rubble, sticks, and no competent soil. Because the material was completely unsuitable for use as a form for shotcrete placement, they had to over-excavate the site and build one-sided forms as if building an above-grade structure. The downslope side of the pool is defined architecturally by a retaining wall with the remainder of the structure entirely below grade.

The forming was tricky. It had to be flexible enough to create the curvature but sturdy enough to prevent the structure from moving during the plumbing and steel installation (not to mention the later shotcrete process). If they didn't get it right, the wall could have been off by a couple inches (mm), which is never acceptable.

Because of the perimeter overflow system, the top of the walls had to be formed with two precise top-of-beam details to create the 6 in. (150 mm) wide gutter. In all, the gutter measures 36 in. (450 mm) wide in its entirety. That meant very precise box forms had to be used to hold the tolerance on the edge when we shot the shell.

Site Preparation

After we over-excavated the pool by approximately 10 ft (3 m) all the way around, they brought in soil, compacted it into place, and carved into it to create the pool shape (Fig. 1 and 2). To help keep everything in place, they then applied a sacrificial layer of concrete via the wet-mix shot-

Fig. 1: Beam profile and edge forming

Fig. 3: Plumbing system under shotcrete shell

Fig. 2: Application of sacrificial shotcrete layer for soil containment

Fig. 4: Steel reinforcement on radius steps

Fig. 5: Floor shotcrete (placed in stages)

Fig. 6: Wall shotcrete and gutter detail

crete process (approximately 5 yd^3 [4 m^3]) to the vertical soil prior to reinforcing bar installation.

Although the water table is below the pool structure, the soil is very dense and retains moisture. Because the clients plan to add all sorts of plantings, there would be a large amount of water flowing around the structure that could be retained by the soil, which could create a hydrostatic imbalance when the pool is drained down the line for maintenance. They also wanted the hole to remain dry during construction (Fig. 3). For all these reasons, a layer of gravel and a system of 4 in. (102 mm) drainpipes were installed in the pool floor to dewater the pool every day from now until eternity. It's always good to have drainage around an in-ground concrete structure. While shells are built to be watertight, they are not meant to function as underground dams.

Shotcrete Installation

Drakeley employs a crew of eight men: two ACI Certified Shotcrete Nozzlemen, one pump operator, two tenders, and three finishers. All crew members are trained on proper safety procedures—not only in pumping mechanics but also in shotcrete applications based on ACI CP-60, "Craftsman Workbook for ACI Certification of Shotcrete Nozzlemen." The shotcrete crew is also up-to-date on all current swimming pool shotcrete position statements from ASA.

They installed 270 yd^3 (200 m^3) of concrete material using wet-mix shotcrete application (Fig. 4 through 6) for an average daily installation

Fig. 7: Curing process for maximum strength gain

Fig. 8: Finished structure suited to surrounding landscape

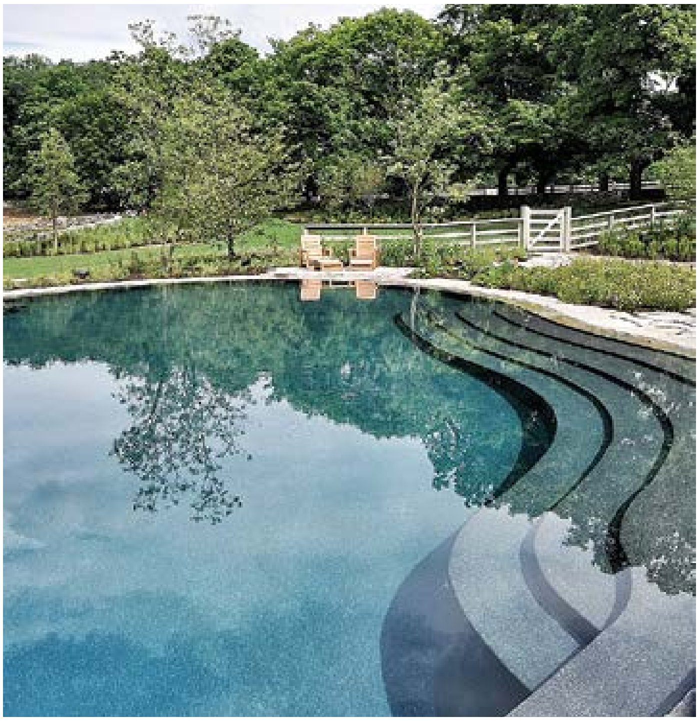


Fig. 9: Tight tolerances and advanced design features facilitated by the shotcrete process

of approximately 60 yd^3 (46 m^3). The mixture design included 750 lb (340 kg) of cement with 50 lb (23 kg) of fly ash and 8% batched entrained air, with a water-cementitious material ratio (*w/cm*) of 0.45. No additional water was added to the delivered concrete outside of or beyond the total allotted mix water from the plant.

Equipment included an Allentown PC 20 shotcrete pump with 4 in. (100 mm) pump discharge; an Ingersoll Rand 375 air compressor; 4 x 3 in. (100 x 75 mm) reducing bushing to 3 in. (75 mm) steel slick line run to pools edge; 3 x 2 in. (75 x 50 mm) reducing bushing at pool edge connected to rubber 2 in. (50 mm) hose connected to 2 in. (50 mm) nozzle body; and miscellaneous shotcrete tools and aids.

The placed material was rough-screeded with finishing tools, allowing crews to keep uniform lines and still maintain an excellent bond plain for future plaster finish (Fig. 7).

The weather at the time of sprayed applications fell below 32°F (0°C) at night, so heat-retaining blankets were used to protect newly placed material from freeze damage during the hydration and strength-gain process.

The shotcrete process made this project both achievable and sustainable. The free-flowing pool design was a key feature for the client and was facilitated through the one-sided, non-restricted forming and installation inherent to the shotcrete process. They were able to install 6000 psi (40 MPa) watertight concrete to every angle and curve in the pool, with relatively low levels of labor and materials. By contrast, cast-in-place methodology would have required three sides of forming, considering the interior slot overflow/gutter design of the pool. The amount of materials, labor, and energy needed to complete the concrete installation via cast-in-place would have doubled in comparison to the shotcrete process.

Final Details

The edge detail was created with Roxbury Granite Stone, which is also used on the surrounding deck (refer to Fig. 8 and 9). Our masons did a great job of carefully honing the pieces, which range in length from approximately 1 to 4 ft (0.3 to 1.2 m), to create a precise edge with less than 1/8 in. (3.2 mm) tolerance. Each stone was selected, shaped, and marked to indicate its location. It was precision work using material that was a challenge to simply lift into place.

Inside the pool, the returns are all wall-mounted. To some, flow returns make the bottom of a pool look like it has a case of the measles. There are five 12 x 12 in. (300 x 300 mm) Pentair drain boxes in the floor. Three are for the organic ozone, which does the vast majority of the sanitizing and oxidizing work, but a flow-through tablet feeder was also installed to add a tiny residual as a backup for bather-to-bather safety. Both the edge system and primary circulation system run with Pentair's Intelliflo variable speed drive pumps for maximum hydraulic efficiency. The VSD pump on the edge systems enabled us to dial in the minimum flow necessary to cover the edge.

The Outstanding Pool & Recreational Project

Project Name
Finch Farm

Project Location
Salem, NY

Shotcrete Contractor
Drakeley Pool Company*

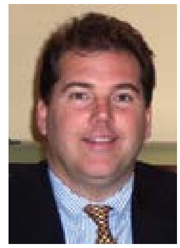
General Contractor
Drakeley Pool Company*

Architect/Engineer
David Peterson

Material Suppliers/Manufacturers
Brewster Transit Mix,
Putzmeister Shotcrete Technology*

Project Owner
Finch Farms

*Corporate Member of the American Shotcrete Association



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

2014 Outstanding Repair & Rehabilitation Project

The 606-Bloomingdale Trail | Viaduct Repairs

By Kevin Doyle

Located on the northwest side of Chicago, IL, the abandoned railway known as the Bloomingdale Line, originally constructed in 1873, runs east and west through four dense neighborhoods including Bucktown, Logan Square, Wicker Park, and Humboldt Park. The line starts at the Kennedy expressway, just north of the loop, half way between Wrigley Field and US Cellular Field, and heads west for 2.67 miles (4.29 km). The line was built shortly after the Chicago fire in 1871 by Chicago and Pacific Railroad to connect outlying rail ports to the Chicago River and to help support the city's expanding industrial sector. Due to a high number of accidents involving trains and residents all over the city in the late 1800s, the city passed an ordinance mandating that all rail lines in the city be elevated and, in 1910, the Bloomingdale Line was raised to 15 ft (4.6 m) above street level.

Use of the line greatly reduced in the 1980s and train service was eventually rerouted to other rail lines. By the mid-1990s, all rail activity ceased, creating an ideal platform for an elevated rails-to-trails conversion. The out-of-service rail line was largely left alone and reclaimed by wildlife and plants. The idea for "The 606" has its origins in the CitySpace Plan of 1998, which showed the Logan Square community area did not meet minimum standards for open space per capita. In fact, of the 77 community areas, it ranked second to last at 99 acres (40 ha) deficient for the population. In 2004, the City of Chicago adopted the Logan Square Open Space Plan, which helped identify ways to increase open space to achieve the minimum standards. The Bloomingdale Line was called out as a way to provide open space in an otherwise dense and built-out community.

The City of Chicago and the Chicago Park District, with the support of local residents and The Trust for Public Land, proposed to officially repurpose the elevated tracks into a 2.67 mile (4.29 km) long recreational trail for biking, running, and walking. "The 606" refers to the park and trail system that is currently under construction, the centerpiece of which is the Bloomingdale Trail. "The 606" gets its name from the zip code prefix, 606, which all Chicagoans share; the Bloomingdale Trail is named for the street right-of-way where the trail is located. The proposal encompassed structural concrete repair and rehabilitation work of 36 concrete bridges and retaining walls, landscaping, bridge deck waterproofing, new bridge construction, decorative guardrail, new lighting and security cameras, the creation of new parks, and installation of numerous access ramps along the length of the trail.

The project was let out to bid early May 2013, bid late in May 2013, and awarded shortly thereafter, demonstrating the urgency the City had to get this project under way. American Concrete Restorations (ACR) was contracted to repair the bridges and retaining walls following the Chicago Department of Transportation Structural Repair of Concrete Specification, which gives the contractor a choice of formed concrete repair or shotcrete. Due to the need for extensive coordination with the surrounding communities, ACR was finally called upon to begin work in late October 2013.

With frost already present and frigid cold temperatures soon to be upon Chicagoland, ACR devised a plan to keep the project moving forward through the winter months. This plan consisted of performing the necessary concrete removals at the bridge locations followed by fully enclosing and heating the structures for shotcrete work to proceed. Along with a late start in the year and the cold weather setting in quickly, this project had a variety of obstacles, including access into heavily congested neighborhoods and residents' properties, repairs during limited closures of main thoroughfares, and a structure that was in much worse shape than originally anticipated (Fig. 1).

Shotcrete Segment of Project Overview

The shotcrete portion of "The 606" was located at each of the 36 bridges and also the retaining walls and caps that spanned the 2.67 miles (4.29 km) of the project on the north and south sides of the trail. Work at the bridge locations encompassed the entire substructure including the wing walls, abutments, columns, and parapets. Each of the 36 bridges crossed two-lane streets, had three piers, and 15 columns. The trail also crossed five arterial streets, each with four lanes of traffic. At these locations there were four piers and 20 columns. At the longest bridge crossing, Humboldt Park Boulevard, it crossed six lanes of traffic, and there were 11 piers and 33 columns (Fig. 2).

Challenges

Upon commencement of the project, ACR realized that the bridges were in far worse condition than shown on the plans. Quantities immediately began increasing, as did the depths of the repairs, due to the fact that these walls were constructed with 1 in. (25 mm) unwashed river rock aggregate and without reinforcing steel. It was imperative to maintain excellent communication with the general contractor and the owner's engineers to verify work to be done and any additional repair steps to be taken, such as the addition of reinforcing bar, shoring, and identifying areas of complete deterioration requiring full replacement.

Because all the bridges are in close proximity to residences, schools, daycare centers, parks, dog parks, small businesses, and main thoroughfares, some special precautions had to be taken to protect private property and also to protect the heavy pedestrian and motor traffic that travelled through these areas. Along this 2.67 mile (4.29 km) jobsite, ACR encountered numerous neighborhoods encompassing various demographics. Many work zones were located adjacent to schools, requiring ACR to use extreme caution when conducting repairs and moving machinery in close proximity to young children who are often unaware of their surroundings and the dangers of a construction zone.

Due to the congestion of the work area and the proximity to neighboring homes, parks, and schools, ACR sandblasted with water to keep dust to a minimum. ACR also cleaned up their work area at the end of every day to prework conditions, thus leaving the neighborhood safe for pedestrians and vehicle traffic (Fig. 3).

As the bridges provided the only means of travel for residents from one side of the trail to the other, ACR had to phase its work at the bridge locations, keeping one lane of traffic and one sidewalk open at all times.

ACR encountered both winter and summer conditions during the course of the project. This change in environment called for different approaches to quality control. When starting the project in late October, the cold temperatures of the infamous 2013-2014 Chicago winter were

Fig. 1: Repair areas were found to be not only much larger in the field but also deeper than was called out on the plans and also lacking any reinforcing bar

Fig. 2: Repaired 11 piers spanning 250 ft (76.2 m) over six lanes of traffic

Fig. 3: ACI Certified Nozzleman shotcreting newly-reinforced repair areas

already setting in. ACR devised a comprehensive plan for dealing with the upcoming winter months to accommodate low temperatures of up to –40°F (–40°C) wind chill temperatures. Each bridge was wholly enclosed using heavy-duty, fire-retardant tarps (Fig. 4 through 6). ACR also deployed large propane heaters to ensure proper ambient and substrate temperatures. Where full road closures were necessary, ACR was allowed a maximum of 2 weeks to complete the work on the specific bridge, including 7 days for curing, to satisfy the restrictions of the City of Chicago permits for street closures. ACR also used heaters to keep the water warm for mixing and torpedo heaters to warm the skids of pre-bagged material and the staging area. ACR used both infrared and standard thermometers to confirm the temperature of the substrate, water, pre-bagged material, and mixed material stayed at or above the specified minimum temperatures. The temperatures were recorded on quality control checklists every hour to document ACR's ability to maintain a high-quality shotcrete mixture. ACR's plan succeeded in providing quality repairs while allowing the project to progress through the brutal Chicago winter.

Upon the arrival of the hot summer months, ACR had to pay special attention to make sure the shotcrete mixture remained at satisfactory maximum temperatures. To maintain the temperatures required in the specifications, ACR replaced the water supply midday with fresh cold water or added ice to the water supply containers. When possible, ACR's staging area along with the pre-bagged skids of material were set on the North side of the bridge next to the retaining wall to decrease the amount and duration of direct sun exposure. If this was not possible, canopies erected over the material and shotcrete pump provided shade to aid in temperature control. Similar to the winter months, ACR used infrared and standard thermometers to verify the temperature of the substrate, water, pre-bagged material, and mixed material to ensure they stayed below the specified maximum temperatures. The

Fig. 4: Heated enclosures were installed on portions of bridge during winter months

Fig. 5: Large propane heaters kept temperatures inside enclosure within specifications during cold winter months

Fig. 6: Shotcrete placement inside a heated bridge enclosure

temperatures were also recorded on quality control checklists every hour.

The retaining walls posed an entirely different set of challenges. The walls ran the entire 2.67 miles (4.29 km) length of the trail between the bridges on both sides of the trail. Many of these walls were located in the backyards of residents and some of the houses were very close to the walls, at times separated only by a 4 to 5 ft (1.22 to 1.5 m) pathway. ACR had to coordinate with the general contractor and owner's engineers on a daily basis to ensure that the residents permitted ACR adequate access to their yards to perform the work. In addition, some of these homes maintained elaborate gardens and expensive landscaping, requiring specialized property protection.

Specifically, one of the yards ACR needed to access housed a picturesque koi pond and an herb garden owned by a well-known chef. This garden is closely tended by a professional gardener, and the harvest is used in several restaurants (Fig. 7). Thus, ACR had to deploy multiple levels of protection for the plants and planters from dust, debris, and overspray. Further, the retaining wall next to this garden was covered in decorative vines, and ACR had to coordinate with the chef's gardener to ensure proper pruning or removal without unnecessary damage to the surrounding foliage. In other areas, ACR had to install temporary framing on the outer edge coupled with protective mesh and tarps to ensure that the shotcrete work was not damaging homes and yards. ACR also encountered an area of retaining wall where the cap was directly above a residential balcony. To perform removals and shotcrete repairs without damaging property below, two stages of protection were deployed. First, ACR installed a fabric tarp along the guardrail of the trail to keep debris from travelling over the side. Additionally, the area designated for repair was framed to ensure that all chipping debris would remain on the trail-side instead of falling to the balcony and property below. This one-sided formwork also gave the nozzleman something to shoot against. As ACR progressed along this 2.67 mile (4.29 km) jobsite, encountering different temperaments of residents, gaining permission to access the repair areas along the retaining walls ran the spectrum of difficulty.

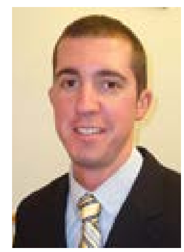
Significance to Project

When compared to form-and-place repair techniques, shotcrete proved a far more efficient method of repair on the 36 bridges and miles of retaining walls that allowed for quicker completion with excellent structural capability. As in all construction projects, time was of the essence. Many of the bridges required the erection of shoring towers simply to stabilize a severely

Fig. 7: Elaborate gardens of homeowners required covered repair areas that needed thorough planning, preparation, and coordination

deteriorated substructure and required them to be in place until the specified 14-day compressive strength tests of the shotcrete was met. The use of shotcrete and its versatility had many advantages over form-and-place. One advantage was the ability to remove the shoring towers long before the 14-day compressive strength requirement when the pre-bagged shotcrete material reached 70% of its strength. This allowed for reopening the streets in compliance with the City of Chicago's permit requirements. Another advantage in using shotcrete was repairing the retaining walls adjacent to private backyards, including that of a well-known chef. ACR staged the shotcrete equipment on the opposite side of the trail and ran the shotcrete hoses up and over the trail as opposed to through the yard and gardens. In addition, this set-up eliminated the need for tradesmen to access the yards to set-up and strip formwork for a form-and-place operation, thus completely preventing the damage or inconvenience that access could create. Using the shotcrete method also meant that there was no possibility of a form blowing out during casting and damaging the yard. The shotcrete process also allows a visual confirmation of encapsulation of the reinforcing bar throughout the shotcrete placement process, while cast-in-place work requires casting into a closed form where incomplete consolidation and resulting voids aren't evident until stripping the forms. After the shotcrete was placed, a double layer of curing compound was applied, thus eliminating the need to impede on private property for any form removal, grinding, or patching.

The scope of work resulted in over 15,000 ft^3 (425 m^3) of removal and replacement with high-quality shotcrete. All the shotcrete was placed by ACI-certified Nozzlemen employed by a qualified shotcrete contractor. The shotcrete was placed with a 0.42 water-cementitious materials ratio, along with the addition of 10% by weight of 3/8 in. (10 mm) river rock. Safety, time, and quality all significantly contributed to the very successful use of shotcrete by the Chicago Department of Transportation (CDOT) on "The 606" project. The general contractor and the subcontractor are also proud of their safety record of zero accident reports while working in one of the most congested parts of the city. All work was done to OSHA regulations and CDOT environmental requirements. All of the compressive strength test results exceeded the specification's requirement and the shotcrete solution resulted in a long-term, affordable repair with minimum impact on the surrounding community.



***Kevin Doyle** graduated from The Ohio State University in 2009 with a bachelor's degree in construction management. Having worked for a privately owned government contractor out of college, Doyle gained the experience from the owner's perspective that would prove valuable once he joined American Concrete Restorations, Inc., in April 2013. Doyle brought his understanding of the necessity for strong communication and teamwork between a contractor and owner to this project and helped to ensure project progress remained on track. "The 606"-Bloomingdale Trail is his first major project in which he helped manage, and thus Doyle is extremely proud that it has been awarded ASA's 2014 Outstanding Repair and Rehabilitation Project.*

The Outstanding Repair & Rehabilitation Project

Project Name
606-Bloomingdale Trail | Viaduct Repairs

Project Location
Chicago, IL

Shotcrete Contractor
American Concrete Restorations, Inc.*

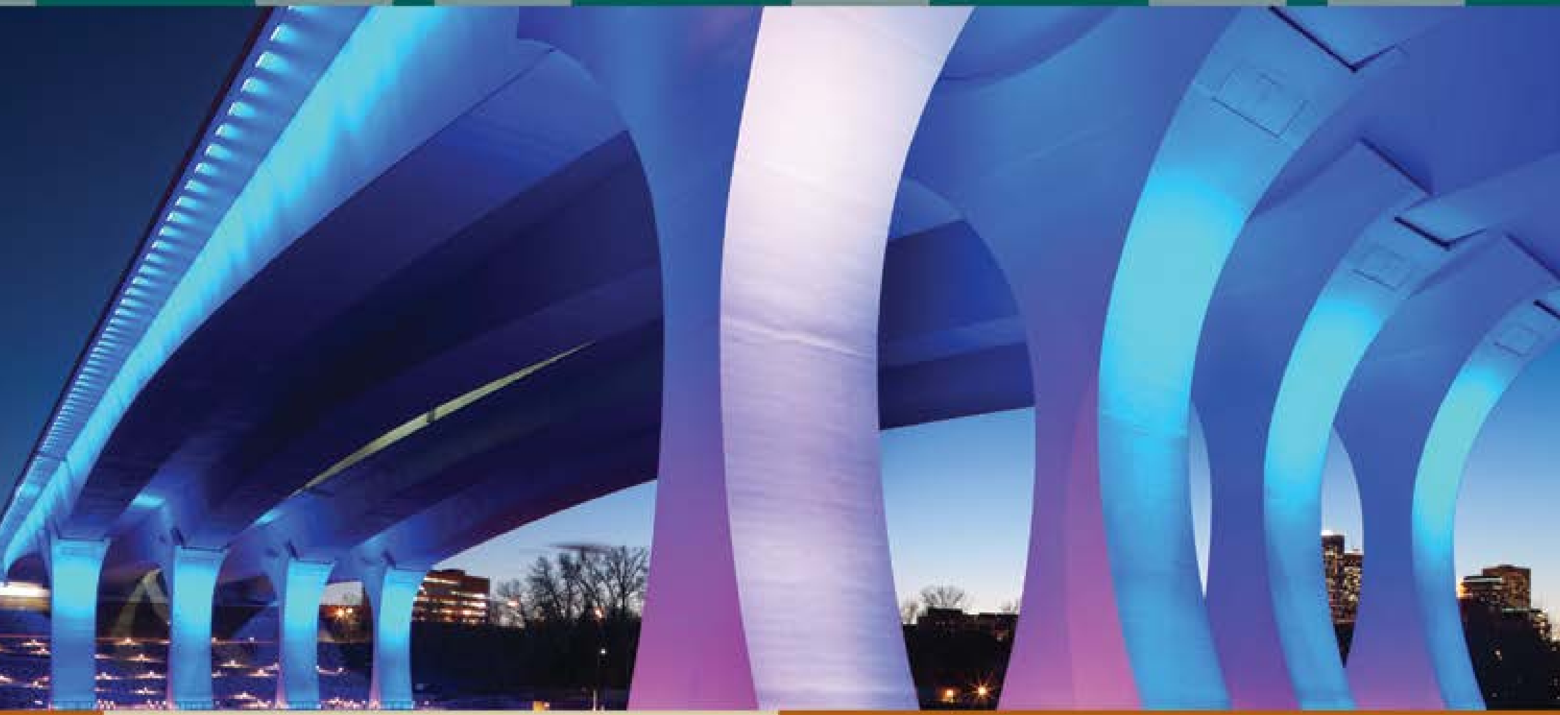
General Contractor
Walsh Construction

Architect/Engineer
Transystems

Material Supplier/Manufacturer
SPEC MIX*, Putzmeister Shotcrete Technology*

Project Owner
City of Chicago—Department of Transportation

*Corporate Member of the American Shotcrete Association



2014 Outstanding Infrastructure Project

McCormick Dam & Power Station: Submerged Concrete Repairs

By Roger Côté, Harold Ferland, and Kevin Robertson

The McCormick Dam and power station was built in 1952 on the Manicouagan River by the Quebec and Ontario Paper Company and the Canadian British Aluminium Company. It was named after Colonel Robert R. McCormick, who owned and published the *Chicago Tribune*. It is currently owned and operated by the Société en Commandite Hydroélectrique Manicouagan. The dam is situated approximately 1.9 miles (3 km) west of Baie-Comeau, QC, Canada, in the Côte-Nord area of the province of Quebec.

Groupe-conseil TDA, a well-established and leading consulting firm from la Côte-Nord area, was hired to inspect the dam, the retaining walls of the reservoir, and the water discharge (tailrace) to determine the condition of the concrete after 60 years of exposure to heavy water flow and freezing-and-thawing cycling and to formulate a plan to rehabilitate the structure.

The project was released for tender in early 2013 and was awarded to BBMarine. BBMarine is a specialized marine contractor from la Côte-Nord with over 35 years of experience in the construction, inspection, repair, and maintenance of marine structures.

Fig. 1: Area to be repaired

Scope of Work

The results of Groupe-conseil TDA's inspection confirmed abundant surface scaling at and below the waterline along the entire length of the reservoir (basin) retaining walls and the tailrace (spillway). The average depth of the repairs was approximately 2 in. (50 mm). Damage to the reservoir (basin) retaining walls equated to a surface area of approximately 10,763 ft^2 (1000 m^2), while the tailrace (spillway) required approximately 6458 ft^2 (600 m^2) of repair (Fig. 1).

The location of the repairs created many logistical and procedural challenges. To overcome those challenges, Le Groupe-conseil TDA specified that the damaged concrete be removed and replaced using pressure grouting techniques, through which nonshrink grout would be pumped from surface into the forms. Divers would be required to direct the pressure grouting process and to ensure the watertight forms retained all of the grout.

The thought of forming a total area of 17,221 ft^2 (1600 m^2), much of it underwater (using divers), concerned the construction team because of cost implications and the effect it would have on the entire construction schedule.

Logistics

The logistical challenges continued after BBMarine mobilized on site. The majority of the areas to be repaired provided limited access or room for equipment, materials, and formwork. Access to the repair locations was therefore limited to barges.

BBMarine initiated discussions with Groupe-conseil TDA, Béton projeté MAH Inc., and King Shotcrete Solutions to investigate alternative solutions for completing the concrete repairs. The group reached consensus that if concrete replacement was executed using the shotcrete process, it would allow easier access to the repair areas and it would contribute to an accelerated construction schedule. More importantly, all agreed that replacing nonshrink grout with concrete (as a repair material) would result in much more durable and longer-lasting repairs, especially considering the extreme freezing-and-thawing environment.

For a number of reasons, Béton projeté MAH Inc. elected to use the dry-mix process over wet-mix shotcrete. The dry-mix process allowed them the ability to start and stop without having to clean out hoses. The challenges associated with the placement of shotcrete on the water (primarily lighter-weight hoses and longer conveying distances) were also better addressed using the dry-mix process. Easier access to the shotcrete material, through the use of 2200 lb (1000 kg) bulk tote bags, was another key benefit of the dry process. And in addition to the logistical benefits such as easier material handling, prepackaged materials provided much improved consistency, which resulted in higher levels of quality control.

Materials engineers from King Shotcrete Solutions (the material supplier) designed a mixture that would provide reduced shrinkage and long-term durability. Silica fume provided a denser matrix and improved adhesion and cohesion during placement. The use of powdered air-entraining admixtures provided optimal spacing factor and air void system to improve durability. The use of micro-synthetic fibers helped reduce the potential for shrinkage cracking, which also added to the long-term durability of the repairs.

Béton projeté MAH Inc. was awarded the subcontract to complete the shotcrete placement and finishing. They have over 120 years of combined shotcrete experience in all aspects of shotcrete placement (repair, new construction, and artistic work). BBMarine retained the responsibility for all other logistics, concrete removal, surface preparation, and so on.

Repair Process

For the shotcrete process to work, BBMarine worked closely with the shotcrete subcontractor to develop a planned procedure for surface preparation, shotcrete placement, and shotcrete finishing. The key challenge was access to the repair areas located below the waterline. BBMarine relied on their extensive experience working in marine environments to design a special mobile cofferdam system that would allow them to move the unit along the 0.6 mile (1 km) reservoir (basin wall). All surface areas to receive the shotcrete were prepared using the hydrodemolition method (Fig. 2 and 3). A special hydro rig was set up on a floatable barge, which allowed the crew to complete the concrete removals using a 20,000 psi (140 MPa) water blast. The barge that hosted the hydrodemolition rig was set up ahead of the shotcrete barge and moved along the reservoir basin wall so that the repair area was prepared before the arrival of the shotcrete barge.

Both mobile cofferdam systems were set up to allow a work area of approximately 17 ft long x 4 ft high x 4 ft deep (5.2 x 1.2 x 1.2 m) and were temporarily anchored to the concrete wall of the reservoir basin (Fig. 4 to 6). The area of contact between the mobile cofferdam and the surface of the concrete was sealed to prevent water from reentering the cofferdam. Gas-powered dewatering pumps were then used to remove the water from inside the cofferdam system and allow access for the removal crew and the shotcrete crew. The shotcrete crew was provided with a wooden platform system, set up behind the cof-

Fig. 2: Mobile hydrodemolition rig

Fig. 3: Surface preparation, hydrodemolition rig

Fig. 4: Area ready for shotcrete

ferdam, which allowed the shotcrete nozzleman to maintain the proper distance 3 to 5 ft (0.9 to 1.5 m) from the end of the nozzle to the receiving surface. Once placement and finishing was complete, the portable cofferdam would be moved to the next section while skipping the section directly beside to be able to be anchored into existing concrete and not the fresh shotcrete.

The flexibility of the dry-mix shotcrete process allowed Béton projeté MAH Inc. to set up the machine on solid ground in areas that gave them access to a forklift and enough room to maneuver the 2205 lb (1000kg) bulk bags. On average, they required approximately 250 to 300 ft (76 to 91.5 m) of hose to access the work area. With the repair areas in most cases submerged, the receiving area was always saturated, which helped to ensure a strong and durable bond between the parent concrete and the repair material. Approximately 350 to 2205 lb (1000 kg) bulk bags were used on the project (Fig. 7).

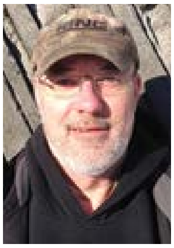
A line wire was used by the Béton projeté MAH Inc. crews to maintain the same thickness and surface profile as the existing concrete. Once an area was shot, the crew cut off any excess shotcrete, ensuring the area was plumb and level with the existing concrete. A mechanical spinning trowel was used for the rough finish and then a magnesium trowel for the final finish. Once the shotcrete reached its initial set, the dewatering pumps were shut off to re-submerge the repair and maintain ideal curing conditions (Fig. 8).

The cooperation between the general contractor (BBMarine), the shotcrete contractor (Béton projeté MAH Inc.), and the material and equipment supplier (King Shotcrete Solutions) resulted in an extremely successful project with the end result being a satisfied owner (Société en Commandite Hydroélectrique Manicouagan). The success of this project will no doubt result in more opportunities in which shotcrete will play a vital role in the marine infrastructure rehabilitation market in la Côte-Nord (Fig. 9 and 10).

Fig. 5: Mobile cofferdam set up

Fig. 6: Nozzleman shooting in mobile cofferdam system

***Roger Côté**, Eng., is the Director of Engineering for BBMarine. His area of expertise includes application and design equipment for concrete rehabilitation.*



***Harold Ferland** is the co-owner of Béton projeté MAH Inc., a company that has been doing only shotcrete work for 14 years throughout Canada. Ferland is an ACI Certified Nozzleman for dry- and wet-mix shotcrete (overhead and vertical). He has been in the shotcrete industry for 29 years.*

***Kevin Robertson** is a Technical Sales Representative for King Shotcrete Solutions, Boisbriand, QC, Canada. His areas of expertise include shotcrete materials, application, and equipment, focused mainly on concrete rehabilitation applications. Robertson is a member of ASA, the American Concrete Institute (ACI), and is on the Board of Directors of the Quebec Province Chapter of the International Concrete Repair Institute (ICRI).*

Fig. 7: Shotcrete equipment setup

Fig. 8: Shotcrete crew cutting and doing the rough finish using mechanical trowel

Fig. 9: Finished section of reservoir (basin) wall

The Outstanding Infrastructure Project

Project Name
McCormick Dam & Power Station: Submerged Concrete Repairs

Project Location
Baie-Comeau, QC, Canada

Shotcrete Contractor
Béton projeté MAH Inc.

General Contractor
BBMarine

Architect/Engineer
Groupe-conseil TDA

Material Supplier/Manufacturer
King Shotcrete Solutions*

Project Owner
Société en Commandite Hydroélectrique Manicouagan

*Corporate Member of the American Shotcrete Association

Fig. 10: Finished section

2014 Honorable Mention

Long Prairie Digester Rehabilitation Project

By David Graham

The Long Prairie Digester is a wastewater treatment facility constructed in 2012 to process wastewater generated by food processing operations. The facility includes four reinforced concrete process tanks and one open-top receiving tank.

The enclosed process tanks vary in size. Two of the tanks measure 282 x 39 ft (86 x 12 m); one is 59 x 24 ft (18 x 7.3 m); and the other is 87 x 24 ft (26 x 7.3 m). The wall height of the enclosed tanks is 22 ft (6.7 m). The open-top receiving tank is 21 x 21 ft (6.4 x 6.4 m) with a wall height of 12 ft (3.7 m).

Fig. 1: Tank before repair

The tanks were originally constructed with cast-in-place concrete slab-on-ground floors, 18 in. (450 mm) thick insulated concrete form (ICF) walls, and topped with a precast concrete roof system. A polyurea lining material was sprayed over the interior wall insulation and the underside of the precast roof (Fig. 1).

The Problem

After original construction, the tanks were tested for watertightness. During the testing phase, the tank walls exhibited extensive leaking (Fig. 2 and 3).

The insulated form wall system made it impossible to determine where the leaks originated. It was immediately evident that removal of all interior insulation would be necessary to properly inspect tank walls, expansion, and construction joints.

After removal of interior insulation, the exposed walls revealed extreme honeycombed areas resulting from poor consolidation during original construction. Also, the ICF wall ties used consisted of a hollow tie without a waterstop feature; thus, water could be leaking from anywhere in the walls through existing voids or through any of the thousands of hollow ties.

The Repair Solution

The plan provided for repair of structurally deficient areas and protection of carbon steel wall ties while providing a smooth, level surface to receive a final protective lining system.

Due to the high volume and severity of poorly consolidated areas, it was determined that the tank walls required repair prior to final lining application. Honeycomb areas were chipped back to sound concrete and brought back with shotcrete to original wall plane using King Packaged Materials MS-W1 with poly fibers. These areas were not troweled and were left with a natural gun finish.

After repair of honeycombed areas, 6 x 6 in. W1.4 x W1.4 (152 x 152 mm W9.1 x 9.1) welded wire reinforcement was securely anchored to all wall surfaces. Wall surfaces were washed with clean water and allowed to reach saturated surface-dry condition. A minimum of 1-1/2 in. (38 mm) of King Packaged Materials MS-W1 with poly fibers was applied to the wall surfaces and finished with steel trowel to provide a tight, level surface. All newly placed concrete was water cured for 7 days.

Site Conditions

The site provided many challenges during the life of the project. The existing tanks were constructed with the finished floor elevation 8 ft (2.4 m) below grade. The water table in this location was higher than the existing floor elevation, causing groundwater to seep into the tank through floor sumps and at the floor-to-wall construction joint. A dewatering plan was implemented that included installing dewatering wells around the tank perimeter to draw down groundwater elevation. This dewatering system was operated and monitored 24/7 to provide dry working conditions during shotcrete and protective lining operations.

The only access available to each of the tanks was from the roof, through existing 42 x 42 in. (1.1 x 1.1 m) roof hatches. No additional openings were allowed, thus limiting the size of access equipment that could be used to complete the work. Electric scissor lifts were selected to access the walls. Due to the small roof openings, the lifts were disassembled and lowered into the structure in pieces and reassembled inside the tank. The smaller tanks and areas with limited work area required scaffolding to reach all repair areas.

Fig. 2: Poorly consolidated concrete

Fig. 3: Honeycomb at cold joint

Fig. 4: Shotcrete placement

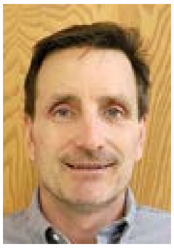
Fig. 5: Shotcrete placement at weir

Fig. 6: Completed repair

The construction schedule was compressed and required multiple operations to run concurrently in multiple tanks at the same time. Concrete demolition, abrasive blasting, welded wire reinforcement installation, and shotcrete application were all tasks which were required to take place at the same time.

Shotcrete Placement

To complete this project, 640 bulk bags of King Packaged Materials MS-W1 with synthetic fiber were used. The prepackaged dry material was placed into a Cemen-Tech MCD 10-150 mobile concrete dispenser, where it was mixed to the proper slump and conveyed into an Allentown Powercreter 20S shotcrete pump. Pumping distances varied from 200 to 300 ft (61 to 91 m) in length. Shooting wires were installed and shotcrete was placed by ACI-certified nozzlemen. The final finish was with steel trowel to provide a uniform surface to receive the final protective lining system (Fig. 4 through 6).



***David Graham**, Project Manager for PCiRoads, LLC, since 2007, is an ACI Certified Nozzleman for both dry- and wet-mix shotcrete. With over 30 years of experience in the shotcrete industry, he has managed numerous projects nationwide that include the use of shotcrete on buildings, bridges, tunnels, dams, silos, tanks, and soil stabilization.*

Honorable Mention

Project Name
Long Prairie Packing-Digester Rehabilitation

Project Location
Long Prairie, MN

Shotcrete Contractor
PCiRoads, LLC*

General Contractor
PCiRoads, LLC*

Architect/Engineer
BKBM Engineers

Material Supplier/Manufacturer
King Shotcrete Solutions*

Project Owner
Long Prairie Packing Co.

*Corporate Member of the American Shotcrete Association

2014 Honorable Mention

Liberty Tunnel Arch Restoration with a Shotcrete Alternative

By Axel G. Nitschke and John Becker

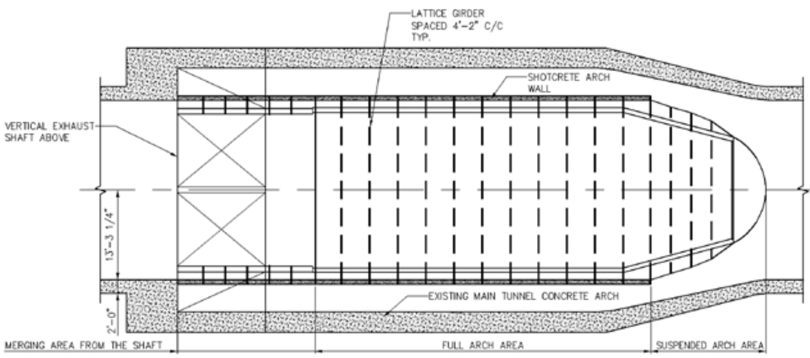


Fig. 1: Tunnel ventilation arch wall section plan view

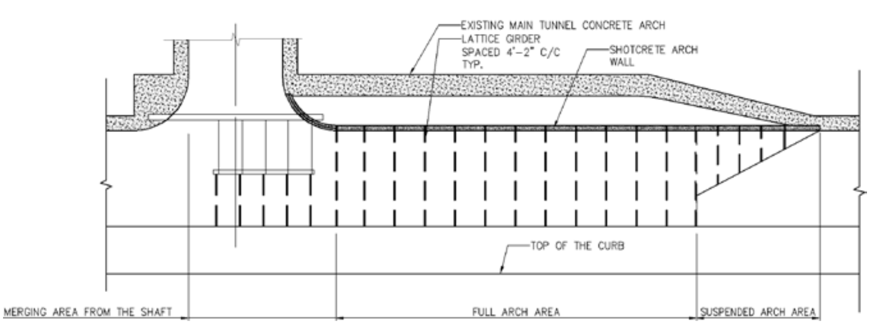


Fig. 2: Tunnel ventilation arch wall section—longitudinal section

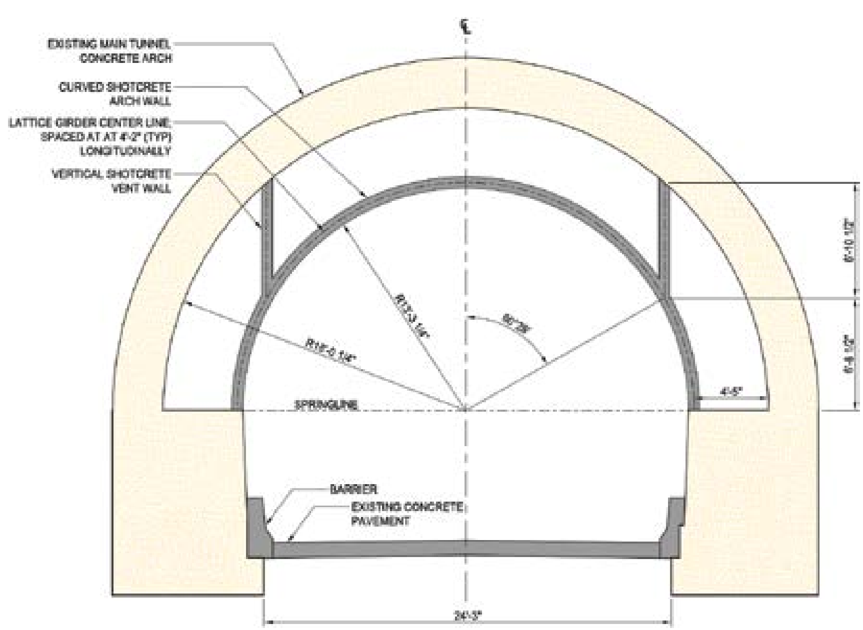


Fig. 3: Alternative design self-bearing shotcrete arch section

The Liberty Tunnel provides a direct commuting route from the South Hills suburbs to downtown Pittsburgh, PA. The Liberty Tunnel is a horseshoe-shaped tunnel consisting of two northbound and southbound tubes and has an overall length of 5888 ft (1795 m). The tunnel consists of two vertical vent shafts to draw exhaust from the midpoint of each tunnel and force a supply of fresh air into the tunnel through the so-called "arch walls." An arch wall is an arch structure which is offset from the structural lining of the tunnel to provide for air channels. The ventilation arch wall section acts like a macroscopic air nozzle—fresh air is supplied from the ventilation shaft and pushed along the vent supply area on either side of the arch wall. The arch walls are open at the end of the nozzle, which allows the fresh air to enter into the tunnel away from the exhaust point (Fig. 1 through 4).

Swank Construction Company was awarded the Liberty Tunnels rehabilitation project by the Pennsylvania Department of Transportation (PennDOT) in May 2013. The project included, among other scopes, the demolition and renewal of the ventilation arch walls inside the tunnels, close to the ventilation shaft. Gall Zeidler Consultants (GZ), in cooperation with Swank Construction and Coastal Gunite, provided an alternate design and construction concept for the Liberty Tunnels rehabilitation project.

Structurally, the arch wall section can be divided into three sections from left to right in Fig. 1 and 2: 1) merging area from the shaft; 2) full-arch area, where the arch wall is closed at the bottom; and 3) suspended arch area, where the arch wall is open at the bottom to provide an outlet for the fresh air (see also Fig. 4). This article focuses on the full-arch area (center) and does not address the merging area from the shaft (left) or the suspended arch area (right).

Arch Restoration

Original Design

The original arch wall used U-shaped steel profiles as structural members, which were tied with radial hangers to the structural tunnel arch above. Vertical walls separated the center part from the sidewall areas, as shown in Fig. 5. The original rehabilitation design proposed demolishing and renewing the existing ventilation arch walls, following the original design with U-shaped steel beams and radial hangers embedded in the concrete (refer to Fig. 5 and 6). The concrete arch was supposed to be reinforced with welded wire reinforcement. During the arch wall demolition, it was intended to use the existing steel framing hangers that were in good condition and replace the deteriorated ones. A curved steel formwork forming both sides of the free-standing arch wall was supposed to be used to form the cast-in-place arch. In addition, two vertical walls and concrete embedment of the hangers on top of the arch were to be formed and placed.

Self-consolidating concrete (SCC) is a high-performance concrete that can flow easily into tight and constricted spaces without segregating and without requiring vibration. However, fresh SCC exerts high hydrostatic stress, which has to be borne entirely by the formwork until the concrete develops strength. This creates the risk of rupturing the formwork and concrete blowouts. Therefore, specialized formwork consisting of steel or very strong timber formwork embedded with studs and anchors of sufficient strength is required to prevent concrete blowouts or lifting of the form from hydraulic stresses. Such custom-made formwork incurs high costs, especially due to its very limited reuse at the given application. In addition, the schedule impact by the risk of blowouts or deformation of the formwork was considered very high by the contractor, because the limited shutdown period of the tunnel left no time for on-site adjustments or rework.

Reusability of the existing hangers embedded in the concrete also posed an uncertainty because its usability could only be determined after the demolition of the existing arch wall. The number of deteriorated hangers or hangers which were damaged during the demolition was therefore unknown at the start of construction. Further, sorting out the hangers and replacing the deteriorated ones was considered a time-consuming activity in itself. The hangers also posed an additional hindrance during formwork installation.

Alternative Design

As an alternative design, the use of cast-in-place concrete was replaced by sprayed shotcrete and the structural system was modified into a self-bearing arch. The self-bearing arch allowed the complete removal of all hangers during the demolishing process.

The self-bearing shotcrete arch concept is often used to extend the underground section of a mined

Fig. 4: Finished rehabilitation

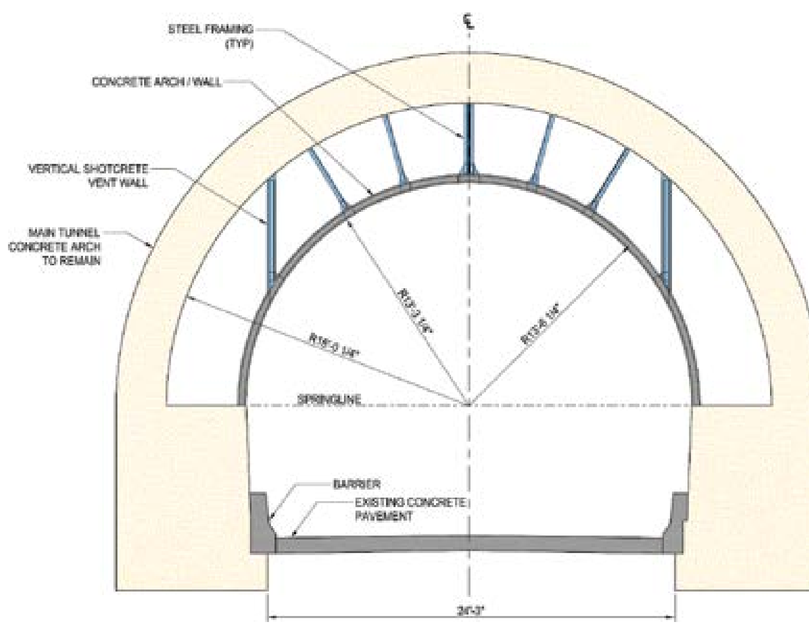


Fig. 5: Existing tunnel ventilation arch wall section—cross section

Fig. 6: Embedded hangers in existing void space between main tunnel and ventilation arch wall

tunnel into the open portal area by providing a free-standing arch often termed as shotcrete canopy. Recent examples for the use of shotcrete canopies can be found at the Weehawken Tunnel in New Jersey and Devil's Slide Tunnel in California. While the initial lining during tunnel excavation and support is applied against the ground, an artificial surface on the backside has to be provided for a free-standing arch to allow for the buildup of the shotcrete lining.

The cross section in Fig. 3 illustrates a typical configuration of a self-bearing shotcrete arch. Structurally, the arch wall is 6 in. (152 mm) thick and supports itself as a free-standing, self-bearing arch, loaded by the weight of the two vertical overlying walls. These vertical walls do not have any structural function and are for ventilation purposes only. The arch walls and the vertical walls have embedded lattice girders at a typical spacing of 4 ft-2 in. (1.27 m) center-to-center. The arches were reinforced with two layers of welded wire reinforcement, W9 x W9 at 6 in. (152 mm) center-to-center spacing in both directions, as a minimum reinforcement to control cracking from shrinkage and temperature changes.

Construction Sequence

The schematic of the construction sequence is illustrated in Fig. 7 and detailed in the following steps (see Fig. 4 and 7 through 10):

Step 1: The construction started with demolition of the existing ventilation arch wall.

Step 2: In the second step, lattice girders were installed along the arch periphery and along two vertical wall sections. The lattice girders were secured with undercut anchors at the top and dowels at the bottom of the arch of the main tunnel lining. The lattice girders were comprised of a

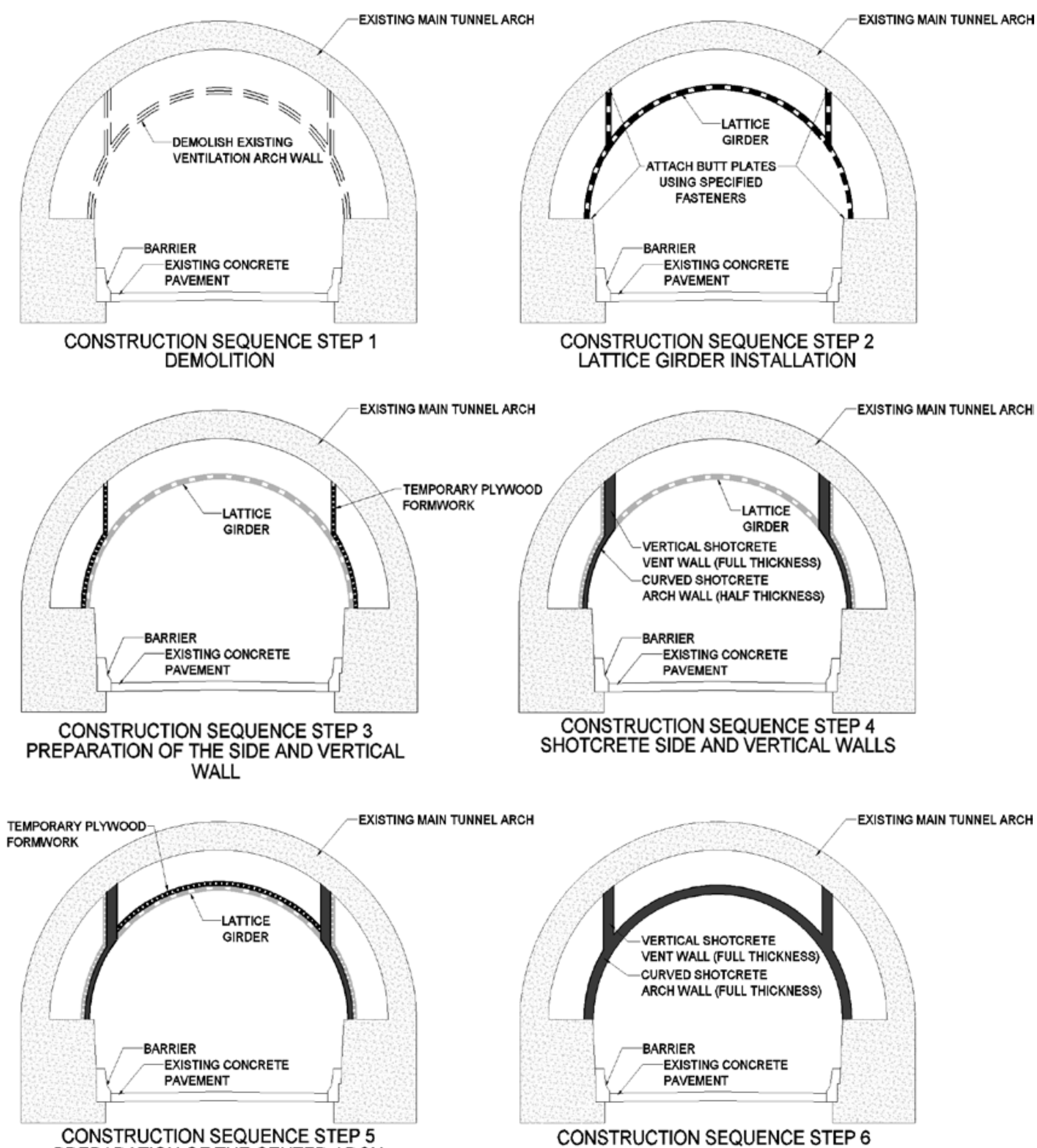


Fig. 7: Typical construction sequence

Fig. 8 (left and above): Construction sequence Step 3—lattice girder and extrados reinforcement sidewall sections

three-piece arch plus one piece each for each vertical ventilation wall on either side.

Step 3: A light plywood formwork was set up along with first layer of welded wire reinforcement at the extrados (exterior curve of the arch) side of the lattice girder. The center part of the arch was left open to provide access for the construction of the vertical walls. Figure 8 illustrates the erected lattice girders of the arch walls and vertical wall sections. The center arch section is open to allow shotcreting of the vertical walls. In the back, the suspended section of the arch wall, acting as a ventilation nozzle, which was not discussed in detail in this paper, can be seen.

Step 4: Shotcrete was applied at the rounded and vertical wall sections—excluding the center part. Only the vertical wall sections were completed to full thickness and with both layers of reinforcement, while the intrados layer of reinforcement at the arch wall sidewall was left out for later completion. As observed in Fig. 9, the

Fig. 9: Construction sequence Step 4—curved and vertical sidewall sections are shotcreted

Fig. 10: Construction sequence Step 5—preparation of center arch section

curved and vertical sidewall sections have been partially shotcreted.

Step 5: The center arch section was closed by installation of the plywood and reinforcement at the extrados side of the arch. As soon as the vertical wall sections were completed, the plywood and reinforcement in the center arch section could be installed and shotcreted, which is illustrated in Fig. 10. After this step, the intrados (interior curve of the arch) level of reinforcement covered by the final layer of trowel-finished shotcrete can be installed.

Step 6: The center arch section was sprayed up to the intrados layer of reinforcement, followed by the installation of the intrados layer of reinforcement along the entire arch and completion of the shotcrete arch wall to full thickness, including a trowel finish. Finally, at the end, the plywood at the backside was removed, completing the arch wall construction. Figure 4 shows the arch wall section after its rehabilitation, looking into the air nozzle opening. The smooth trowel finish of the shotcrete makes it difficult to recognize that shotcrete in lieu of cast-in-place concrete was used.

Construction Challenges

The shutdown period for tunnel closure was very limited and demanded a very tight and compact construction schedule. The construction was split into two phases: Phase 1 for the southbound tunnel and Phase 2 for the northbound tunnel. As part of the bid documents, PennDOT set forth 18-day closures per phase. Failure to meet the 18-day closure would result in a penalty of $40,000 per day. During the planning phase, it was apparent that meeting the 18-day restriction with the original design would be extremely challenging and alternatives were investigated. During development stages of the alternative shotcrete design, it was determined the arch walls could be completed in 16 days.

The demolition of the existing arch walls started immediately after tunnel closure, followed by the installation of new shotcrete arch walls. The southbound tunnel (Phase 1) was completed just hours before the opening of the tunnel for traffic. However, the northbound tunnel (Phase 2) was completed in about 14 days; 2 days under the maximum allowed 16 days.

The design specified stringent experience requirements for the shotcrete applicator to ensure the required high quality. Coastal Gunite was the subcontracted shotcrete specialist contractor and worked with a crew of nine to 12 people per 12-hour shift. The concrete material was hauled in dry bulk sacks and mixed on site inside a concrete truck inside the tunnel, which ensured sufficient quantities available in place given the tight construction schedule. The concrete mixture included polyfibers and a corrosion inhibitor. Excluding the finish coat, the wet-mix shotcrete used a liquid accelerator, injected at the shotcrete nozzle, to reach the specified set times and meet the early strength requirements required by the design. The shotcrete was placed in three lifts per wall. The first layer of shotcrete was placed encapsulating the first layer of mesh and left enough of the lattice girder exposed such that the second layer could be installed. The second placement encapsulated all of the steel and was left rough so that a monolithic finish coat could be applied last to provide aesthetic appeal. The final layer was finished with a broom and was sprayed with a curing compound to attain proper cure and avoid surface cracking.

Conclusions

For the Liberty Tunnel rehabilitation project, time was of the essence due to a short and limited closure of the tunnel. The alternative design of the self-bearing shotcrete ventilation arch wall provided the contractor greater flexibility and reduced construction risk during the ventilation arch wall installation.

The simplicity in the design and the easy and quick installation of the shotcrete arch wall system allowed the project to be completed on time and within budget. The tunnel was even completed 2 days earlier than the proposed schedule and on budget with 18% cost savings to the owner. Such design has showcased the effective and fast use of shotcrete as means for rehabilitation and repair works in existing tunnels that only allow limited time for tunnel closures.

Honorable Mention

Project Name
Liberty Tunnel Arch Restoration

Project Location
Pittsburgh, PA

Shotcrete Contractor
Coastal Gunite Construction Company*

General Contractor
Swank Construction Company, LLC

Architect/Engineer
Gall Zeidler Consultants

Project Consultant/Inspection
Hill International Inc.

Material Supplier/Manufacturer
The QUIKRETE Companies*

Project Owner
Pennsylvania Department of Transportation

*Corporate Member of the
American Shotcrete Association

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ACI Committee 318, 2005, "Building Code Requirements for Structural Concrete (ACI 318-05) and Commentary," American Concrete Institute, Farmington Hills, MI, 430 pp.

Axel G. Nitschke *received his MSc and PhD in civil engineering in 1993 and 1998, respectively, from Ruhr University Bochum, Bochum, Germany, and is a licensed professional engineer in Virginia and California. He has gained more than 20 years of in-depth, on-the-job experience in all aspects of underground construction, geotechnical engineering, and mining. He has worked on the engineering and construction of a large number of tunnel projects in Europe, the United States, Canada, and Colombia. He is well-experienced in all ground conditions, ranging from soft ground to hard rock, and the associated implications for design and construction methods. Nitschke has held key positions such as Senior NATM Engineer, Contract/Claims Manager, Risk Manager, Design Manager, and Project Manager.*

John Becker *is an ACI Certified Nozzleman who, for the last 5 years, has worked in many capacities—most recently as Project Manager—for Coastal Gunite Construction Company, based in Cambridge, MD. In addition to the Fort McHenry Tunnel, he has been involved with many shotcrete projects large and small, including the $15 million Bonner Bridge Rehabilitation Project in Nags Head, NC, and the $5 million Old Mill Creek Sewer Rehabilitation Project in St. Louis, MO.*

2014 Honorable Mention

Alameda Square

By Paul Mendoza

Alameda Square is an historical industrial complex in the Fashion District of Downtown Los Angeles, CA. This hub, built in the 1920s, will place a community of creative companies at the intersection of the Los Angeles Fashion and Arts Districts. The owner, Atlas Capital Group, LLC, is revitalizing Alameda Square and leasing the stylish and practical space to several fashion tenants who are dedicated to American clothing manufacturing.

Fig. 1: An opened area showing the tile insulation and exposed existing reinforcing bar at the joists

Fig. 2: This is a prepped area prior to shooting; sound existing reinforcing bar was left in place and reinforced with new reinforcing bar and dowels. The edge form was set to bind the sides of the joist infill

Alameda Square Building 3, constructed entirely with reinforced concrete, at one point in its history was used as a deep-freeze facility by a food packaging company which had insulated portions of the concrete slabs and beams with cork and clay tiles. The years of exposure to freezing-and-thawing conditions caused spalling on the interior beams, concrete joists, and slabs; spalling was also evident on the exterior architectural concrete face of the building (refer to Fig. 1). The building was later repurposed as a garment manufacturing facility and still functions as such today.

The objective of this rehabilitation was to chip out spalled and deleterious concrete, remove and repair corroded reinforcing bar, and restore these areas with new shotcrete to prevent potential safety hazards from further spalled concrete and return the building concrete structure back to its original strength and function (refer to Fig. 2).

Several areas were identified as requiring rework and were repaired. The superior ability of shotcrete to bond in the overhead application made it a more viable alternative to typical cast-in-place concrete, an important factor to consider for structural rehabilitation of the building. By using shotcrete for the interior ceiling repairs, an added benefit for the tenant/owner was the ability to contain the area shutdown for construction to the floors with repairs, as opposed to cast-in-place that would have required shutting down commercial activity on additional floors because the work on a particular floor would require pumping concrete from the floor directly above the repairs. In addition, choosing shotcrete reduced construction forming time and materials. Also, because shotcrete can be applied and finished more quickly, the project schedule was shortened. To complete the work, the owner shut down three floors of the warehouse building at a time. Once the shotcrete work was completed, they were able to immediately move in their tenants and then shut down the next three floors above. Each day of downtime cost the owner productive revenue.

Fig. 3: The final shotcrete rod finish minimized the amount of work at the face

Fig. 4: A core taken from an in-place test panel. Note near the top is a faint red line—this is the tile layer seen in previous photos. In the 13 in. (330 mm) thick overhead section, ACI Certified Nozzlemen were able to achieve a solid bond without any separation between the new shotcrete and existing material. Due to the length of the core, it was not possible to drill through the length without breaking during the extraction

Thus, minimizing the out-of-service periods was crucial to the project's budgetary concerns. The shotcrete application process allowed for a way to quickly make the repairs without sacrificing the quality and safety of the finished rehabilitation (refer to Fig. 3).

The project consisted of the following primary activities: overhead beam strengthening, large spall repairs at interior beams and stairwells, and restoration of the exterior concrete façade.

The overhead portion consisted of a tight lattice work of reinforcement with two horizontal No. 4 (No. 13) reinforcing bars at the top and two No. 7 (No. 22) reinforcing bars at the bottom of the beams, No. 4 (No. 13) stirrups at 12 in. (305 mm) on center, No. 4 (No. 13) reinforcing bar dowels at 12 in. (305 mm) on center with a 90-degree hook, and 5/8 in. (16 mm) diameter threaded rod at 18 in. (457 mm) on center horizontal through existing beams. The gap between existing beams was filled, creating a section totaling 13 in. (330 mm) thick and 12 in. (305 mm) wide between beams. Cores taken from repaired sections proved there was a solid bond between the new shotcrete and the existing concrete of the structure (refer to Fig. 4).

The vertical spall repair that occurred in the stair wells and on the exterior façade varied from

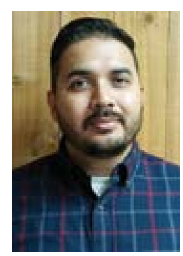
Fig. 5: The exterior façade that has been chipped back to sound material and reinforcing bar installed

3 to 12 in. (178 to 305 mm) thick depending on the extent of the concrete that was chipped away and replaced. This is a six-story building plus a basement with floor-to-ceiling heights of 12 ft (3.6 m). For the stairwells, Nationwide Shotcrete, Inc., ran steel pipe and concrete hoses to each level and had scaffolding on each of the landings in the stairwell to allow for full access to all of the spalled areas. Due to the building size, the exterior façade repair required three aerial man lifts to provide access for the ACI Certified Shotcrete Nozzlemen and finishers (refer to Fig. 5 and 6).

Along with the benefits of speed and ease of overhead application, the use of shotcrete increased the sustainability of the project. The concrete mixture designs for the wet-mix shotcrete used a combination of silica fume and fly ash, which are recycled cementitious replacement materials. Shotcrete application also requires less formwork than the traditional cast-in-place concrete application, minimizing the total formwork material used for the project as well as reducing the time to place and strip the formwork. Reducing the amount of raw materials used and sourcing recycled materials for the mixture designs made the use of shotcrete over cast-in-place methods both an environmentally minded and cost-effective decision (refer to Fig. 7).

Fig. 6: The exterior façade during the shoot—several aerial man lifts were needed to properly reach the work spread over a wide area. This area was given a rubber float finish

Fig. 7: The exterior façade after shotcrete operations were completed



Paul Mendoza *is an Estimator/Project Manager at Nationwide Shotcrete, Inc. He has 7 years of experience in the shotcrete industry, working for shotcrete and concrete contractors in southern and northern California. He is working toward his BS in civil engineering and is certified as an Engineer-In-Training in California.*

Honorable Mention

Project Name
Alameda Square Building 3

Project Location
Los Angeles, CA

Shotcrete Contractor
Nationwide Shotcrete, Inc.*

Concrete Contractor
Wallock & Maggio, Inc.

General Contractor
Nemo Constructors, Inc.

Architect/Engineer
Farooq Maniar, Inc.,
Consulting Structural Engineers

Material Supplier/Manufacturer
National Ready Mixed Concrete Company

Project Owner
Atlas Capital Group, LLC

*Corporate Member of the
American Shotcrete Association

2014 Carl E. Akeley Award


Carl E. Akeley


Lihe (John) Zhang

The ninth annual Carl E. Akeley Award was presented to Dr. Lihe (John) Zhang of LZhang Consulting and Testing Ltd. for his paper, "Variability of Compressive Strength of Shotcrete in a Tunnel-Lining Project." This paper, published in the Fall 2014 issue of *Shotcrete* magazine, reported on the statistical data derived from a civil tunnel project in western Canada. Compressive strength was found to be influenced by mixture design, nozzleman skills, curing conditions, and test panel handling. The award was presented by ASA Publications Committee Chair Ted Sofis.

ASA established the Carl E. Akeley Award to honor his founding of what is today referred to as the shotcrete process. This award is presented to the author(s) of the best technical article appearing in *Shotcrete* magazine in the past 12 months, as determined by the Akeley Award Committee of ASA.

Carl E. Akeley invented the cement gun in 1907 and introduced a commercial version of it at the Cement Show in New York in December 1910. For this reason, Akeley is considered the inventor of the shotcrete process.[1]

Born in Clarendon, NY, on May 19, 1864, Akeley was a noted naturalist, taxidermist, inventor, photographer, and author. He made many significant contributions to the American Museum of Natural History and many other museums around the United States. He initially invented the cement gun to repair the façade of the Field Columbian Museum and later used it to improve the quality of his taxidermy exhibits at the museum. Akeley made five expeditions to Africa, during which time he procured many animals for museum exhibits. President Theodore Roosevelt accompanied him on one of those expeditions and encouraged him in his development of the cement gun. During his fifth expedition to Africa, he contracted a virus and died on November 17, 1926.

References

1. Teichert, P., "Carl Akeley—A Tribute to the Founder of Shotcrete," *Shotcrete*, V. 4, No. 3, Summer 2002, pp. 10-12.

Past Akeley Award Recipients

- 2006—Jean François Dufour, "State-of-the-Art Specification for Shotcrete Rehabilitation Projects"
- 2007—Knut F. Garshol, "Watertight Permanent Shotcrete Linings in Tunneling and Underground Construction"
- 2008—E. Stefan Bernard, "Embrittlement of Fiber-Reinforced Shotcrete"
- 2009—Dufour, Lacroix, Morin, and Reny, "The Effects of Liquid Corrosion Inhibitor in Air-Entrained Dry-Mix Shotcrete"
- 2010—Lihe (John) Zhang, "Is Shotcrete Sustainable?"
- 2011—Charles S. Hanskat, "Shotcrete Testing—Who, Why, When, and How"
- 2012—R. Curtis White Jr., "Pineda Causeway Bridge Rehabilitation"
- 2013—Jolin, Nokken, and Sawoszczuk, "Sustainable Shotcrete Using Blast-Furnace Slag"

2014 ASA President's Award


Oscar Duckworth

The ASA President's Award was established in 2005 to recognize the person or organization that has made exceptional contributions to the shotcrete industry. It is the sole responsibility of the current ASA President to select the recipient of this award.

Since 2006, seven well-deserving individuals and one organization were awarded the ASA President's Award, all of whom dedicated their time and energy to advance the shotcrete industry.

For 2014, outgoing President Charles Hanskat presented the ASA President's Award to Oscar Duckworth for his outstanding service to ASA and the shotcrete industry. Duckworth has provided untold hours of his personal time and effort to advance both the education and safety of shotcrete nozzlemen through ASA programs.

He created much of the "ASA Safety Guidelines for Shotcrete" document, then shepherded approval through the ASA Safety Committee, and a careful review by the ASA Board of Directors. Duckworth took the lead and, working with Marc Jolin, updated our 8-hour ASA Nozzlemen Education session to bring it up to date, incorporating more detailed technical and safety-related material. The new nozzleman education sessions rolled out to our examiners in early 2014. Then, having cleared those hurdles, Duckworth took to heart ASA's desire to better educate shotcrete inspectors, and has produced a new educational session for shotcrete inspectors. The first trial presentation of this new educational program was at World of Concrete this year. Along the way to tackling these challenges, Duckworth has served on a variety of Board committees, chaired the Safety and now Education committees, and served on the Executive Committee. ASA and the entire shotcrete industry are indebted to Duckworth for his selfless and tireless efforts to raise the bar for safety and education in our industry.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2015 Media Kit

Shotcrete Calendar

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

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

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

JUNE 7-11, 2015
The International Bridge Conference
David L. Lawrence Convention Center
Pittsburgh, PA
www.eswp.com

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

OCTOBER 14-16, 2015
ICRI 2015 Fall Convention
Theme: "Modern Trends in the Repair Industry"
Hilton Ft. Worth
Ft. Worth, TX
www.icri.org

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

NOVEMBER 8-12, 2015
The ACI Concrete Convention and Exposition
Theme: "Constructability"
Sheraton
Denver, CO
www.concrete.org

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

FEBRUARY 1, 2016
ASA Committee Meetings at World of Concrete
Las Vegas Convention Center
Las Vegas, NV
www.shotcrete.org

FEBRUARY 2-5, 2016
World of Concrete 2016
Las Vegas Convention Center
Las Vegas, NV
www.worldofconcrete.com

MARCH 16-18, 2016
ICRI 2016 Spring Convention
Theme: "Maintenance and Protection in Harsh Environments"
The Condado Plaza Hilton
San Juan, Puerto Rico
www.icri.org

APRIL 16, 2016
ASA Spring 2016 Committee Meetings
Hyatt & Frontier Airlines Center
Milwaukee, WI
www.shotcrete.org

APRIL 17-21, 2016
The ACI Concrete Convention and Exposition
Hyatt & Frontier Airlines Center
Milwaukee, WI
www.concrete.org

JUNE 26-29, 2016
ASTM International Committee C09, Concrete and Concrete Aggregates
Chicago Marriott Downtown
Chicago, IL
www.astm.org

OCTOBER 22, 2016
ASA Fall 2016 Committee Meetings
Marriott Philadelphia
Philadelphia, PA
www.shotcrete.org

OCTOBER 23-27, 2016
The ACI Concrete Convention and Exposition
Marriott Philadelphia
Philadelphia, PA
www.concrete.org

DECEMBER 4-9, 2016
ASTM International Committee C09, Concrete and Concrete Aggregates
Renaissance Orlando at SeaWorld
Orlando, FL
www.astm.org

D3522 Attachment from Blastcrete

The D3522 Attachment from Blastcrete Equipment Company can be powered by an existing hydraulic power source. It is lighter, more versatile, and much more affordable than hot epoxy pumps and mixer/pump combinations with built-in power supplies, especially because skid steers and other equipment with auxiliary hydraulic hookups can power the unit.

The D3522 Attachment features a hydraulic squeeze (peristaltic) pump that is built for long life and low total cost of ownership. The pump has two rollers that rotate clockwise and squeeze a 2 in. (51 mm) rubber pumping tube. The rotation generates suction from the receiving hopper and pushes the material through the pump and out the discharge into the delivery hose. The epoxy materials do not come in contact with the moving parts of the squeeze pump, unlike a rotor stator or piston-style pump. The D3522 Attachment's primary wear part, a 2 in. (51 mm) rubber pumping tube, can be replaced in 20 minutes or less.

The D3522 Attachment can pump hot epoxy or cementitious grouts at variable speeds from 0 to 6 yd^3/h (0 to 4.59 m^3/h flow rate) and deliver up to 400 psi (3 MPa) of pumping pressure. Those capabilities, coupled with the unit's light weight, make it easy to transport and highly versatile. Contractors can use the pump for a wide variety of applications, such as grouting to mount and secure heavy industrial equipment and pumping fiberglass jackets for pier rehabilitation and stabilization.

The D3522 Attachment also can be used for spraying plaster and small wet-shotcrete applications.

The unit boasts a variety of safety features to protect the operator. For example, if the pump becomes plugged, the operator can easily reverse the pump for 5 seconds to relieve pressure on the delivery hose.

Blastcrete designed the D3522 Attachment for easy operation. The unit has a large, well-marked control panel with simple control levers to operate the pumping function. The control panel is near the hydraulic hookups for easy access.

The D3522 Attachment also is easy to clean and maintain. After the unit has been emptied of excess material, contractors can rinse the hopper with water and insert a round sponge ball into the suction hole of the pump. The hopper is then flooded with water or other solution for cleaning epoxies. The ball is simply pumped through the pump and delivery hose to ensure it is clean and clear.

For more information, contact Blastcrete Equipment Company, 2000 Cobb Avenue, Anniston, AL 36201; phone (800) 235-4867; fax (256) 236-9824; e-mail info@blastcrete.com; visit **www.blastcrete.com**.

New Putzmeister MINELIFT 4 Scissor Lift Platform for Mining

To continue optimizing logistics of underground mining operations, Putzmeister has developed the MINELIFT 4 scissor lift platform. With a lifting height of 13 ft (4 m) and a 4 ton (3.63 tonne) capacity, the equipment provides a mobile and secure working platform for load and personnel lifting in underground mining and can also be set up for all kinds of installations, such as piping and ventilation. In this way, MINELIFT 4 is adaptable to customers' needs.

MINELIFT 4 is available in a configuration setup for the installation of water, air, drainage, and tailing pipes in underground mining. It incorporates a drop-wing platform extension that expands the wide lateral by 28 in. (700 mm), providing a work surface total of 134 x 100 in. (3400 x 2550 mm). The high load capacity crane allows pipes to be lifted in an easy and safe way. For mounting, MINELIFT 4 incorporates a pipe handling system with two independent telescopic arms, designed for pipes from 4 to 8 in. (100 to 200 mm) and with load capacities of 661 lb (300 kg) each. In this way, MINELIFT 4 facilitates safe and efficient operation during pipe installation in underground mining.

For ease of operation in ventilator mounting, MINELIFT 4 is available with an auxiliary lift platform that provides a load capacity of 5512 lb (2500 kg) and lifts up to 43 in. (1100 mm) from the main platform. By incorporating this optional equipment, MINELIFT 4 becomes a complete solution for lifting and installation work in underground mining.

MINELIFT 4 features compact design with heavy-duty axles and four steering and driving wheels (4x4), as well as a powerful six-cylinder 130 kW (174 hp) engine. The Integrated Continuously Variable Drive (ICVD) without gear shift allows you to leverage the maximum engine power at any time without breaks in traction, making operation easier for the driver. The combination of the hydrostatic drive system, slope measurement, and Putzmeister control software form the core of the automatic downhill speed control system. The equipment automatically adapts its maximum speed to the slope, taking full advantage of the engine retention capacity, thereby reducing the probability of operational errors. Service brakes on both axles are multi-disc in oil bath, hydraulically operated with two independent circuits. This system provides great stopping power and a long working life, even in the most demanding conditions. This ensures maximum operational safety, performance, and durability of the equipment.

MINELIFT 4 features a FOPS/ROPS certified driving cabin, designed according to ergonomic standards to reduce operator

fatigue and increase productivity. The equipment has LED work lights both on the platform and on the vehicle, providing operators with a safe environment inside the mine. Thanks to the reverse camera with night vision, the operator can maneuver in reverse with confidence and accuracy. At the request of the customer, the equipment is available with an enclosed cab, which can include air-conditioning and heating.

Visit **www.putzmeisterunderground.com** or contact Putzmeister Underground at info@putzmeisterunderground.com for more information.

Normet Introduces Latest Mining Equipment Offering

Normet launched its new generation mining equipment offering in the MF and LF Series at the Bauma China 2014 exhibition in Shanghai, China. The offering sets a new standard for comfortable underground drive with unique axle suspension system and redesigned ergonomic cabins. The new offering is ready for industrial Internet, as machines can register all data and transfer it for further analysis via WLAN.

The new offering will gradually be available in 2015 with

several engine options to fulfill different exhaust emissions regulations around the world.

Normet has introduced a hydraulic axle suspension system for 11 and 18 ton (10 and 16 tonne) machine classes. The suspension enhances vehicle handling at higher speed, reduces cycle time, and increases the productivity and efficiency of a vehicle. Front axle suspension is available for all Utimec, Multimec, Variomec, Charmec, Spraymec, and Himec product families in the MF and LF Series. Utimec MF and LF personal (PER) transporters consist of both front and rear axle suspension to provide the same comfort for the driver and the passengers in the transport compartment. The suspension system can also be easily retrofitted to the older models.

The new FOPS- and ROPS-approved safety cab provides superior visibility and a comfortable compartment for the driver and passenger. Wide door openings, handrails, and ideally positioned nonslip steps allow for easy entry and exit. Enclosed cabs have a noise level of less than 80 dB.

The new offering comes with the new electrical system and the second-generation NorSmart control system. Traditional gauges have been replaced with the new Multi Information Display (MID), which provides all the necessary driving information such as speed, fuel consumption, RPM, and temperatures. NorSmart can record all vehicle data such as speed, gear selection, use of brakes, engine and hydraulic oil temperatures, and engine and gearbox oil pressures. All of the sprayed concrete and charging work process data is recorded on Spraymecs and Charmecs. The recorded data can be transferred for further analysis and supervisory checks via WLAN or by USB. Site-specific industrial Internet applications such as M2M and remote diagnostics can be arranged through NorSmart.

BASF Showcases Innovative Underground Construction Solutions at Arabian Tunneling Conference and Exhibition in Abu Dhabi

BASF Construction Chemicals has marked an emphatic participation at the upcoming Arabian Tunneling Conference and Exhibition in Abu Dhabi, showcasing innovative products for Underground Construction (UGC) within its Master Builders Solutions portfolio.

BASF has highlighted groundbreaking technologies such as the Sprayed Concrete Equipment Simulator—an interactive tunneling construction software. Visitors to the stand were invited to personally experience the on-site simulator. BASF's admixture systems and solutions for waterproofing were also on display.

Throughout the conference, BASF's UGC specialists headlined a series of technical seminars. Karl Gunnar, Technical Manager for Underground Construction Solutions, spoke about spray-applied waterproofing membranes, while Daniel Montalban, Global Technical Manager for TBM (Tunneling Boring Machines) applications, presented a paper on these applications. Additionally, Nick Chittenden, Regional Manager for BASF Underground Construction Middle East, outlined the company's strategy of combining global intelligence with local experience to guarantee the success of its applications at the Young Engineer Forum.

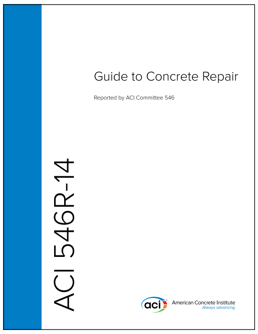
Speaking ahead of the conference, Nick Chittenden said, "Supported by a global team, BASF is a world leader in the provision of reliable, customer-oriented solutions for tunneling applications. Our portfolio includes sprayed concrete, injection solutions, products for TBM, waterproofing systems, and fire protection products.

"The Arabian Tunneling Conference and Exhibition has evolved as a definitive regional industry event and offers us an ideal platform to promote our products, projects, and services to the region's burgeoning construction industry. We will leverage our participation as gold sponsors to collaborate with prospective clients and global decision-makers, as well as network and share knowledge with industry peers for the ultimate benefit of the construction sector."

Hosted by the UAE Chapter of Society of Engineers with the support of the International Tunneling and Underground Space Association (ITA) that BASF is affiliated with, the Arabian Tunneling Conference and Exhibition took place on December 9-10, 2014, at the Abu Dhabi National Exhibition Centre.

The 2-day conference and exhibition is the only event of its kind in the region, making it the essential meeting point for tunneling professionals involved in the design, management, and maintenance of underground infrastructure. The event is anticipated to bring together more than 800 multidisciplinary engineering professionals, constructions professionals, scientists, and educators from across 25 countries. For more information, visit **www.uaetunnelling.org**.

ACI Releases New Guide to Concrete Repair



ACI has announced the release of the latest ACI 546R-14, "Guide to Concrete Repair." This guide presents recommendations for the selection and application of materials and methods for repairing, protecting, and strengthening concrete structures. An overview of materials and methods is presented as a guide for selecting a particular application. References are provided for obtaining in-depth information on the selected materials or methods. For more information or to attain copies of this publication, please visit **www.concrete.org**.

Shotcrete FAQs

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

Question: *We are an architectural design firm that specifies extensive amounts of shotcrete to mimic rockwork in our designs for large-scale animal exhibits. We often encounter differing views on the need for galvanized or coated reinforcing bar in our shotcrete work, especially when they are used as pool lining walls containing salt water. Can you tell us your opinion on whether galvanizing or coating of reinforcing bar is necessary if both integral and surface waterproofing are specified?*

Answer: Shotcrete is a process of placing concrete. The need to use galvanized or any other type of reinforcing is, or should be, based on the needs of the project and the preference of the structural design engineer. For liquid-containing concrete structures, the designer may review ACI 350-06, "Code Requirements for Environmental Engineering Concrete Structures," which has specific concrete material, cover, and reinforcing requirements for concrete exposed to a variety of chemical and saltwater exposures. (The aforementioned ACI Committee 350 publication may be purchased from the American Concrete Institute at **www.concrete.org**.)

Question: *I am lowering the roof of the draft tube on a hydropower dam. The work is all overhead and has a slope to it. The new roof profile will be lowered from 2 in. (51 mm) (initial edge) to 6.25 ft (approximately 2 m) thick. The plan is to use rock anchors to transfer the load to the existing concrete, and tie in a reinforcing bar grid at the lower section of the new roof profile (4 in. [102 mm] cover). Shotcrete is being planned for the infill material. The traditional ACI 318 design method was used for sizing reinforcing bar.*

The concern I have in the design is the application of the shotcrete. The plan is to allow the contractor to install a wire mat (or reinforcing bar mat) approximately 2 in. (51 mm) from the existing concrete roof, then apply shotcrete until reaching the reinforcing bar location, up to 6 ft (1.8 m) thick, then apply the finish layers. I have concerns about how thick shotcrete can be applied overhead. I have received feedback from some shotcrete companies that one can apply up to 4 ft (1.2 m) thick overhead layers, yet others say to never apply more than 4 in. (100 mm) layers. I also have concerns of delamination between the shotcrete and the existing concrete during the installation process, and potential shotcrete falling under its own weight in the thicker locations.

Do you know of any situation where shotcrete was installed overhead to thicknesses of 6 ft (1.8 m)? How thick can the shotcrete be before additional reinforcement is required to hold it for overhead applications? Is there a recommended maximum thickness for overhead application of shotcrete being placed before additional reinforcement is required? For the area that is 6.25 ft (2 m) thick, should I be using multiple layers of reinforcement (or fiber reinforcement) to prevent fallout?

Answer: This is a very challenging potential installation and there could be several potential approaches. For the shotcrete to bond to the existing concrete, the existing surface should be properly prepared, removing any unsound concrete, then roughened and cleaned to allow for a good bonding interface. You mentioned using rock anchors or bolts. These should be installed before any shotcrete.

For each 6 in. (152 mm) layer, a layer of welded wire reinforcement or structural fibers should be used. These, in conjunction with the rock bolts, should ensure the stability of each layer of the shotcrete from falling.

The surface reinforcement should not be installed before most of the area is within 6 to 8 in. (152 to 203 mm) of the final surface.

There is currently similar thicknesses being placed on the East Side Access in New York City to build back the overbreak for the initial tunneling to the "A-line" or profile that was intended for the mining.

Question: *We're designing two steel stacks to be located in Texas and subject to hurricane winds. The diameters are 9.19 and 4.92 ft (3 and 1.5 m), respectively. Both stacks are 118 ft (36 m) high. To reduce the vortex shredding oscillation effects, we want to increase the mass of the stacks by means of internal gunite lining. Our calculation provides good results considering approximately 2 in. (51 mm) thick interior liner.*

For this scope, is it better to consider external or internal lining? Would there be any advantage to applying an external liner with respect to the interior solution? Which of these two is the most cost-effective solution?

Answer: Shotcrete would work well either for the stack exterior or as an interior lining. The 2 in. (51 mm) thickness could be easily applied on either the outside or inside surfaces.

For the 9 ft (3 m) diameter stack, it would be easier and more cost-effective to scaffold and gun the inside of the stack. The work could be done with less difficulty, from an interior hanging platform suspended with sky climbers. There would be less cost involved with rigging than there would be with scaffolding or rigging around the outside circumference of the stack.

For the 4.92 ft (1.5 m) diameter stack, there is much less room to work inside, so unfortunately it may need to be gunned on the outside.

Question: *I am building a perimeter overflow pool and need to know the best way to finish the trough. I have one shotcrete* *company that wants to hand-finish the 6 in. (152 mm) wide trough; another wants to shoot up to foam. Can you tell me which is best and why?*

Answer: This is a classic performance-versus-prescription situation. The owner or customer should specify the desired end product and the contractor should choose the means and methods. Although they may both provide a great product, what works for one contractor or what he/she is comfortable doing may be completely different than another contractor.

Question: *Would epoxy-coated reinforcing bar be required for a shotcrete site retaining wall that does not have waterproofing behind it?*

Answer: Shotcrete is a method of placing concrete and the properties of properly placed shotcrete are equal to those of cast concrete. We have seldom seen the use of epoxy-coated reinforcing bar in retaining walls with or without waterproofing. (The California Department of Transportation builds many retaining walls with cast concrete and with shotcrete and seldom uses epoxy-coated reinforcing bar or waterproofing.)

It is important that you use a contractor qualified and experienced in this type of work and who uses ACI Certified Nozzlemen and a qualified crew.

Question: *I am involved with an above-grade canal replacement project that used shotcrete. The forms were recently pulled from one of the vertical walls, and extensive defects were visible throughout the wall length. Reinforcing bar shadowing occurred at nearly every vertical bar as well as numerous void pockets of various depths (some even up to 3 in. [76 mm]).*

Demolishing and replacing the wall is not a viable option. I am responsible for developing repair recommendations to the client and would like to know if there are any standards for shotcrete tolerances, specifically in regards to defects. I am going to specify that a repair mortar be used for repairing the defects and would appreciate any insight into this, as well as any wisdom that could be offered in dealing with reinforcing bar shadowing.

Answer: This seems to be two questions:

1. The repairs should be accomplished as recommended in ICRI Technical Guidelines: the area to be repaired should be chipped out to sound concrete, sandblasted or waterblasted to remove any bruised material, dampened to a saturated surface-dry condition, and patched with a reputable and known repair mortar.

2. ACI 506 defines "shadow" as any porous areas behind an obstacle, such as reinforcement. Proper shotcrete application by an experienced nozzleman with adequate equipment and crew will create shotcrete sections that have minimal shadowing and voids. However, sometimes upon stripping of the backside forms there is a noticeably darker coloration of the concrete surface immediately behind reinforcing bars. This darker coloration often does not have porous areas, but is an indication that the reinforcing bar is close to the form and, although good, dense material has been placed, it has a slightly higher cement paste content and thus appears darker on the surface. Sounding the area of discoloration should identify any porous areas that should be repaired, as mentioned previously.

It should be noted that this is not unique to shotcrete. Cast concrete that is not properly placed and fully consolidated often exhibits voids and rock pockets that need to be repaired upon stripping of the forms.

Question: *We are the Architects of Record for a multi-family rehabilitation here in Portland, OR. The existing building is three stories plus a half basement. It is a historic building and is also an unreinforced masonry building. As a result, it requires significant seismic upgrades.*

Our structural engineer is proceeding with a design that uses several 4 in. (102 mm) thick shotcrete walls as shear elements throughout the building. In most instances, these walls are being constructed adjacent to an existing wall to minimize their impact to the existing floor plans.

This seems fine against the exterior masonry walls but we have concerns where the shotcrete is to be installed directly adjacent to a standard architectural partition (gypsum wall board and wood studs). We are planning on plywood sheathing to act as a one-sided form to prevent the shotcrete application from harming the existing stud wall. However, we were curious if we should also include a water barrier so that the application did not allow moisture to migrate into the existing walls during the installation. Is this assumption correct? And if so, is there a performance or product recommendation that you can offer for this purpose?

Answer: Shotcrete has been used in similar structural upgrades for decades quite successfully. There are many ways to ensure that the moisture from the fresh shotcrete would not impact the existing partitions. Methods for protection include use of green board (as used in a shower or bath), plywood, painted coatings, moisture-resistant sheeting, and so on.

Shotcrete is placed with a low water-cement ratio (*w/c*) and the water is needed by the shotcrete to hydrate the cement and harden. As long as the existing surface or treated surface does not actively absorb the moisture, the shotcrete will use the available internal moisture to hydrate the cementitious materials.

Question: *We're proposing to install a new shotcrete shear wall against existing 8 in. (203 mm) CMU walls for a project of ours. STRUCTURAL has provided a steel reinforcement cage across each wall plane, which is tied to the existing CMU wall with a series of anchors running horizontally and vertically. Between this new shotcrete wall and existing CMU wall, we are calling for a vapor barrier layer to retard moisture migration from the exterior to the interior. At this point, we are considering going with a PROSOCO Cat-5 fluid-applied vapor barrier system over the CMU but were curious how this might interface with the shotcrete.*

Have you dealt with this vapor barrier issue before, or seen similar installations? Would the steel reinforcing cage be adequate to support the shotcrete by itself during application, or should we be concerned about the surface of the backup wall?

Answer: Shotcrete has been placed against fluid-applied waterproofing and other smooth surfaces, which would likely be similar to the surface you are concerned with. An experienced shotcrete contractor should be able to install this shear wall, taking care to apply the shotcrete in a sequence which inhibits the material from sagging or sloughing. The key is hiring a good, well-experienced shotcrete contractor.

The reinforcing bar size and spacing can help provide support for building up the shotcrete. The spacing should be no greater than 12 in. (305 mm) on center each way and must be rigid.

Question: *I am currently working on a project that involves repairing the concrete walls of a sanitary sewer interceptor structure and line pipe and was wondering if you had any reference information regarding shotcrete being used to repair similar items and how well it has held up. Any information you send will be greatly appreciated.*

Answer: Shotcrete, both wet- and dry-mix, have been used to repair and reline sewer structures for many decades and has held up well as a lining or repair material. It is important to have the work done by a qualified shotcrete specialty contractor and to specify a durable concrete mixture design. The following are links to articles which may also be of interest to you:

- www.shotcrete.org/media/Archive/1999Spr_Snow.pdf, "Rehabilitation of Sanitary and Storm Sewers Using Shotcrete"
- www.shotcrete.org/media/Archive/1999Win_Yoggy.pdf, "Shotcrete, Airplanes, and Automobiles"
- www.shotcrete.org/media/Archive/2006Win_Morgan.pdf, "Advances in Shotcrete Technology for Infrastructure Rehabilitation"
- www.shotcrete.org/media/Archive/2013Sum_Sustainability.pdf, "Ability to Access Restricted Space and Difficult-to-Reach Areas, Including Overhead and Underground"

Question: *We have a project in the Los Angeles, CA, area that we have designed as poured-in-place concrete. The contractor would like to shotcrete all basement walls. However, we have columns that are integrated with the wall. A City of Los Angeles technical bulletin does not address shotcrete columns in a wall where the bar spacing varies from the wall. Do you have any* *experience with this issue and is there a way to shotcrete both the wall and the column?*

Answer: There have been many prior projects in the city of Los Angeles where columns and pilasters are incorporated into perimeter basement walls. This would likely require a preconstruction mockup panel and might require a waiver from the City Engineering Department. It is extremely important to ensure that the work is done by a qualified and experienced shotcrete specialty contractor who has documented experience doing similar work.

Question: *Can Pozzutec 20+ (or any other accelerating admixture) be used with a dry-mix shotcrete? If so, has it been used on any large-scale projects?*

Answer: Pozzutec 20+ is intended for use in ready mixed concrete. Although it may work with dry-mix shotcrete, there are other products that are designed for use in the wet and dry shotcrete processes.

Question: *We are looking at constructing climbing boulders made with shotcrete and using a polystyrene core. Does the polystyrene need to be covered with a protective membrane to protect it during the spraying process? Also, could the polystyrene contribute to the structural integrity of the boulders, or should it just be used as a void-forming material?*

Answer: Polystyrene is available in various densities and the denser the product, the less likely that the shotcrete process will cause any damage to it. The question of the structural value of the polystyrene needs to be addressed by a competent structural engineer. It is not something that we, as a shotcrete association, feel qualified to comment on.

Question: *I am an architect working on a project in which a masonry building was "coated" with a shotcrete or gunite material. It is reported that this was troweled on approximately 20 years ago.*

We have made test holes and it is adhered very well, except where moisture penetration through the parapet has compromised adhesion. This is installed with five layers approximately 1 in. (25 mm) thick. We are considering leaving the material in place, patching as required, and removing the existing nonpermeable paints (which are peeling). Our thought is to coat the surface with a variegated colored stain, allowing for permeability of vapor.

Can the material be patched as necessary? What is the recommended finish? Do we need to be concerned that the material could permit water penetration? Are there certified contractors in the Cleveland, OH, area?

Answer: From what you have described, the original work may have been done by the shotcrete process or hand-applied. Typically in the shotcrete process, over a large area at the thickness of 5 in. (127 mm), you would expect to see reinforcing mesh or reinforcing bars.

The material can be patched. If the areas are small, it may be prudent to hand patch. Shotcrete is most effective in larger applications. It is important to select a good repair mortar or mixture design.

ASA does not have a recommended finish. Generally in this type of application, the goal would be to match the existing surfaces as close as reasonably possible.

Many patches are done on bridges and other structures without regard to water penetration.

We do not have certified contractors; however, many of our corporate contractor members have ACI Certified Nozzlemen on their teams and the Buyers Guide on the ASA website can be searched by location and specialty. Also on our website, we have a position paper on "Shotcrete Contractor and Crew Qualifications" with a handy checklist summary that would be useful in qualifying potential contractors for your project (**www.shotcrete.org/media/Archive/2014Win_ShotcreteCorner.pdf**).

New ASA Members

AMERICAN SHOTCRETE ASSOCIATION

CORPORATE MEMBERS

D Construction Inc.
Coal City, IL
Primary Contact: Jeff Gillan
j.gillan@dconstruction.net

Global Specialty Contractors, Inc.
Eagan, MN
Primary Contact: Zach Brazier
zach@globalspecialty.net

Malcolm Drilling Co. Inc.
San Francisco, CA
Primary Contact: John Starcevich
jstarcevich@malcolmdrilling.com

Morrison Engineers PLLC
www.morrisonengineers.com
Raleigh, NC
Primary Contact: James Hoover
james@morrisonengineers.com

Pipe Technology, a Westflex, Inc., Company
www.pipetechnology.com
Hawthorne, CA
Primary Contact: Brian Craig
brian@pipetechnology.com

Prometheus Construction
www.prometheusconstruction.com
Honolulu, HI
Primary Contact: Brian Mahnken
brian@prometheusconstruction.com

Ralph L. Wadsworth Construction Company
www.wadsco.com
Draper, UT
Primary Contact: Tera Wadsworth
tera@wadsco.com

New ASA Members

AMERICAN SHOTCRETE ASSOCIATION

RWR Construction Inc.
www.rwr-inc.com
San Rafael, CA
Primary Contact: Rod Roche
rod@rwr-inc.com

Sika Schweiz AG, Aliva Equipment
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Zurich, Switzerland
Primary Contact: Matthias Hagler
haegler.matthias@ch.sika.com

SprayForce Concrete Services Ltd.
www.sprayforceconcrete.com
Calgary, AB, Canada
Primary Contact: Jay Unruh
info@sprayforceconcrete.com

Texan Gunite
Cedar Park, TX
Primary Contact: Juanjose Armenta-Aguirre
texanccs@gmail.com

CORPORATE ADDITIONAL INDIVIDUALS

Patrick Bridger
King Packaged Materials Company
Allentown, PA

Steven Crawford
Superior Gunite
Lake View Terrace, CA

Frank Townsend
Superior Gunite
Hillsborough, NJ

INDIVIDUALS

Amer Beirouty
Saudi Concrete Technique Co.
Riyadh, Saudi Arabia

NOZZLEMEN

Kevin Born
Ashbury General Contracting and Engineering
San Francisco, CA

PUBLIC AUTHORITIES & AGENCIES

Shannon Golden
Alabama Department of Transportation
Montgomery, AL

STUDENTS

Mohsen Azimi
North Dakota State University
Fargo, ND

Simon Berube
Laval University
St. Nicolas, QC, Canada

Matthew Hitt
Buhl, AL

Saqib Hussain
National University of Sciences & Technology
RawalPindi, NS, Pakistan

Qian Wu
Austin, TX

Nathan Ziegler
Amherst, MA

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.

Use of Cathodic Protection in a Shotcrete System

By Jesse Osborne

Used successfully for over 100 years, shotcrete, or gunite, is concrete that is conveyed or transported with a concrete pump or pneumatic gun and sprayed into place. While the method has remained relatively constant, the equipment, materials, and applications are continuously improved and expanded. Today, concrete can be applied through the use of robotics in areas formerly considered inaccessible or unsafe, shotcrete can be batched as self-consolidating concrete (SCC), and materials containing macrofibers can be placed thinner while still maintaining structural integrity. Along with the continuous improvement, there are also some occurrences that have plagued shotcrete for years.

One of the chief issues is corrosion of steel reinforcement. The use of synthetic fibers has reduced the dependency on steel; however, steel cannot be easily replaced in all applications. When steel reinforcement is used, it is a good idea to protect it with the use of one of the available corrosion control methods currently available. There are various methods of protection available to the concrete industry. Calcium nitrite has been available for many years and has a proven track record of success. The mechanism for this method of protection essentially slows the ingress of chloride and "binds" it up through a process referred to as ion exchange before it reaches steel reinforcement. Cathodic protection is also used extensively in the concrete repair segments, as well as in new construction. Cathodic protection involves the use of zinc anodes. This method of corrosion protection has been available for some time, but its use in shotcrete is comparatively new.

Under normal conditions, steel in concrete is essentially protected. There is a passive layer that protects the steel in concrete due to the high pH of portland cement. However, when chlorides or CO_2 eventually reach the steel, the passive protective layer breaks down and corrosion is initiated by the creation of several microscopic corrosion cells.

Corrosion is an electrochemical process involving the flow of electrons through metal and the flow of ions through an electrolyte. There are four necessary components to a corrosion cell: an anode, a cathode, a metallic path, and an electrolyte. In a corrosion cell, the most active metal will act as the anode with the most noble metal acting as the cathode. Corrosion typically occurs at the anode. Because of inconsistencies in the purity of structural steel, it is likely to have microscopic corrosion cells within a single piece of steel. The corrosion cell will look like this:

Anode = parts of the structural steel
Cathode = parts of the structural steel
Metallic path = the steel itself
Electrolyte = shotcrete

Cathodic protection works by introducing a more active metal (zinc) to the electrolyte (in this case, shotcrete) and connecting it metallically to the structural steel using the tie wires that are attached to the anode. Because zinc is a more active metal than steel, all of the steel becomes the cathode. So the alternative (more active) corrosion cell will now look like this:

Anode = sacrificial element
Cathode = structural steel
Metallic path = galvanized steel tie wires
Electrolyte = shotcrete

Cathodic protection dates back almost 200 years and can be traced to British naval vessels, where it was used to slow the corrosion of the steel hulls on ships. Its use in concrete repair and protections has been common for the last 30 to 40 years. These anodes are manually attached to steel reinforcement before the concrete or shotcrete is placed. While these anodes eventually require replacement, they will extend the expected repair interval by two to three times, making them a worthy investment.

The concept of cathodic protection in concrete and concrete repair is relatively straightforward and widely accepted. The mechanism by which it works (explained previously) is fairly simple.

The anodes corrode in place of the reinforcing steel. To achieve this, there are some stipulations that need to be addressed to ensure adequate protection. First, the anodes need to be spaced properly. To properly space the anodes, some information needs to be acquired. For instance, what is the chloride content of the existing structure (in concrete repair cases) or what is the expected chloride content (for new structures)? To properly determine the chloride content of the structure, the surrounding content should be tested in accordance with ASTM C1218/C1218M. Once the chloride content is determined, the steel reinforcement needs to be identified. The reinforcing bar size, density, and distribution are also considered in the spacing of the anodes. Examples of how this information is used to determine the anode spacing is shown in Fig. 1 and 2.

This type of spacing criteria is used when the concrete/shotcrete has a volumetric resistivity of less than 15,000 ohm-cm. When the concrete/shotcrete has a volumetric resistivity higher than 15,000 ohm-cm, a correction factor is typically applied. Shotcrete often includes silica fume in both wet and dry mixtures. Silica fume will naturally increase the matrix resistivity, so testing the resistivity is highly recommended. The testing equipment is relatively inexpensive and easy to operate. Once the chloride content (or expected chloride content for new structures) is determined, the reinforcing bar density is identified and the resistivity is tested; the anode spacing factor is then set. For the anodes to work properly, they should be in full contact with the reinforcing steel that they are going to protect and also need to be fully encapsulated in the surrounding concrete or shotcrete. Normally, this is not an issue. However, in shotcrete, full encapsulation takes a little bit more attention. Shotcrete should be placed by ACI certified and experienced nozzlemen. Special attention should be used to ensure that adequate encapsulation of the anodes is performed. If complete coverage is not obtained, there is a risk of more concentrated chloride migration to more focused areas of the anode, which would lead to premature repair of the area.

Anode spacing in shotcrete deserves a clear explanation. Cathodic protection depends on chloride migration, or movement, through the concrete/shotcrete matrix. With the higher volumetric resistivity of most shotcrete mixtures due to high cement factors, addition of silica fume, and lower water-cement ratios (*w/c*), the

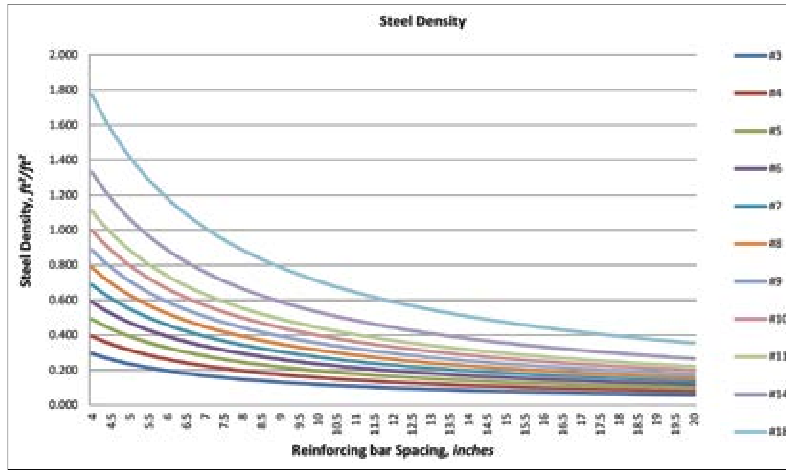

Fig. 1: Steel density

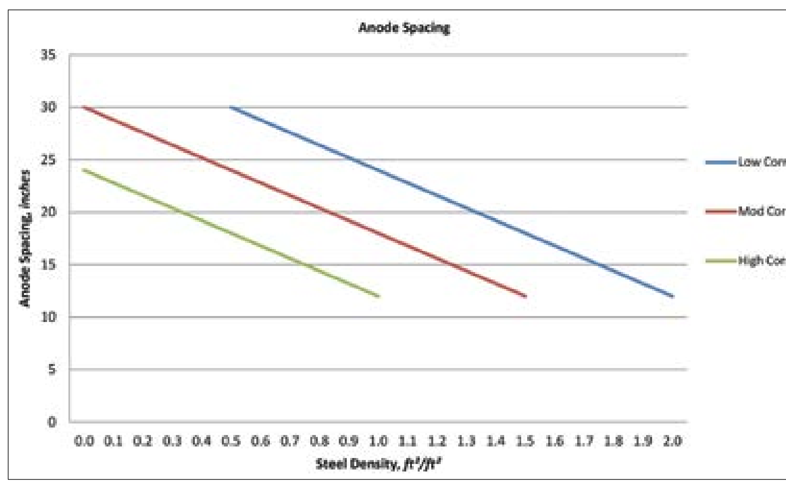

Fig. 2: Anode spacing

Fig. 3: Reinforcing bar sentinel tie-in

Fig. 4: Sentinel install

chloride movement is slowed to the point that the protective coverage range of the anodes is reduced significantly. For this reason, the spacing of the anodes is reduced to ensure protection of the steel. Determination of the resistivity is recommended in all projects and is essential in shotcrete projects. Determining the mixture resistivity, as stated earlier, is fairly simple and inexpensive. The Florida DOT has done extensive testing and published the data and results. This paper is available on the Florida DOT website.

The type of anodes themselves plays a large role in the protection. Typically, the contact area between the anode and reinforcing steel should be stable and insulated to contact only at the ends to prevent "dumping of current" onto the reinforcing bar. This current dumping can lead to overloading the cathodic protection system and cause premature failure of the anodes. Also, the amount of sacrificial material that is used (zinc, in most cases) will play a significant role in the amount of protection and the life span of the anode. Using more zinc in the anodes is essential in high-chloride environments. Increasing the service of the anodes prolongs the time interval for anode replacement, which obviously saves more money. The anodes need to be attached to the reinforcing bar in a manner that will secure them as snugly as possible. They are usually attached to the reinforcement with some type of steel tie. The steel tie portion of the anode is subjected to corrosion, as well; therefore, using a corrosion-resistant material such as galvanized steel for the tie-downs is important. If the ties corrode prematurely, the anode is no longer attached to the reinforcing bar and protection will not occur.

Eventually the anodes require replacement. However, this replacement lasts approximately two to three times longer than conventional concrete before it would need to be repaired, and the replacement is, for the most part, easier than a standard repair (as long as the replacement takes place before corrosion is able to reach the reinforcing bar). There are various testing procedures used to determine when the anodes need to be replaced. Once this testing indicates that it is time to replace, the area around the anode is saw cut and chipped away to reveal the reinforcing bar and a new anode is attached. Repair material comprised of similar material to the original structure is recommended to maintain the same spacing criteria.

The use of shotcrete as a base material, as well as a repair process, is continually growing in popularity. The use of cathodic anodes as a method of corrosion protection is also popular with historical success. The combination of the two materials is an obvious good fit. Initial time, labor, and material costs are overcome by the savings that are experienced by extended repair time cycle.

Reference

"Cathodic Protection Systems—Use of Sacrificial or Galvanic Anodes on In-Service Bridges," NYSDOT Office of Operations, Transportation Maintenance Division, Bridge Maintenance, 2008, 24 pp.

Jesse Osborne *is currently the Mining and Tunneling Segment Manager for The Euclid Chemical Company, based in Cleveland, OH. He has been with Euclid Chemical for over 10 years and has over 30 years of experience in the concrete and cement construction industry with positions ranging from research and development to product and segment marketing. He is a member of SME and NPCA.*

AMERICAN SHOTCRETE ASSOCIATION

Watertight Shotcrete for Swimming Pools

Shotcrete is an ideal construction method for a concrete swimming pool. The versatility of shotcrete placement allows for the construction of a concrete pool shell of virtually any size and shape. Standards for shotcrete design and applications can be found in American Concrete Institute (ACI) Committee 506 guides,[1] specifications, and technical notes, as well as ASA position papers.[*] Responsible shotcrete contractors specializing in concrete pool construction must use appropriate design, quality materials, and construction techniques to build a fully functional pool with long-term durability that is essentially watertight under normal service conditions. Watertightness of the shotcrete material is a crucial durability and serviceability property of any properly constructed water-holding shotcrete structure. Shotcrete placement that allows water to pass through the concrete of a pool shell is a sign of flawed material or placement techniques.

Pools are complex concrete structures with irregular shapes, varying thicknesses, numerous shell penetrations, and variable soil conditions. The structural requirements for a pool shell must be evaluated by a professional engineer who is qualified for structural evaluation. A proper design will include specifications for subgrade preparation, concrete shell thicknesses, concrete materials, reinforcing steel layout, and pipe and fixture penetration details. With an appropriate design, proper materials, and quality placement, the experienced builder creates a pool that meets loading conditions, provides long-term durability, and is essentially watertight.

The concrete material used to construct the pool shell must meet watertightness requirements. Scientifically defined, watertightness of the concrete material is the result of complex mass transport mechanisms (capillarity, permeability, and water diffusion) that refer to various properties of concrete.[2] A definition of watertightness is "impermeable to [measurable flow of] water except when under hydrostatic pressure sufficient to produce structural discontinuity by rupture."[3,4] A proper concrete mixture design is a prerequisite for successful shotcrete application of concrete. A well-designed, shootable mixture should be selected with a proper aggregate gradation, allowing it to pass through a shotcreting system. Special attention should be given to the amount of fine aggregate and cementitious paste necessary to cover the aggregate surface area (minimum 4:1 cementitious-to-aggregate ratio, and ideally 3:1). Sufficient cementitious paste and a low water-cementitious material ratio (*w/cm*) are necessary for producing a dense, watertight final product.

Assuming the correct mixture design, compressive strength of the concrete is generally indicative of the *w/cm* (lower *w/cm* equates to higher strength) and the potential watertightness of the shotcrete in the pool shell. Complete compaction of the pool shell concrete is a direct result of the velocity (typically 65 to 115 ft/s [20 to 35 m/s][5]) at which the mixture is shotcreted onto the substrate. The high impact energy produced by proper shotcrete equipment and placement techniques achieve maximum in-place encapsulation and compaction with minimum voids for a given concrete mixture. Compressive strength is measured through core samples taken from in-place material or shotcrete test panels. Because concrete compressive strength is affected by the same physical properties that affect watertightness, it is possible to evaluate the quality of a shotcrete pool shell—both from a structural and a watertightness point of view—by considering the compressive strength of the shotcrete produced. Thus, in this context, compressive strength is an appropriate predictor of watertightness.

Shotcrete made from properly graded aggregates, quality cement, and potable water; properly placed by a qualified shotcrete crew; consolidated at the requisite velocity; and properly cured will easily yield a 28-day compressive strength of 4000 psi (28 MPa). In reality, 5000 psi (34 MPa) is desirable for enhanced durability and is routinely achievable by careful attention to materials and placement techniques. Table 4.2.2 of ACI 350-06[6] (refer to Fig. 1) has requirements for special exposure conditions. The table indicates concrete intended to have low permeability when exposed to water should have a maximum *w/cm* of 0.45 with a minimum 4000 psi (28 MPa) compressive strength. However, when the concrete is exposed to chlorides (brackish water, salts, and seawater), ACI 350 requires a *w/cm* of 0.40 and compressive values of 5000 psi (34 MPa) to provide protection for embedded reinforcement. Thus, lower

[*]NOTE: "Shotcrete" and "concrete" are two distinct terms. Shotcrete is defined as "concrete placed by a high-velocity pneumatic projection from a nozzle."[3] In other words, concrete is the **material**; shotcrete is the placing **process**. The end result is a *concrete* structure built with the *shotcrete* process. However, many members of the industry will use the terms interchangeably *when the reference to the shotcrete process is implied*. We do the same in this Paper, using "shotcrete" and "concrete" interchangeably. A "shotcrete pool shell" is understood to be comprised of concrete, and a "concrete pool shell" is—in this context—understood to have been placed using the shotcrete process.

TABLE 4.2.2—REQUIREMENTS FOR SPECIAL EXPOSURE CONDITIONS

Exposure condition	Maximum water-cementitious materials ratio, by weight*	Minimum f_c', psi*
Concrete intended to have low permeability when exposed to water, wastewater, and corrosive gasses	0.45	4000
Concrete exposed to freezing and thawing in a saturated condition or to deicing chemicals	0.42	4500
Concrete exposed to corrosive chemicals other than deicing chemicals	0.42	4500
For corrosion protection of reinforcement in concrete exposed to chlorides in tanks containing brackish water and concrete exposed to deicing chemicals, seawater, or spray from seawater	0.40	5000

*A lower water-cementitious material ratio or higher strength may be required for durability of concrete exposed to sulfates (Table 4.3.1).

Fig. 1: Table 4.2.2 of ACI 350-06[6]

w/cm and higher compressive strength provide better protection for embedded reinforcement in water containing structures. Concrete technology and common sense show that watertightness will be improved using a concrete with a low *w/cm* with sufficient paste content—that is, well-consolidated by the placement techniques and properly cured and protected after placement—thus creating a dense impermeable concrete.

There are many reasons why a shotcrete placement would not achieve specified minimum compressive strength. These include poor workmanship, defective equipment, undesirable environmental conditions, or the inadequate selection of ingredients including poorly graded aggregates, soft or deleterious aggregates, expired cement, or contaminated water. In any case, compressive strength values less than 4000 psi (28 MPa) are, in most cases, the result of intentionally or unintentionally ignoring the rules of good practice[7,8] and will result in pool shell shotcrete that is not as watertight.

As with any other concrete structure, shotcrete pool shells must be properly designed—both from a structural and a concrete material perspective. Good quality shotcrete properly designed, manufactured, placed, and cured will produce the desired result—a durable and essentially watertight structure. Experienced pool builders pay attention to all the details of the shotcrete process and building pool shells with watertight shotcrete. Watertightness of shotcrete should be the expectation of all parties: the client, the designer, and the contractor.

References

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3. ACI CT-13, ACI Concrete Terminology, American Concrete Institute, Farmington Hills, MI, 2013, http://www.concrete.org/portals/0/files/pdf/ACI_Concrete_Terminology.pdf.

4. ASA Pool & Recreational Shotcrete Committee, "Position Statement #2, Definitions of Key Shotcrete Terminology," *Shotcrete*, V. 15, No. 3, Summer 2012, p. 29.

5. Ginouse, N., and Jolin, M., "Material Velocity at the Nozzle," *Shotcrete*, V. 15, No. 4, Fall 2013, pp. 22-24.

6. ACI Committee 350, "Code Requirements for Environmental Engineering Concrete Structures (ACI 350-06) and Commentary," American Concrete Institute, Farmington Hills, MI, 2006, 487 pp.

7. Crom, T. R., "Dry-Mix Shotcrete Nozzling," *Concrete International*, V. 3, No.1, Jan. 1981, pp. 80-93.

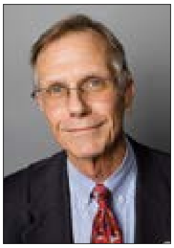
8. CP-60, "Craftsman Workbook for ACI Certification of Shotcrete Nozzleman," American Concrete Institute, Farmington Hills, MI, 2009, 126 pp.

Position Statements

ASA has produced position statements on the best practices for proper shotcrete placement. To date, four position statements from our Pool & Recreational Shotcrete Committee and one from our Board of Direction have been issued. These statements have been previously published in *Shotcrete* magazine.

Visit **http://www.shotcrete.org/pages/products-services/shotcrete-resources.htm**.

ASA Executive Director



Charles Hanskat

ASA is proud to announce the appointment of **Charles S. Hanskat** as full-time Executive Director effective February 2015. Following the Board vote to confirm an Executive Director who will also act as Technical Director to support and promote ASA's mission, Hanskat's new role was announced at ASA's recent Annual Meeting and Awards Banquet in Las Vegas, NV. Hanskat's background in the industry on various ACI committees, including ACI Committee 506, Shotcreting, and C660, Shotcrete Nozzleman Certification; the Strategic Development Council; ASTM International; and most recently, ASA President and Shotcrete Nozzleman Examiner, brings a wealth of experience to this role and the Association.

ASA Officers and Directors Elected

Executive Committee

Left to right: Scott Rand, Marcus von der Hofen, Lihe (John) Zhang, and Bill Drakeley

The ASA membership has elected the following individuals to leadership roles in the Association, with terms beginning February 2, 2015. President **Marcus von der Hofen**, Coastal Gunite Construction Co.; Vice President **Bill Drakeley**, Drakeley Industries; Secretary **Scott Rand**, King Packaged Materials Company; and **Lihe (John) Zhang**, LZhang Consulting & Testing Ltd., were all elected to 1-year terms. Michael Cotter was reappointed as Past President for another 1-year term in consideration of Hanskat's new appointment.

Board of Direction

Three individuals were (re)elected to 3-year terms as ASA Directors, beginning on February 2, 2015. **Patrick Bridger**, King Packaged Materials Company, was reelected to a second term. **Oscar Duckworth**, Valley Concrete Services, and **Frank Townsend**, Superior Gunite, were elected to first terms.

Patrick Bridger

Oscar Duckworth

Frank Townsend

These three Directors join the previously elected Directors and the ASA Executive Committee to form the 14-member ASA Board of Direction.

2014-2015 ASA Graduate Scholarships Awarded

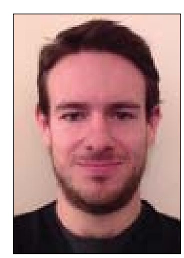
The 2014-2015 ASA Graduate Scholarships have been awarded to Simon Bérubé, Pasquale Basso Trujillo, and Qian Wu. Each student received a stipend of $3000 (USD) for tuition, residence, books, and materials.

Simon Bérubé earned his Bachelor's in civil engineering from Université Laval, Québec, QC, Canada, where he is continuing on to earn his Master's in the same field. He is interested in the field of shotcrete repairs and is currently researching spray distribution and the rebound of materials.

Pasquale Basso Trujillo received his Bachelor's in civil engineering and administration from Universidad Panamericana, Mexico City. He is now pursuing his Master's in civil engineering at Université Laval, Québec, QC, Canada. He is researching the development length of reinforcing steel in shotcrete structures and hopes to continue his research through a Doctorate.

Qian Wu graduated from the South China University of Technology with his Bachelor's in civil engineering. She is now working toward her Master's in civil engineering at the

Simon Bérubé



Pasquale Basso Trujillo

Qian Wu

University of Texas at Austin, Austin, TX. She is interested in developing industrial applications of cement-based magnetorheological fluid. She hopes to eventually go on and seek her PhD in civil engineering.

These scholarships are awarded each year to students pursuing higher education in the field of concrete with an interest and potential for professional success in the shotcrete industry. Established in 2008, the ASA Graduate Scholarship Program seeks to identify, attract, and assist outstanding graduate students in their pursuit of careers in the field of concrete, particularly in the application of the shotcrete process. This program opens each year in late spring. Visit **www.shotcrete.org/pages/education-certification/grad-scholarships.htm** for more details on the ASA Graduate Scholarship Program.

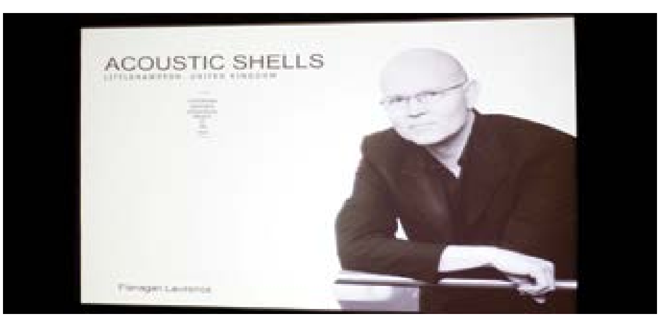
Tenth Annual ASA Outstanding Shotcrete Project Awards Banquet

It was a packed house at the New York, New York Hotel & Casino on Tuesday, February 3, 2015, as ASA celebrated its Tenth Annual Outstanding Shotcrete Project Awards Banquet at World of Concrete. Attendees gathered to socialize with fellow ASA members and celebrate the top projects of 2014 that have exemplified the effective and beneficial use of shotcrete as a placement method for concrete construction. You can see this year's award-winning projects beginning on p. 16 of this issue.

Special thanks are in order to ASA's banquet sponsors—without their generous donations, this event would not be possible. A complete list of these companies can also be found in this issue, beginning on p. 10. Think you've got what it takes? Start submitting your projects now!

We urge all ASA members to begin thinking now about current shotcrete projects that may be worthy of consideration in 2015 as an Eleventh Annual ASA Outstanding Shotcrete Project Award. Let the outstanding projects you complete this year be the ones we celebrate at next year's ASA Awards Banquet!

To encourage even more entries, this year we're opening up the project-of-the-year submittal webpage right after the banquet; so, when you get back home, get a jump on the competition and submit your entries! The 2015 Awards Program will accept projects completed between January 1, 2013, and September 1, 2015; multiple projects may be submitted from the same company. Deadline for submissions will be October 1, 2015. More information can be found at **www.shotcrete.org/ASAOutstandingProjects**.



ASA Spring 2015 Committee Meetings in Kansas City, MO

The ASA Spring 2015 Committee Meetings will be held at the Kansas City Marriott and Convention Center on Saturday, April 11, 2015.

The following committees have scheduled working meetings: the ASA Executive Committee, the Education Committee, the Pool & Recreational Shotcrete Committee, the Safety Committee, the Publications Committee, the Marketing Committee, the Membership Committee, and the ASA Board of Direction. These meetings offer participants the opportunity to network with colleagues, provide input on shotcrete materials and publications, and take part in carrying out ASA's overall mission.

The ASA committee meetings are held in conjunction with The American Concrete Institute (ACI) Concrete Convention & Exposition but do not require registration with ACI. ASA meetings are open and free to anyone with an interest in the shotcrete process. If you are active in the shotcrete industry, you are welcome and encouraged to attend.

Scheduled times for all meetings can be found at **www.shotcrete.org/pages/news-events/calendar.htm**.

Workers' Dust Protection

By Ray Schallom III

There have been articles, safety tips, and numerous discussions over respirators and dust masks in past issues of *Shotcrete* magazine that show and talk about what your workers should be wearing. These date back to the early 1970s, when the industry began a growing awareness of lung impairments resulting from exposure to cement dust for long periods of time. Cement dust can build up in your lungs if you do not wear any type of dust protection. I can remember when one of the old-timers who mentored me during that time had a heart attack; the X-rays showed he had a small cement buildup in his lungs. The company immediately went out and outfitted every shotcrete crew with half mask and full face mask respirators. Forty years later, I am now one of those old-timers and I still wear my respirator in and around the shotcrete operation. Unfortunately, the latest industry challenge we face today is the confusion between silica fume (also called microsilica), which has a very small round particulate, and larger silica sand particulates, which are jagged. The jagged particulates from the silica sand do not pass through your lungs like the rounded silica fume particulates do. Figures 1 through 3 show different types of N-95 rated masks and filters.

This article will deal with dust generated by the shotcrete processes and which mask meets Occupational Safety and Health Administration (OSHA) and National Institute for Occupational Safety and Health (NIOSH) minimum requirements. I have been around the dry and wet shotcrete processes for close to 40 years as a worker/mixer/gun tender, gun runner/operator, nozzleman, finisher, foreman, superintendent, project manager, and now owner. Over the past 40 years, I have been put through tests to check the level of dust generated during the work shift, which showed what type of dust protection my crew and I needed for the job. I have been on simple bridge repair projects to very difficult confined space projects. The dust monitors all came back with almost the same results. If the worker was wearing at least an N-95 dust mask (Fig. 1), the dust generated by the shotcrete

Fig. 1: Honeywell odor-removing double band

Fig. 2: 3M half mask with P100 dust filters

Fig. 3: MSA half mask with N-95 prefilters

process would protect the worker adequately during an 8-hour work day. The double rubber band paper mask meets OSHA and NIOSH minimum requirements. (N series is for environments free of oil aerosols, R series is resistant to oil mist for up to an 8-hour shift, and P series is oil proof with time use restrictions specified by the manufacturer.)

One problem with the double rubber band dust masks is when the worker breathes; the exhaust breath has nowhere to escape but upward around the nose, causing the worker's safety glasses to fog up. Another issue with the paper mask is a worker can go through five paper masks in 1 day because of moist breath, sweat, or other types of mists in the air. Now multiply that by 5 days—you now bought at least one box per worker for the week. If the conditions are right, you may be able to get by with one mask per day, but that's highly unlikely in most nozzling conditions.

Back when I was promoted to superintendent, one of my many tasks was controlling personal protection equipment (PPE) safety costs. I looked at every item closely; some were obvious, which were corrected right away. The main issue was the costs of dust masks versus the cost of a fitted half mask respirator per worker. For me it was easy; I had dealt with the paper mask issues as a worker and realized it was cost-effective to properly fit each worker with a half-mask respirator. These half-mask respirators can be cleaned and disinfected on a regular basis. The only steady cost would be the cartridges and prefilters or just the N-95 prefilters. There are several brands and models—some of which require cartridges where you can place an N-95 prefilter over top of the cartridges, then snap on a retaining cap to secure each prefilter. This protects the cartridge from clogging up, and for the most part all you do is replace the prefilter. I use an MSA Comfo Classic half mask, which comes with the cartridge receptacles. I am able to place two N-95 prefilters in each receptacle and snap on the retainer caps to keep the prefilter pads in place, which is shown in the mask in Fig. 3. (This particular mask is 6 years old!) Everyone has their preference on half masks. The projects I have been on the past 20-plus years only required me to use the prefilters for dust protection. My last CAT scan of my lungs showed up clear. In my last breathing exam, I was able to exceed the passing limits set on the machine—the technician had to reset the machine higher each time to check my maximum lung capacity. I am happy to say that wearing the approved OSHA and NIOSH respirators my entire career is proof that it pays off in the long run.

This article is not intended to make everyone go out and buy half-mask respirators. It is intended to make you aware that as long as your workers are wearing N-95 rated masks, you have met the minimum requirement. Remember that different environments and projects may require the use of half masks with certain cartridges or air-fed masks. In some cases, it's cheaper to buy either the double rubber band dust masks or half masks with prefilters in bulk than it is to buy one at a time. There are safety supply houses around the country that have good deals on safety items in bulk. It adds up at the end of the year when you start buying one at a time at a local lumber yard on an as-needed basis.

Think smart, be smart, and wear your PPE correctly. It's the later years in life that you begin to have health issues which could have been avoided.

Ray Schallom III *is an underground shotcrete application specialist and President of RCS Consulting & Construction Co. Inc. He has 40 years of experience as a Project Manager, Owner, and Superintendent. Schallom works with State DOT departments with their shotcrete specifications and trains engineering company's inspectors in the field of shotcrete. He is a Past President of ASA, Past Chair of the ASA Education Committee, and is a member of the ASA Publications, Underground, Marketing, Sustainability, and Pool & Recreational Shotcrete Committees. Schallom is also a member of ACI Committees 506, Shotcreting, and C660, Shotcrete Nozzleman Certification, and ACI Subcommittees 506-A, Evaluation; 506-B, Fiber-Reinforced; 506-C, Guide; 506-E, Specifications; 506-F, Underground; and 506-G, Qualification for Projects. Schallom is a retired ACI Certified Nozzleman in the wet- and dry-mix processes for vertical and overhead applications with over 40 years of shotcrete nozzling experience in wet- and dry-mix handheld and robotic applications. He is an ASA-approved Shotcrete Educator and an ACI-approved Shotcrete Examiner for wet and dry applications. Schallom is also a member of ASTM Committee C09, Concrete and Concrete Aggregates, and ASTM Subcommittee C09.46, Shotcrete.*

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