Shotcrete MAGAZINE

A quarterly publication of the American Shotcrete Association

Volume 17, Number 3 ◆ Summer 2015

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Pools

AMERICAN SHOTCRETE ASSOCIATION


"FROM MY PERSPECTIVE,
IT'S EASY TO SEE
WHY SO MANY PEOPLE
COUNT ON KING."
– Scott Rand, Vice President, Sales

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Features

Departments

On the cover: Residential Pool, Roanoke, VA
Photo Courtesy of National Pools of Roanoke Inc.

Fortitude

By Marcus H. von der Hofen

This issue's message goes out to our members in the field where their hard work is the backbone of what we do.

A couple of days ago, a new pool was being installed a couple doors down from me. So I strolled down the street to take a look at the operation. The bilge pump wouldn't prime, and there was at least 2 ft (0.6 m) of water in the deep end. The reinforcing steel wasn't finished yet, with some laying on the formwork and the rest on the ground. There were no guide wires despite having a straight beam to shoot. As I stood there, like a tourist, one of the crew members came over to me and says with a snicker, "Just another day as a guniter."

I can't count the times I have walked onto a job and been welcomed with the incomplete work of others. Though I don't work in the pool industry, I've seen shotcrete crews face this type of aggravation a thousand times. That crew member had absolutely no idea that I knew exactly what he meant when he said "just another day as a guniter."

So what are you thinking right now? Here comes bad shotcrete?

Two crew members came around the corner with a backup sump pump and proceeded to get it working on the water in the deep end. The guy who had snickered to me grabs some dobies and starts fixing the reinforcing steel at the back form. The second crew member fell in behind stringing the guide wires. Customary banter ensues as one member is told that it's not necessary for him to watch the pump run. As the water level goes down in the deep end, the guys dobie up the reinforcing steel on the floor. The nozzleman starts getting his hose laid out, and tells a crew member, in a kind manner, to do something. More of the customary construction crew banter ensues…with language I don't need to repeat.

The nozzleman grabs the hose, uses an air-water blast to wet up anything that was dry and goes to work. He shoots in the floor and cove around the base of the wall and then moves on with some excellent bench gunning technique on the walls—maintaining clean reinforcing steel and a consistent receiving surface. A couple of finishers jumped in behind him and started cutting cove and face. Then the unbelievable happened: they shoveled the rebound and cuttings out of the pool. I went back about 2 weeks later and the pool shell looks great as it waits for the tile and plaster. There was no leaching, and the surface is free of cracks. Not really a surprise is it?

We can all get together and make rules, exchange knowledge, make presentations, slide shows, and safety plans, but if we can't get shotcrete placement executed correctly in the field, what is it worth? This company's crew displayed the element that is required of us all for success: "fortitude." Without it, all the training, certifications, and knowledge are useless.

I personally want to thank all the thousands of guniters and shotcreters out there that are carrying the burden of this trait. A trait that is never stated in the guides and manuals we produce, but is proof of the strength, commitment, and hard work our field crews do to get it done right. It is because of you our industry thrives and has a great potential for future growth.

ASA Marketing Committee

By Joe Hutter

10th Annual ASA Outstanding Shotcrete Project Awards Program

The ASA Marketing Committee has had an active first few months in 2015, starting with the behind-the-scenes efforts to organize our annual awards banquet held again this year at the New York, New York Hotel & Casino in Las Vegas, NV. If success is measured in attendance and sponsorship participation, this year's banquet was the most successful since the inaugural event in 2006. Over 160 ASA members attended the banquet and 34 sponsors pledged over $40,000 in support of the banquet and ASA. From the perspective of enthusiasm and enjoyment, all those who attended enjoyed the opportunity to mingle with like-minded colleagues, share some cocktails and a great meal, and celebrate excellence in our industry.

The ASA Awards have always provided excellent exposure for our industry, our association, and especially to the contractors, manufacturers, and suppliers whose projects are selected for an award. The winning projects are published not only in our own *Shotcrete* magazine and on the ASA website; they are often also picked up and re-published in other industry publications and websites. In addition to the free publicity that winning an award provides, marketing-savvy winners can also increase their exposure through their own marketing efforts. Press releases announcing the accomplishment, announcements on the winner's website, featuring award-winning projects in client presentations, and using many forms of social media marketing are some examples of how ASA award winners have taken advantage of the opportunity provided through the ASA Outstanding Shotcrete Project Awards Program.

To encourage more project submittals this year, ASA opened the Awards submittal website page shortly after the banquet. This early start date will hopefully provide time for ASA members to log photos and prepare submittals for their best projects. For 2015, we hope to double the number of entries, so all ASA members should take cameras to their jobsites and start planning for their outstanding project submittals now. January 2016 may seem like a long time from now, but a simplified submittal process, available through ASA's website (**www.shotcrete.org/ASAOutstandingProjects**) will allow projects to be submitted any time between February 1 and October 1, 2015. Submit your shotcrete project today and you may be chosen as one of the 2015 ASA Outstanding Shotcrete Project Award winners.

ASA Rebranding

ASA was established in 1998 and since that initial launch of our Association, the Marketing Committee has been active in the promotion of the shotcrete process to engineering consultants, DOTs, and other specifiers across North America. After 17 years, however, the time has come to develop a new, fresh look that will carry ASA into the next decade and beyond. The task of rebranding ASA has fallen to the Marketing Committee and we are pleased to announce that the process of developing a new ASA look and image has begun.

Rebranding of the Association's image is among the most important tasks that ASA's Marketing Committee has undertaken for 2015. There are several projects that rely on the completion of the rebranding project, including the design of a new ASA booth and other similar marketing initiatives that will feature new look and a new ASA logo.

To begin the rebranding process, the ASA Marketing Committee requested proposals from two marketing firms to develop a new visual concept for ASA in line with the new initiatives unveiled last year with ASA's Strategic Plan. After consultation with the Executive Committee, it was agreed that a contract to develop this new ASA brand would be awarded to Kulör Design, a small, boutique design firm that specializes in complete corporate branding and identity services.

Kulör Design is situated in Montreal, QC, Canada, and was established in 2004 by Art Director and Graphic Designer Liette Bernard. She brings more than 20 years of industry experience working for major clients such as General Motors Canada, Coke, and McDonalds. The initial design work has already begun and it is expected that an official unveiling of the new ASA logo and look will be ready for the ASA Fall 2015 Committee Meetings in Denver, CO. We look forward to seeing as many ASA members there as possible!

ASA Marketing Committee

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Marcus H. von der Hofen | Coastal Gunite Construction Co.

Summer's Here— Time for ASA Road Trips

By Charles S. Hanskat, PE, ASA Executive Director

The weather is warmer, and I've finally been able to hang up the fleece jacket. It's nice when walking the dog at 6:00 a.m. doesn't require three layers, boots, gloves, and a wool hat. Here at ASA we've been very busy in raising awareness of ASA in a number of industry market segments that will pay back with long-term benefits to our shotcrete industry. Take a look at the Association News column in this issue, and you'll see ASA members and staff have been very actively involved in a number of activities to promote the quality and application of shotcrete. From the News you'll see we've gone on the road to meet with and work with state agencies, international conferences, ASTM standards committees, ACI technical and certification committees, and associated organizations across the globe.

Certification activity continues to be strong through the first half of 2015. We're seeing many new certifications, but also a lot of recertifications for nozzlemen with a good mix between wet-mix and dry-mix with both vertical and overhead orientations. In June, we held one of the largest ASA/ACI certification sessions, with 19 nozzlemen shooting a total of 47 panels (vertical and overhead combined). Thanks to our ASA examiners, Marc Jolin and Carl Baur, who conducted this large session professionally and efficiently. They also had the assistance of one of our future examiners, Michael Cotter, who certainly helped keep the session rolling and I'm sure learned a lot of the details required for a successful certification session. We've added two new ASA/ACI examiners, Lars Balck and Ted Sofis. Congratulations to both and we look forward to working with you on your future certification sessions around the world.

One of the great things about my job is getting the technical inquiry calls (or e-mails) that come in from engineers, architects, owners, or contractors who don't know much about shotcrete, or those who think they know shotcrete but have some misconceptions on how shotcrete performs. It seems every contact has a different issue, and being able to analyze their problem, quickly respond, and raise their knowledge about shotcrete is a rewarding feeling. Also, having the ability to quickly and efficiently address their questions often makes it easier for a specifier to include shotcrete in their project and ultimately make more opportunities for our members.

Speaking of opportunities for our corporate members, I've also seen that after answering some of our technical inquiries, several specifiers and owners then went on to use our ASA Bid Request program. The Bid Request program allows owners and specifiers to submit a bid request to ASA, which we then forward to all of our corporate members. Making the specifier or owner feel comfortable with ASA as a technical resource and also a conduit to qualified, experienced member companies helps confirm ASA is fulfilling our commitment to the members and the industry.

Finally, the Executive Committee is taking our Strategic Plan, assigning committee responsibilities, and setting up a monitoring system to track progress on our strategic goals. We will be holding web meetings with our committees between the face-to-face meetings at the ASA Spring and Fall meetings to assure committee agendas are moved forward on a more timely schedule. We continue to make major advancements with our programs and activities, and the strategic plan is our roadmap for the future growth of ASA, and acceptance of shotcrete as an equal (or superior) to cast concrete.


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Swimming Pool Penetrations

By Jonathan E. Dongell

Shotcrete swimming pools, spas, and water features require a proper mixture design and attention to detail in application that ensures watertightness. A good shotcrete structure, enhanced with a good interior finish coating, should not leak water. While the shotcrete can be engineered and placed in a manner that creates a structure that is watertight, it is an unrealistic expectation that shotcrete will be watertight at penetrations or where it butts up to a dissimilar material. Swimming pools are typically shot monolithically, meaning one continuous application, with no relief joints. Therefore, it is logical that some separation will develop at penetrations, primarily as a result of normal shrinkage that occurs during the setting of hydraulic cement in shotcrete. While the function of an experienced shotcrete nozzleman is to fully encapsulate piping, light niches, and other penetrations within shotcrete, a certain amount of shrinkage and separation around penetrations subsequent to application is inevitable for most monolithic structures.

Fig. 1: Water intrusion at penetrations from behind structure

Therefore, all penetrations should be sealed or plugged. Some interior finishes that are continually trowelled to a hard, smooth finish may be capable of sealing around penetrations. Others, such as exposed-aggregate finishes, may require that a sealant or plugging material be applied prior to applying the interior finish coating. It is common practice to dig out ("cup out" or "box out") the shotcrete around some or all penetrations. Typically, dig outs for return lines are a nominal 1.5 to 2 in. (38 to 50 mm) in depth by a nominal 3 to 4 in. (75 to 100 mm) around the piping. Suction lines may require a much larger dig out, depending on the type of main drain base ring and cover that will be installed.

Dig outs allow better access to the piping, making it easier to cut the pipe far enough back to ensure that fittings will be flush with the anticipated surface of interior finish coating. Dig outs also allow access and space to apply a sealant or plugging material around the penetrations, ensuring they will be watertight. Other penetrations that require no other adjustment or work to be done prior to the application of the interior finish coating may often have little or no dig out. The burden of ensuring penetrations are sealed and/or plugged may fall to the builder, plasterer, or the pre-plaster prep crew depending on which party is given the responsibility. Ideally, the engineer or architect should stipulate the sealing or plugging of penetrations in a manner that ensures all are watertight.

Fig. 2: Piping with and without fitting prior to sealing

Fig. 3: Piping with fittings and sealed

Fig. 4: Improper sealing at pipe-shotcrete transition, leaving unsealed areas. Applying a sealant to the entire dig out area that is not compatible with cementitious materials

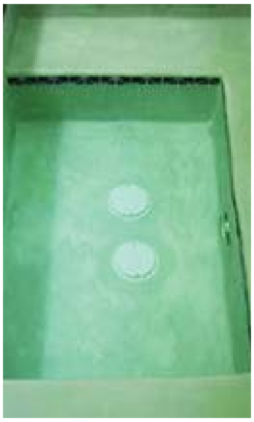

Fig. 5: Hydration issue due to variation in plaster thickness at dig outs

The following considerations, as to the type of material and method of installation, are suggested for sealing or plugging penetrations:

1. The use of non-shrinking or low-shrinkage cementitious plugging material;
2. Non-sanded cementitious materials should be used only as a thin slurry coating within the dig out, as per manufacturer's recommendations, and should not be used as a method of filling the entire dig out;
3. The inclusion of a polymeric fortifier, proven stable underwater, with the cementitious plugging material, as per manufacturer's recommendations;
4. The use of sealants that are not compatible with cementitious materials should be confined to sealing only the immediate area at the interface of the penetration and the shotcrete and should not be used to seal or coat the interior of the dig out, piping, or other fixtures;
5. The removal of any loose material or debris and thorough washing around penetrations to ensure a good adhesion bond or "keying" of the interior finish coating with the shotcrete;
6. Plugging or filling dig outs flush with the overall shotcrete surface, as opposed to using finish coating material while plastering, may help to prevent differential hydration discoloration caused by the interior finish coating's increased thickness at dig outs; and
7. Plugging material should be allowed to thoroughly dry or cure, as per the manufacturer's recommendations, prior to applying the interior finish coating.

Sealing of Other Cracks

The use of a good shotcrete mixture design and limiting of the water-cement ratio can reduce the amount and size of shrinkage cracks that develop in shotcrete. Proper engineering, shotcrete materials, and trade practices should ensure that the hardened structure will have no structural cracks. Plastic and autogenous cracks may be visible on the surface of a monolithic shotcrete structure; however, these will be sealed shut with the application of the cementitious interior finish coating. Structural movement cracks may not. Continued movement of the structure can reopen existing cracks or create new cracks.

__Jonathan E. Dongell__ is Director of Research & Development, Pebble Technologies, Scottsdale, AZ. Dongell has worked in concrete construction and with cementitious materials spanning over 30 years. His roles have included Technician, Superintendent, Manager, Contractor, and President. He is Past President, Whitestone Cement Company, Scottsdale, AZ (1998-2005), and Universal White Cement Co, Inc., Glendale, AZ (1992-1998). He is a member and past Chair of ACI Committee 524, Plastering, and is a member of ACI Committees 201, Durability of Concrete; 225, Hydraulic Cements; 232, Fly Ash in Concrete; 308, Curing Concrete; 350, Environmental Engineering Concrete Structures; and 555, Concrete with Recycled Materials. Dongell also currently serves on the Concrete Research Council (CRC). He is a member of several ASA Committees, including the ASA Pool & Recreational Shotcrete Committee. He is a member of several ASTM International committees and subcommittees. Dongell is the author of several books, including The Durability of Cementitious Materials in a Water Contact Environment. *He is an inventor and holds three patents on cementitious materials. He is a designated expert witness in the fields of cement, concrete, stucco/plaster, and water chemistry. He was the recipient of the ACI Delmar L. Bloem Distinguished Service Award in 2007.*


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Project Profile: Underwood Pool Belmont, MA

By Mason Guarino

The Underwood pool in Belmont, MA, is known as the first outdoor public swimming pool built in the United States. It was originally built in 1912. Our recent project to renovate the pool was specified shotcrete as the knowledgeable pool design engineer wanted the capabilities of shotcrete. This job used all the best characteristics that shotcrete can offer from light formwork to bonding capabilities. We ended up using all of our shotcrete and pool construction knowledge to create a successful project for the Town of Belmont, MA.

When the bids came in, all the bidders but one were high. Then the lowest bidder decided to drop out when he saw how low he ended up being. The next low bid was about \$400,000 over what was budgeted. However, being a relatively wealthy Boston suburb, the Underwood Pool Committee turned to the town for help to raise that last \$400,000 required to get the job going. A local bank stepped up early, saying it would match every donation, so the town only needed to raise about \$200,000 to fund the project. The town ended up raising the money in about a month and a half so the project could then proceed. The bad news was the delay in funding pushed the construction start time back over 2 months. This moved the start date for South Shore Gunite Pools & Spas, Inc. (SSG), and the swimming pool construction to late November.

As a swimming pool project, shotcrete was the obvious method for construction. It helped that the engineer agreed and had specified the project as a shotcrete structure. Fortunately, they did not specify wet- or dry-process shotcrete. This is a good practice because the shotcrete method should always be up to the applicator. SSG chose to go with the wet-mix method as this is a large project and the high production capability of wet-mix was needed. The project consists of two swimming pools: one was a 6000 ft^2 (560 m^2) water surface area competition pool with racing lanes with a 11 ft (3.4 m) deep diving well and the other was a 5000 ft^2 (465 m^2) water surface area wading/play pool. The project ended up using about 500 yd^3 (380 m^3) of shotcrete total. The final decision was whether or not to use ready mixed concrete. SSG has the capability of batching concrete material for shotcrete on-site and it is our preferred method. We chose to go with the on-site batching method as the space was available and the overall job made this approach feasible. Anything under 100 yd^3 (76 m^3) is typically a ready mixed job.

With a late November construction start and a complicated excavation, which included dewatering issues along with a complex form job, SSG was not able to start shotcrete placement until late December. Our original plan was to start on the larger pool and then move to the smaller pool whenever we could. This meant that some severe winter conditions protection would likely be needed. We hoped the snow would hold off.

The first step in the construction process was to form the floor as quickly as possible, as floor forms would go much faster than trying to build the entire form system Also, the wall forms could be attached to the concrete floor rather than attempting to drive stakes into frozen earth.

The second step was to install ground thaw hose in the 0.75 in. (20 mm) crushed stone layer under the pool. The ground thaw hose was installed in loops at 12 in. (300 mm) on center runs. This process ended up using roughly 5000 ft (1500 m) of ground thaw hose that would be drained and buried at the completion of the project. The ground thaw hose was connected to a glycol heating unit that gave us a constant ground temperature of roughly 50°F (10°C) on the coldest days.

The final step to protect the area to receive the material was building a temporary tent that would trap some heat and keep out some of the cold air and elements. Ropes, braces, and 100 x 60 ft (30 x 18 m) woven tarps were hung over the entire area and six to eight heaters were placed under the tent to help keep temperatures up (refer to Fig. 1).

On typical cold weather projects, we would keep the ground and reinforcing steel warm by laying down thermal blankets until we got to the area, placing the shotcrete, and then covering the fresh shotcrete as soon as it was finished to trap in the heat. This project would require a steel trowel finish so laying anything directly on the fresh shotcrete was not an option.

Jobsite temperatures ended up averaging between a high somewhat below 40°F (4°C) and

Fig. 1: The tent to help trap heat

a low around 20°F (–7°C) on a daily basis. Finally, we had to produce warm concrete that would set in cooler temperatures. Our mobile concrete batch truck has a water tank that used water circulated through a jobsite water heater so all of our mix water ended up being approximately 100 to 120°F (38 to 49°C). All concrete sand and crushed 3/8 in. (10 mm) stone was stored overnight indoors at our warehouse at 50°F (10°C) to keep the material from freezing or even being too cold. Additionally, we used a water reducer that contained a mild accelerator additive.

Once the shotcreting began, we made good progress installing the floor. We chose to shoot the floor because of the many different sloping angles in the floor along with the need for monolithic construction. Some of the areas would be very difficult to cast monolithically with traditional slab construction. SSG shot the floor in 10 ft (3 m) wide strips, taking meticulous care at the joints to maintain a steel trowel-paintable finish upon completion. The edges of the slab were left 3 in. (45 mm) low for the outside 6 ft (1.8 m) to accept the wall shotcrete when the time came. The floor was installed in the week between Christmas and New Year's. The compressive strength test results for the floor were approximately 8000 psi (55 MPa). Once the floor was complete, the crew moved into constructing the wall forms. The wall forms consisted of 1 x 3 in. (25 x 75 mm) rough-cut lumber construction using 1 in. (25 mm) thick rigid foam insulation to help the concrete trap in as much heat as it could while working under a tent. Once the forms were complete and ready for shotcrete, the snow hit. Boston's snowiest winter ever began burying the jobsite in roughly 3 ft (0.9 m) of snow in the first storm and then receiving another 3 ft (0.9 m) of snow 2 weeks later, putting a complete halt to construction and completely negating the use of the rigid foam insulation forms. Boston, roughly 10 minutes from the jobsite, would go on to receive roughly 10 ft (3 m) of snow in the first 4 months of 2015.

The job wouldn't resume again until late April, when the snow finally started to melt and we shoveled off the work area. This delay left our floor exposed for over 3 months to the severe weather, a surface that would then be shot against to maintain a monolithic pool shell. Unfortunately, the jobsite sat in a low, tree-covered area which substantially hindered the melting of the snow. Shotcrete resumed once normal spring conditions started, and made the working conditions much more comfortable and easier to work with. However, there was still the task of creating a steel trowel-finish pool construction.

The wall thickness ranged from 8 to 24 in. (200 to 600 mm). With the varying wall thicknesses, we knew that set times and final finish times would vary significantly. To counter this, SSG decided to go with the layering technique. SSG started by completely cleaning the surface to be shot against to continue the wall of the monolithic pool structure (refer to Fig. 2).

When shot, the floor area immediately under the wall was intentionally left very rough. This area was heavily power washed to remove anything that could hinder a bond. A bonding agent does not need to be used as properly applied shotcrete will adhere to old concrete as if it were

Fig. 2: First layer is ready to receive its final layer once SSD is achieved

Fig. 4: The final layer shot and cut, waiting to receive steel trowel finish

Fig. 3: A core sample from the pool wall where layering was done. Shows excellent reinforcing bar encapsulation and no actual layers

Fig. 5: The steel troweled final finish

shot against fresh concrete/shotcrete. A blow pipe would be used to keep the receiving surface immediately ahead of the nozzleman clean of rebound. The blow pipe would continue to be used throughout construction as the wall reinforcing was No. 4 and 5 (No. 13M and 16M) bars in a 12 x 12 in. (300 x 300 mm) pattern with both front and back layers. To use the layering technique, the first layer of wall would be shot to just cover the first layer of reinforcing bar, leaving about 1.5 to 2 in. (36 to 90 mm) of thickness to go. Because shotcrete bonds so well to itself and other concrete, using shotcrete made this process very easy (refer to Fig. 3). The layering technique allowed the material to be installed faster and for the finishers to work with a uniform concrete material that set up nicely and was predictable. This allowed the finishers to work roughly three times faster than if we shot the full thickness of the wall at one time. This method also made it easier for the finishers to achieve a straighter more accurate wall (refer to Fig. 4 and 5).

Shotcrete was key to building a quickly executed, profitable project. The limited amount of forming kept us moving fast, and the fact that we did not have to deal with any honeycombing or form irregularities on the interior finish wall allowed us to not do any work twice. The layering technique allowed us to maintain an accurate, smooth finish that, once complete, provided an excellent look with the final coat of paint. Our shotcrete success in both the wet and dry process would not have been possible if it were not for the support of the American Shotcrete Association, ACI Certified Nozzlemen, and ASA's highly knowledgeable members.

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

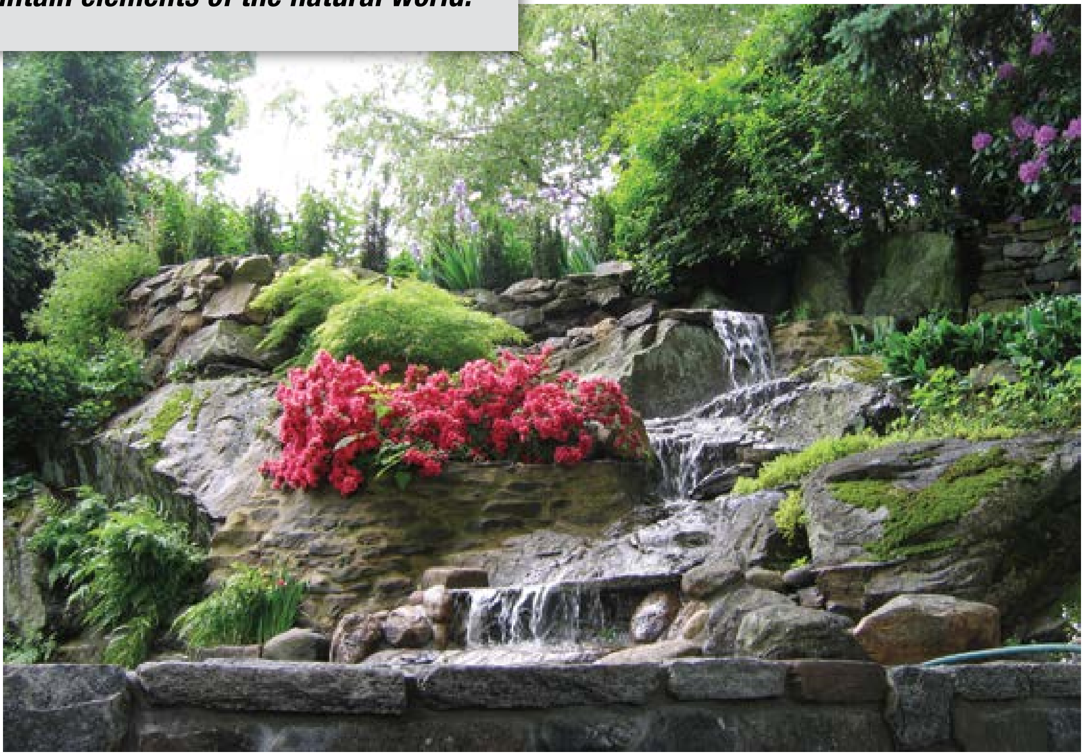
Shotcrete in Landscape Design

By James Scott

When we think of the shotcrete process, mental images of large industrial projects and repairs come to mind, such as tunnels, bridges, and drainage channels. If we keep thinking, we may think of smaller, human-scale recreational projects, such as swimming pools and skate parks. If we think even further, however, we may just bring ourselves back to the very beginnings of shotcreting—where its inventor (Carl Akeley) used it for his craft as a multi-disciplined naturalist.

Modern-day designers and naturalists use the process of shotcrete in the broad natural world of landscape. So, from the beginning, through present day, shotcreting has been used as a means to help one represent and maintain elements of the natural world.

In the natural world and landscape design, a core element is water. In fact, it may be the key element. Flora and fauna without water is an incomplete picture. For those of us who are watershape designers and builders (for example, ponds, pools, fountains, spas, and waterfalls), we sometimes think the watershape is the star of the show (a mistaken premise in the author's opinion), and that the surrounding elements carry a lower value. But, in the natural world, water must carry an equal relationship with other elements in the overall environment. Water must be presented in such a way that it takes no more than an equal footing with the other elements—landform, plant materials, ledge rock, boulders, and the sun. This balance is first achieved in the mind of the designer, but water poses an interesting challenge. Water always conforms to

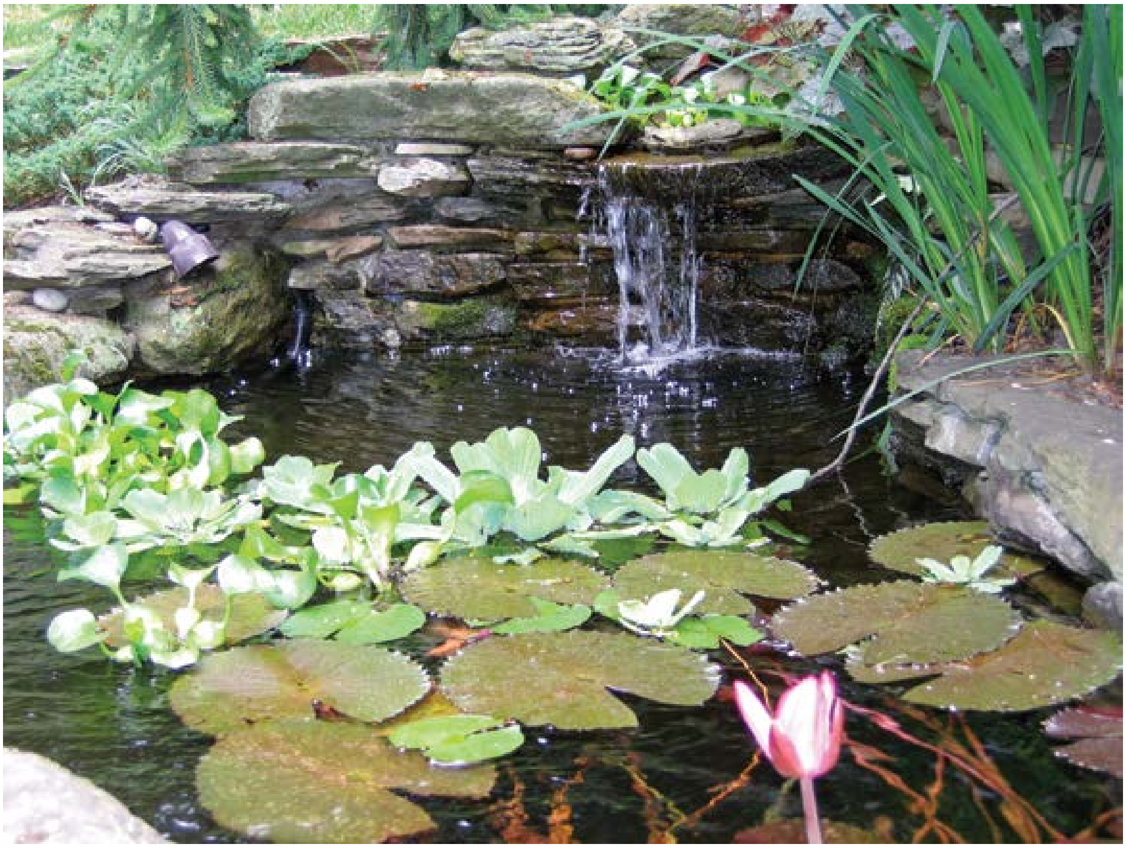


In this landscape, a spa was built against the base of an aged outcropping of ledge rock. Previous attempts had been made to create some sort of circulation down the side of the rock with poor results. Besides not having a basin large enough to catch the falling water, there were several crevices and natural seams in the rock that allowed too much water to pass for continued use. While the spa was being built, with a conjoined recirculation basin, attention was given to the ledge rock issues. Some of the crevices were carefully widened by machine and hand, and then steel-reinforced "patches" were shotcreted into place. Some of the offending seams were simply covered over during this process. Care was taken to protect the surrounding rock, and with some careful rock placement and "aging" techniques, the patches proved quite successful the shape and influences of the vessel it occupies. And in nature, this could be a shallow depression; a deep, still lake, over a rippling placement of stone; or in footprints left by an animal. This is where the value of the shotcrete process comes into play.

The shotcrete process has a long list of advantages that may already be known by the reader. For the landscape naturalist, there is a specific group of advantages that are appealing.

- Because shapes in landscape are often not regular, shotcrete's ability to be shaped into odd and irregular shapes is key. The ability to shape and carve it while in its plastic state is almost like a sculptor molding and shaping clay.
- The naturalist must consider practical matters when it comes to handling water. There are plastic or metal recirculation systems, stone that is used for features, bedrock that may be the base for the shotcrete, and cementitious finishes or coloring agents applied to the shotcrete. The shotcrete process does not alter the concrete's ability to marry well with these other materials. So, all the advantages of concrete are still available.
- Often the designer wants water to move over an existing channel or crevice of natural rock. To help create a watertight surface, shotcrete

For this garden water feature, naturally placed rock along with some masonry veneer was created in the rear of a residential property in a busy northeast city. In addition to its shaping abilities, shotcrete was selected as a means to combat the heavy freezing-and-thawing exposure the vessel would be subjected to. By digging to frost depth and installing a deep base of crushed stone, the shotcrete vessel has been leak-free for many years. The natural gunned finish was an easy way to create a suitable background for the interior spaces of the feature

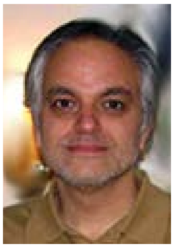


In the world of landscape, formal gardens show one's desire for symmetrical beauty; really a marrying of architecture and nature. In a very real sense, formal gardens are an abstract representation of the natural world; in the same sense a fine artist works. Water, too, then becomes abstracted in the shape of the vessel created herein; a circle. The circle, although not natural, has its own beauty of the geometry. Of all the man-made materials, cementitious matrixes hold a special place with outdoor designers. Concrete, plasters, clay bricks, and other similar masonry matrixes are a bridge between nature and man's architectural world. After all, they all contain mostly natural material whose use dates back thousands of years. In this way, concrete carries a place of honor to the designer. Therefore the circular fountain basin, created through shotcrete, is not only correct for the way it presents the water, but for what it's made from

is used to fill voids and crevices, while not obscuring the natural rock that is meant to be seen. Here's where the high velocity of the shotcreting process assists in developing watertightness. The shotcrete process also accepts admixtures that work towards this goal such as crystalline waterproofers.

- The gunning process of shotcrete enables a rougher, gunned finish, which is helpful in landscaped environments. This roughness can appear natural as it weathers, has the ability to naturally collect silts, earth, and allow spots for moss to catch hold and grow. What we think of as a negative to some architectural environments, becomes a plus when it comes to nature!

So, when you think of the shotcrete process next time, perhaps you'll remember the artistry that it has allowed. And maybe, just maybe, the next time you're admiring a natural environment, what you see as a beautiful piece of nature had a team of skilled shotcreters in first.



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Beginnings

By Lily Samuels and Bill Drakeley

From mine shafts to subway tunnels, from fountains to swimming pools, shotcrete has long been the preferred material of construction for major projects worldwide. This process, which involves the spraying of concrete material at a high velocity onto a receiving surface to achieve compaction, offers substantial advantages over alternative approaches with respect to durability, versatility, integrity, and sustainability.

This has been the case ever since the technique was invented at the turn of the twentieth century, yet only now are watershapers—professionals who have made concrete such a crucial part of their livelihoods—truly coming to understand and appreciate shotcrete for what it is.

Emergence

Shotcrete was born in the heart of a different world. In the late 1800s, the vast mining operations in the Lehigh Valley of Pennsylvania turned out huge quantities of iron ore, but the digging also extracted limestone, chalk, clay, and shale—the basic components used to manufacture portland cement, which, when mixed with water and aggregate, becomes concrete.

Fig. 1: Carl E. Akeley, father of shotcrete

First came the Lehigh Portland Cement Co., founded in 1897, and then the American Concrete Institute formed in 1904, with both emerging in response to the growing interest in using concrete as the foundation of modern construction.

In the 2000 years from the Roman Empire through to the early twentieth century, concrete was primarily cast-in-place—that is, liquid concrete was placed into tightly constructed molds of dense forming. While time-honored, this method limited the use of concrete to applications in which forming was possible.

This severely restricted concrete's use in tunnels, for example, and in other underground settings—which is ironic, given the fact that the Lehigh Valley's cement was a byproduct of iron-mining operations. The need for a different approach was clear. Happily, an inventor came

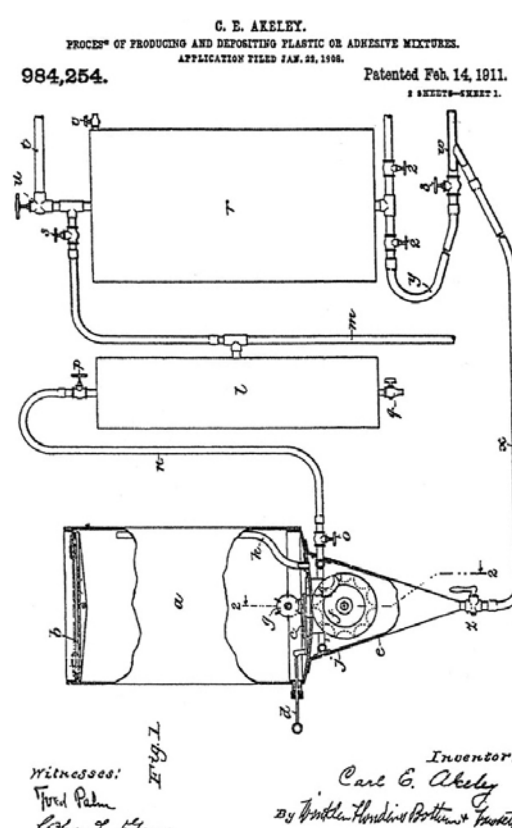

Fig. 2: Figure accompanying Akeley's patent application

along who found a way to break concrete out of its figurative shell.

A brilliant taxidermist, accomplished explorer, and mechanical genius, Carl E. Akeley was working just after the turn of the last century on techniques for hand-tooling realistic skeletal and musculature frames over which to fit the preserved skins of animals for museum displays. In 1907, a particularly insightful museum director saw what Akeley was accomplishing and gave him a different sort of challenge, asking him to replaster the faded façade of the Field Columbian Museum in Chicago.

To simplify the application process, Akeley assembled a pressurized, double-chamber “gun” that sprayed material onto the museum’s vertical surfaces. No less a friend than Theodore Roosevelt, with whom Akeley had traveled for a year on an expedition to Africa, heard about this innovative system and encouraged Akeley to patent it—which he did. In 1911, he was awarded Patent No. 991814 for “an apparatus for mixing and applying plastic or adhesive materials.”

The gun made its public debut that same year at the Cement Show in New York, where the publication *Cement Age* reported that “the cement gun was another revelation in the way of mechanical ingenuity.”

The term gunite was coined a year later, based on the description of “gunning” of material through the device onto the receiving surface. In short order, the word “gunite” was trademarked and would go on to define the technology and its usage until the 1950s.

Growth

In 1916, Akeley sold his patent to Samuel Traylor, a mechanical engineer and the owner of the enormously successful Traylor Engineering and Manufacturing Co., which made its fortune in munitions manufacturing during World War I. Traylor had first encountered Akeley’s machine at the Cement Show in 1911, and while he was fully aware of the initial mechanical problems Akeley had experienced with his early models, Traylor was convinced of its potential and moved forward accordingly.

For his part, Akeley engaged his wanderlust once again and ultimately succumbed to fever in the Belgian Congo in 1926. He died a relatively poor man, despite more than 30 patents he held for a variety of other inventions.

In 1920, Samuel Traylor acquired the Cement Gun Co. of Allentown, PA. His aim was to perfect and effectively market the cement gun, and along the way he singlehandedly launched the shotcrete industry. His new company fiercely guarded the “gunite” trademark while producing equipment and as a subcontractor, applying the material in

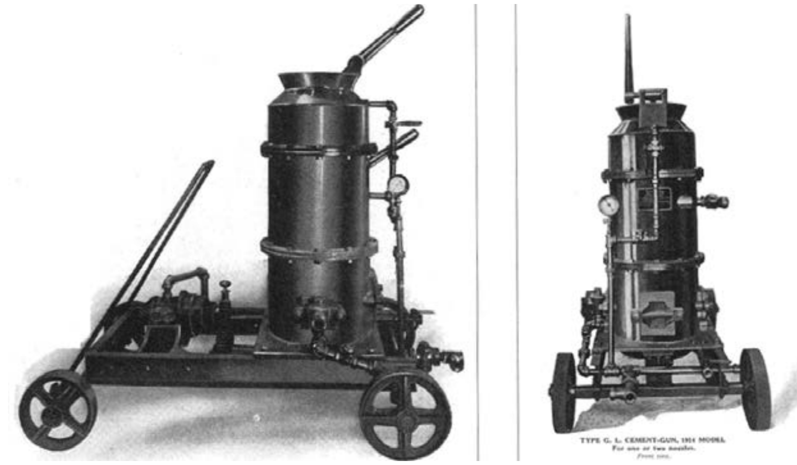

Fig. 3: A later cement gun model available through the Cement Gun Co.

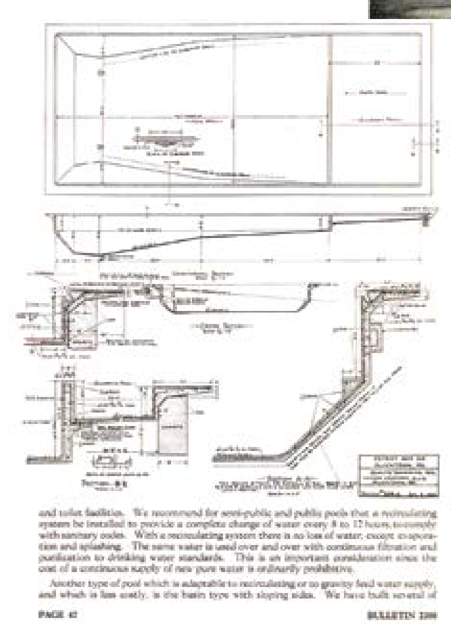

Fig. 4-6: A Cement Gun Co. Bulletin, highlighting one of the first “gunite” swimming pools at the Lehigh Country Club

thousands of projects globally using the dry-mix process. (Wet-mix had not yet been invented.) The company kept tight control by selling the equipment and simultaneously granting permission to use the application technology. Essentially, gunite was open for franchising.

In a savvy blend of due diligence and good marketing, the Cement Gun Co. relentlessly tested the gunite method and mixture designs, reporting their findings in technical papers and bulletins. One of the more fascinating examples here is a discussion of the installation of the swimming pool at the Lehigh Country Club in 1936. One of the first recognizable gunite pools, the structure was shot using a rock wall as the support substrate—the first "form" used in swimming pool construction.

This document is fascinating from a historical perspective, with a construction plan that was a model of careful engineering. But such publications were a method of control as well: They enabled the Cement Gun Co. to set the standard, defining what gunite was (and was not); regulating and setting patterns for use of the new technology; and popularizing both the product and the craft.

Traylor also took pains to see that the engineering community was engaged. The Cement Gun Co. published articles in magazines including *Concrete*, *Engineering News*, and *Structural Engineer*. In addition, testing was conducted at Lehigh University in Pennsylvania and later at the University of California to compare the gunite and cast-in-place methods—and thereby prove gunite's superiority. The wealth of data in circulation served to legitimize the method and consolidate the company's control over the young industry.

Domination

These efforts paid off. The Cement Gun Co. was a force to be reckoned with through the 1920s and 1930s, with the technology spreading to all 50 states and more than 120 countries around the world and finding uses in myriad structural, industrial, and geological applications.

But, as historians point out, while the Cement Gun Co. did much to popularize the method and promote best practices, its aggressive legal team and the tight grip it held on the trademark and the technology severely limited the development of equipment in response to the real-world needs of designers, engineers, and applicators.

This control had begun to diminish somewhat by the late 1930s, but real change came in the aftermath of World War II, when the hyperactive American industrial sector grabbed hold of gunite technology and forced both the company and the technology to diversify.

This diversification did not come without tradeoffs. Once gunite (and what would be known as shotcrete) was released from the powerful grasp of the Cement Gun Co., the industry—despite continuing growth trends—began losing its credibility and faced a lingering decline before coming to the present-day revival brought about by increased interest and investment in knowledge, best practices, and standards for shotcrete applications.

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***Bill Drakeley** is Principal and Owner of Drakeley Industries and Drakeley Pool Company. Drakeley holds the distinction of being the first and only member of American Concrete Institute (ACI) Committee 506, Shotcrete, from the pool industry. He is also an approved Examiner for ACI Certified Nozzlemen on behalf of the American Shotcrete Association (ASA), Vice President of the ASA, an ASA Technical Adviser, a Genesis 3 Platinum member, and a member of the Society of Watershape Designers as well as Chairman of its Advisory Board. Drakeley teaches courses on shotcrete applications at the Genesis 3 Construction School, World of Concrete, and numerous other trade shows. He is a contributor to* Shotcrete *magazine and other industry publications.*

Certification Lessons Learned from the Pool Industry

By Jason Vaughan

When asked to write an article for ASA's *Shotcrete* magazine, it took me awhile to figure out what a small-town pool builder from the mountains of Virginia could share with some of the best shotcrete minds in the world. As someone who is a third-generation pool builder and has worked in all phases of pool construction, including our dry-mix shotcrete (gunite) crews, I have always taken pride in knowing we build quality pool shells. My family-owned company has been in business since 1978 and we have always placed the shotcrete on every pool we have built. In meeting people from across the country in the pool industry, this seems to be relatively rare for a pool company to have both the equipment and the expertise to shoot their own projects. I am proud to say we own four dry-mix shotcrete rigs with four ACI Certified nozzlemen including my brother Austin, my stepfather, and my stepbrother, who all work for our company. With the exception of Bill Drakeley (who was one of our ACI examiners) and a handful of others, not many pool builders are as knowledgeable as they should be about proper shotcrete installation. Bill's efforts to bring shotcrete education to the Genesis 3 program as well as the national and regional

Fig. 1: Dry-mix shotcrete being applied to catch basin wall from inside of the pool due to space in catch basin (Willie Johnson, NP Superintendent, ACI Certified Nozzleman)

pool tradeshows is a great start to increasing the quality of concrete pool construction, which I appreciate. Even with the experience in my own company, we have learned a lot in the past 10 years about proper techniques through classes taught by Bill and the ASA Education/ACI Nozzleman certification program.

As an example of one of our projects, herein is one we built in 2012. Our company was contracted to construct a 25 x 50 ft (7.6 x 15 m) pool for a residential client at the top of a mountain. The pool was designed to be 3 ft-6 in. (1.1 m) deep on the shallow end and 8 ft (2.4 m) in the deep end. It had a large set of steps in the shallow end and a standing ledge along the deep-end wall. To take advantage of the panoramic view, the pool also had a vanishing edge along half of the pool and created a 75 ft (23 m), three-sided disappearing edge. The vanishing edge also had a lower catch basin that was 30 in. (0.76 m) wide and 3 ft (0.9 m) deep. All of the walls on the pool were 12 in. (0.3 m) thick dry-mix shotcrete and used about 50 yd^3 (38 m^3) of material to shoot. The pool also included a floating automatic cover, which required a 4 x 5 ft (1.2 x 1.5 m) housing to be created on the shallow end of the pool. This was a fairly complicated shoot due to the length of vanishing edge wall with the attached catch basin, as well as the recessed cover housing and motor compartment. The interior of the pool was plastered with a black quartz plaster to give a reflective quality to the pool overlooking the valley below.

Lessons Learned from the ASA Nozzleman Education Program

1. Curing of the shotcrete/concrete is a very important step. Proper hydration can help reduce issues such as plastic shrinkage cracking during hot weather. Also, drying shrinkage increases with additional water content so adding excessive water to the shotcrete mixture only decreases the strength and causes additional problems.
2. We found the use of a blowpipe very useful to eliminate rebound in unwanted places. This was something we had heard of but had not implemented until taking the nozzleman

Fig. 2: Shotcreting the exterior wall of the vanishing edge catch basin before edge wall is formed and shot

Fig. 3: Catch basin for vanishing edge before finishes

Fig. 4: Pool shell complete before tile and coping installation

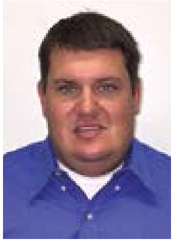
Fig. 5: Floating automatic cover being retracted into hidden cover housing

Fig. 6: Completed pool with three-sided vanishing edge

course. It helped us to maintain quality of shotcrete placement, especially in tight spaces and complex installations.

3. Application techniques were also reinforced in the certification class. The position of the nozzle relative to the surface and the mixing process that occurs with the movement of the nozzle can greatly improve the quality of the in-place shotcrete as well as reduce rebound.

In the pool structure, wet- or dry-mix shotcrete is the backbone of concrete pool construction. There is not enough tile or plaster that can cover up a poor shotcrete installation. Most structural and aesthetic issues from cracks or efflorescence can be traced back to a bad shotcrete job. What is hard for me to understand is: why don't more pool builders know more about the process? What is rebound? Why is it bad? What concrete strength should be used in a pool installation? What are the proper nozzling techniques? These and others are all questions to which good pool contractors must know the answers. There is much more to quality shotcreting than simply holding on the end of a hose. I also have had a hard time with pool consultants giving me grief about accepting the dry-mix process only because they had someone do a bad job in the past. It's not the product at fault—just the application. I encourage all pool contractors, from small to large, to become more involved and more educated about shotcrete so the quality of pool construction continues to get better over time.



Jason Vaughan *is President of National Pools of Roanoke, Inc., in Roanoke, VA. National Pools is a design-build gunite pool builder that services both the residential and commercial pool markets in Virginia and West Virginia. Vaughan is responsible for the design and project management of the majority of the projects built by National Pools for the past 18 years. Vaughan is an active member of the Association of Pool and Spa Professionals (APSP) where he serves as a local Chapter President, regional committee member, and an APSP WAVE Young Professionals Network committee member. His pool industry certifications include Certified Building Professional, National Plaster's Council Start-up Technician, and Certified Service Technician.*

The following article originally appeared in the Spring 2011 issue of ASA's Shotcrete *magazine.*

Why Bonding Compounds are Not Recommended with Shotcrete

The Question of Bonding Agents and Shotcrete

By Ted Sofis

Back when I first joined ASA, the question of bonding compounds with shotcrete came up. As a shotcrete contractor for over 40 years, I had experienced all the problems you can imagine in trying to follow specifications where the use of a bonding agent was required with a shotcrete installation. ASA is made up of a wide range of people in the shotcrete industry, including engineers, contractors, manufacturers, and suppliers, and we all agreed on something. When the question was asked, the response was overwhelming with nearly universal agreement among the ASA membership that use of bonding compounds with shotcrete was actually detrimental to achieving a good bond to a properly prepared substrate. I was not a lone voice in the wilderness.

With good surface preparation and gunning practices, shotcrete provides an excellent bond to the existing substrate

The dry process of shotcrete being gunned on a pier can provide a better bond without using bonding compounds. The nozzleman is filling in the corners first and working toward the middle of the repair area so he doesn't trap rebound in the corners

With a good shotcrete repair, the deteriorated concrete is removed back to sound material, the concrete surface and existing reinforcing is either sand- or waterblasted to clean off scale from the reinforcing bars and create a textured profile on the concrete, the mesh or reinforcing is installed, and the repair area is washed with air and water to clean off any loose particulates and wet the concrete surface to create a saturated surface-dry (SSD) condition prior to the shotcrete placement. SSD refers to a surface that is wet without any standing water. The reason for wetting the concrete prior to placing the shotcrete is to create a better bond. A dry concrete substrate will draw the moisture from the newly placed shotcrete, possibly leaving an inadequately hydrated material at the point of contact between the existing concrete and the shotcrete repair. For this reason, wetting the repair area prior to shotcreting is an important step.

When shotcrete impacts the hard concrete surface, a greater percentage of aggregate rebounds from the surface, leaving a thin layer of more cement-rich paste at the interface between the existing concrete and the new shotcrete. As the shotcrete material builds on itself in its plastic state, the rebound of the aggregate decreases. The velocity of the shotcrete process drives the new material in place, creating an excellent bond with the existing substrate. The use of a bonding compound interferes with this process and in many cases actually creates a barrier or bond breaker.

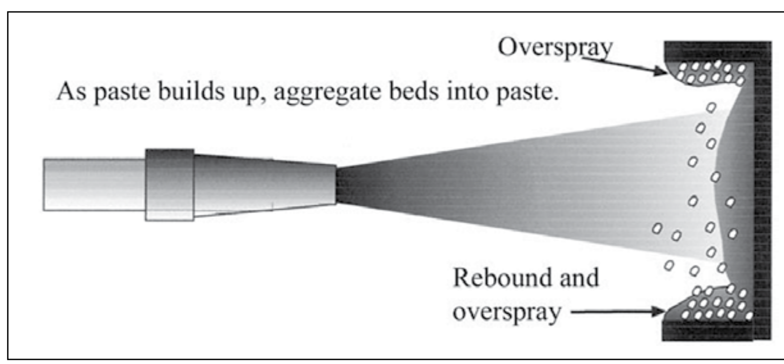
In addition, there are other problems with bonding compounds. With shotcrete, the rebound and overspray will stick to the adjacent areas where a bounding compound has been applied. Rebound

The top of this industrial sump wall is gunned in place using dry-process shotcrete. The shotcrete process provides an excellent natural bond to the substrate without using bonding compounds. In many cases, bonding compounds are detrimental to achieving a good bond with shotcrete

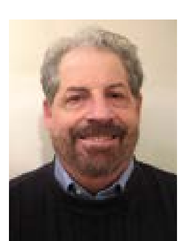
is a cement-poor, aggregate-rich, improperly hydrated by-product of the shotcrete process and is not the material that you want to have at the point of contact. You cannot wash or blow off the rebound and overspray from areas and mesh where bonding compound has been applied. Using a blowpipe to remove rebound will actually cause more unacceptable material to stick to the adjacent areas where the bonding agent has been applied. Also, because shotcrete is sprayed in place gradually across a repair area and isn't cast all at once like a concrete pour, the working time of a bonding compound becomes an issue. If shotcrete isn't placed while the bonding compound is still tacky, the bonding compound becomes a bond breaker. Unless the timing between the application of the bonding compound and the shotcrete is just right, some of the repair areas where the bonding compound has been applied may have hardened by the time the shotcrete is placed. Establishing the "open time" of a bonding agent in place is very difficult to gauge and then coordinate with shotcrete placement.

In summation, when you use bonding compounds with shotcrete, you increase the risk of interfering with the excellent bond produced naturally with the shotcrete process. Rebound and overspray can easily stick to the fresh bonding compound in areas adjacent to the shotcrete placement, which will reduce the bond of subsequently placed shotcrete, creating a high probability that sections of the repair will actually have a bond breaker from the hardened bonding compound. If I've learned anything in my 40 years of gunning, it's that the simpler you can keep things in the field, the more likely you will end up with a good result.

Shotcrete is gunned at high velocity onto the receiving surface. On initial impact, a larger percentage of aggregate rebounds from the surface, leaving a thin layer of cement paste at the interface of the new shotcrete and the substrate



On its initial contact, more aggregate rebounds off the receiving surface, leaving a thin layer of cement paste at the interface between the existing concrete and the shotcrete. The material begins to build on the cushion of plastic material. The velocity of the shotcrete process drives the material in place, creating an excellent bond with the existing substrate.



***Ted Sofis** and his brother, William J. Sofis Jr., are the Principal Owners of Sofis Company, Inc. After graduating from Muskingum College, New Concord, OH, with his BA in 1975, Ted began working full time as a shotcrete nozzleman and operator servicing the steel industry. He began managing Sofis Company, Inc., in 1984 and has over 40 years of experience in the shotcrete industry. He is Chair of the ASA Publications Committee, a member of multiple other ASA committees, and an ACI Examiner. Over the years, Sofis Company, Inc., has been involved in bridge, dam, and slope projects using shotcrete and refractory installations in power plants and steel mills. Sofis Company, Inc., is a member of the Pittsburgh Section of the American Society of Highway Engineers (ASHE) and ASA.*

Hot-Weather Shotcreting

By Andrea Scott

The shotcrete process has a long history, with the pneumatic application of concrete going back over 100 years. It has a wide variety of applications that include new structures, tunnel and mine lining, soil, and repair. Shotcrete is a versatile and efficient method of placing concrete that can save clients a great deal of time and money. As its use in the construction industry continues to grow, new innovations are constantly expanding the realm of what can be done with this process. One thing that hasn't changed are the challenges faced with shotcrete placement of concrete in hot weather.

As shotcrete is simply pneumatically placed concrete, many of the factors that apply to the placement of quality shotcrete will be the same as those discussed in the American Concrete Institute's (ACI) document ACI 305.1-14, "Specification for Hot Weather Concreting." The ACI 305.1-14 specification defines hot weather as:

> "one or a combination of the following conditions that tends to impair the quality of freshly mixed or hardened concrete by accelerating the rate of moisture loss and rate of cement hydration, or otherwise causing detrimental results: high ambient temperature, high concrete temperature, low relative humidity, and high wind speed."

Because shotcrete placement can be slower than cast-in-place and has one face of the fresh shotcrete exposed, controlling temperature takes on heightened importance. The shotcrete contractor also has to contend with moisture loss from the nozzle spray. Some of the problems when dealing with plastic concrete under extreme weather conditions may include increased rate of slump loss, concrete temperature, and water demand, as well as additional plastic shrinkage cracks and crazing. When you add in a shortened setting time, the stakes just get higher.

Working with shotcrete in the arid American Southwest during the brutal summer months can be daunting. It is not unusual for crews to experience daytime temperatures in excess of 100°F (38°C) with humidity levels of less than 10%. This "dry heat" can add to the list of things that can negatively affect your finished product. The rapid moisture loss caused by this environment is much greater than when working in similar temperatures with high humidity. These harsh conditions are inescapable, as projects need to be completed despite the extreme working conditions. The factors that influence the quality and durability of the finished product are many, in this article they will be discussed as they pertain to the wet-mix shotcrete process. Let's start with high ambient temperatures.

Mixed concrete is unforgiving at high temperatures. A concrete mixture that has a set time of two hours at 70°F (21°C) will set up in one hour at 80°F (27°C). A good rule of thumb is that for every 10°F (5.6°C) increase, your set time will decrease by 50%. It is often recommended, but seldom practical to provide shade or cooling misters to large areas of in place work. The forms and grade where the concrete is to be placed should be moistened and kept cool to give the benefits of evaporative cooling, as well as not adding or subtracting moisture from the concrete.

Some of the steps that can be taken to lower ambient temperature can be as simple as watching the weather report and choosing a cooler day of the week for placement of shotcrete, or more commonly, by adjusting the start time of the work shift. With projects underway during the hottest weeks of the warm summer months, our crews often work at night to take advantage of the lower temperatures (Fig. 1). With temperatures falling as much as 20°F (11.1°C), the difference in production is clearly noticeable. High ambient temperature does have a profound effect on employees. In high-heat conditions, the productivity of the workers drops. By changing the start times to the coolest part of the day, you can minimize crew fatigue and increase productivity. After a certain point on the thermometer, the rate of production actually seems to be inversely proportional to the temperature. This is particularly true the first few weeks after a sudden increase in temperatures.

Supervisors should be aware that the risk of heat-related illness is most acute as the team members acclimate to the new conditions. Addressing this topic in preconstruction safety training and onsite safety talks can help to keep it at the forefront of the employee's minds. More frequent rest breaks and ensuring sufficient hydration can help to reduce the risks. In addition, the crew members should also be trained to recognize the signs of heat illness and know what to do in the event it occurs in a worker.

High concrete temperature is next on the list of conditions that can affect the quality of the finished product. The temperature of freshly mixed concrete is largely dependent on the concrete ready mix supplier, and the handling of the ingredients that go in to the concrete prior to arriving on the jobsite. An important step towards keeping mixed concrete's temperature down is by lowering the temperature of the materials used in its production. Acceptable measures to aid in this may include shading of the aggregate stockpiles or sprinkling the coarse aggregate with water for evaporative cooling. Chilled water and ice may also be used to replace a portion of the required mixture water. Concrete can also be cooled by using liquid nitrogen. Many contractors find it useful to use retarding admixtures as well, to delay hydration and subsequent rapid setting caused by high temperatures and allow more workable time.

In the Spring 2015 issue of *Shotcrete* magazine, the "Nozzleman Knowledge" article described the many factors to keep in mind when evaluating a ready mix supplier. It is important to find one that is able to service your project, and provide a mixture that has worked well in the past under similar conditions. By varying the amount of gypsum in the cement to affect the set time, the cement industry works to control the proportions of the mixture to account for local and seasonal fluctuation. Prior test results from other projects, or preconstruction testing, as well as the proportions of the concrete mixture will need to be considered when working in extreme heat. This should be addressed in preconstruction meetings and submittals. It is also helpful to note the location of the material supplier's batch plants, as well as the number of trucks that will be available on shooting days, which will make a difference in the amount of workable time and spacing between truck deliveries of the batched concrete.

Once the concrete is batched, it needs to be mixed and transported to the project location so that it can be discharged, placed, and finished as quickly as possible. As shotcrete placement tends to be slower than cast-in-place, controlling temperature takes on heightened importance. Good preplanning by the contractor can go a long way in facilitating this by ensuring that there is proper traffic control and adequate signage for the drivers to find the pump, as well as allowing enough space for them to back up and start discharging their load. In addition, the placing crew needs to be ready, and of a sufficient size for the shotcrete work that is to be performed. Next, all forms and grade where the concrete is to be placed should be premoistened and kept cool to give the benefits of evaporative cooling. Bear in mind that on projects when applying shotcrete to hot surfaces, such as slope paving, the initial temperature of the concrete being shot may matter less. High ambient temperature and substrate temperature will quickly bring the placed concrete temperature in thinner shotcrete sections to equilibrium so that the initial concrete temperature will have little impact. In the case of slope paving of large areas, there are three things you can do in hot weather. First, continuously wet the subgrade. This is done so no free water or erosion damages the slope. Secondly, place your shotcrete promptly. If a nozzle finish is specified, apply your curing material (liquid membrane curing compound or water) as soon as possible. A hand sprayer will not suffice; you will need a power sprayer or a pressurized pneumatic tank to apply a liberal amount of cure. This prompt, liberal (twice the manufacturer's specification if using a curing compound) application will have a significant impact on the reduction on the formation of plastic shrinkage cracks. If finishing is required, an evaporation retardant will definitely reduce moisture loss. Again, after finishing, cure the work as soon as possible.

Fig. 1: Nighttime shotcrete placement

Shotcreting in hot weather can have advantages. Shotcrete contractors in warmer parts of the country seldom use accelerators, where in colder climates they are often a necessity. Also, shotcreting vertical walls in hot weather allows for rapid vertical application because the lower lifts set quickly. Although, for overhead work, you may still find accelerators beneficial.

Low relative humidity and high wind speed also need to be addressed. Many contractors today are familiar with the graph originally published by the Portland Cement Association that can now be found in the ACI 305.1-14 (Fig. 2). This is a very useful tool. It not only tells what influences moisture loss, but it also quantifies the effects, with the rate of moisture loss being affected by the in-place concrete temperature and the humidity. Using this simple graph will give an idea of the rate of water loss. For those who want

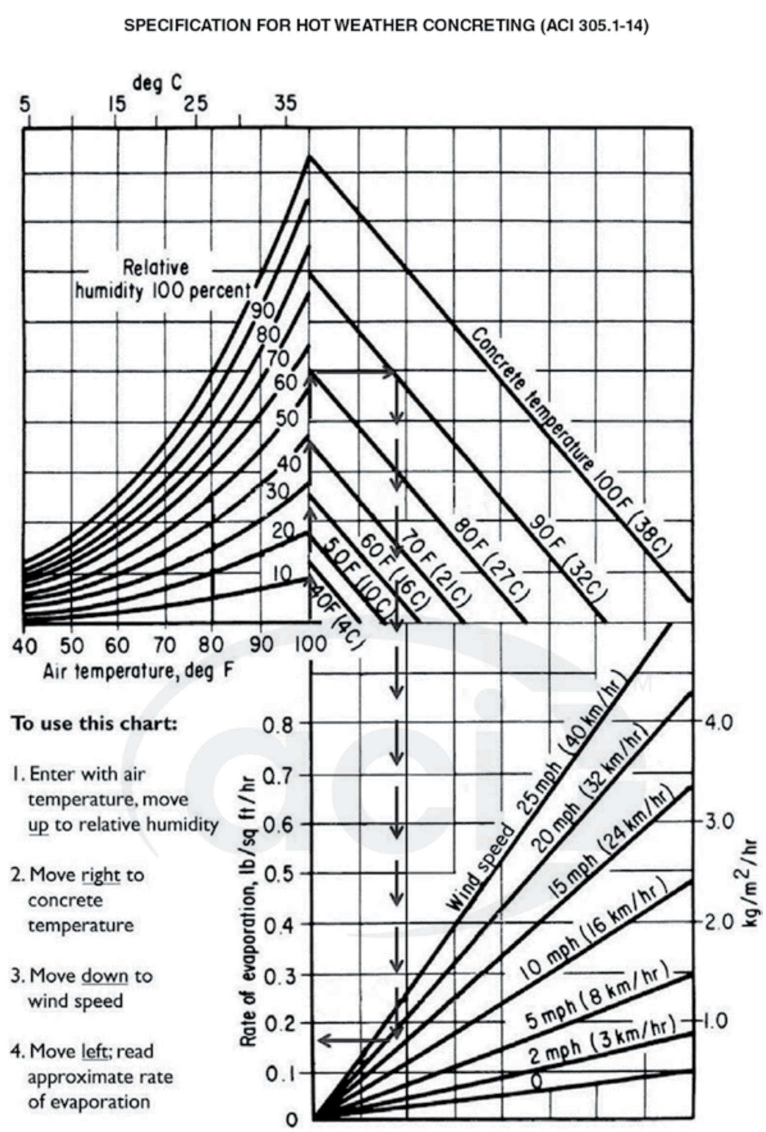


Fig. 2: Effect of concrete and air temperatures, relative humidity, and wind speed on the rate of evaporation of surface water from concrete (ACI Committee 305 [2014])

it even easier, there are devices available that measure these variables and then calculate the results automatically. Having the materials needed for onsite evaporation control is important to protect the fresh concrete and prevent the rapid evaporation of free water when it is deemed necessary under the conditions outlined in Section 3.1.3 of the ACI 305 document. One of the methods for doing this is the application of liquid membrane curing compound. Another method is water curing, which is simply the continuous application of water. For horizontal surfaces flooding works well, if it can be done. With vertical surfaces, covering the work with clean, used carpets is another way to keep the fresh concrete moist. The big advantage of water curing is the additional benefit of evaporative cooling. In cases where compound cure or water curing are not allowable options due to the necessity of subsequent work such as staining or adhesive application, covering with tightly sealed polyethylene sheeting is another option. This membrane will keep the moisture in and mitigate the effect of moisture loss due to wind.

When all the various project and material conditions, and their potential for problems, have been taken into account and addressed, the likelihood of a durable, safe and profitable completed project increases tremendously. Ultimately, isn't that the result the owners, engineers, suppliers, specifiers, contractors, and inspectors who make up the shotcrete industry strive to provide for their clients?

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Need to Get a Project Completed Efficiently? Employ Shotcrete!

By Ray Schallom III and Randle Emmrich

The foundation work for the Baltimore Hilton Convention Center Hotel, Baltimore, MD, began in 2006. The hotel is located across the street from the Oriole Park at Camden Yards baseball stadium and a couple of blocks south of the busy Inner Harbor area. The developers were the Baltimore Development Corporation for the Baltimore Hilton Convention Center Hotel. The project experienced significant delays in work leading up to the foundation wall placement that triggered a search for time-saving construction alternatives to the original construction plan. The wet-mix shotcrete process was chosen over cast-in-place, and the resultant one-sided form method saved both schedule time and money.

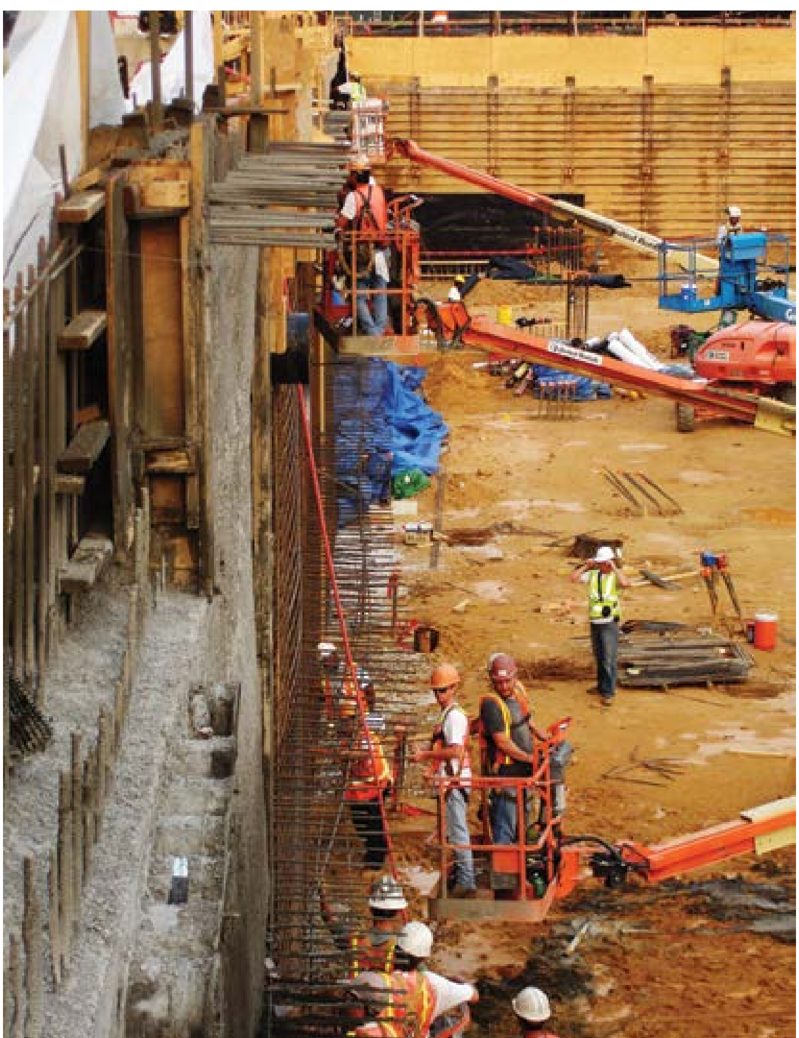

Fig. 1: Lagging and steel I-beam piles with soil anchors. Waterproofing installers and reinforcing bar crew working just ahead of the shotcrete crew

The backside of the wall consisted of drilled I-beams with soil nail anchors and wood lagging placed between the beams to restrain the loose earth behind the wall. Deep-drilled reinforced piles were located every 20 ft (6 m) along the perimeter of the new foundation wall and under each column area in the bottom floor of the excavation. The pile drilling operation had many delays, which pushed the scheduled start for all other work back by several months.

The delays leading up to the foundation wall installation included the wall waterproofing, pipe and duct work blockouts, and reinforcing bar installation. Before this project, all building foundations in Baltimore had been formed and cast with concrete. The original drawings called for two-sided, conventional cast-in-place concrete formwork. Hensel Phelps Construction Company, the general contractor, familiar with the wet-mix shotcrete process from their West Coast projects, proposed shotcrete to the owner and design team as a viable solution to recoup the lost time in the schedule. It took some convincing before the developer and design team agreed to use the shotcrete process over cast-in-place concrete. However, once the use of shotcrete was approved, bids were sent out to several shotcrete contractors. Coastal Gunite Construction Company (Coastal) was chosen for the project. The construction team then initiated the submittal process. Having no one on the design team with wet-mix shotcrete foundation experience made approving submittals a challenge for Coastal and Hensel Phelps.

Fig. 2: (a) The corner of this photo was the starting point for shotcreting; and (b) one of the biggest challenges faced was the wall reinforcing steel moving out 4 in. (100 mm) by the weight of the shotcrete

Fig. 3: Mockup with waterproofing—one of many reinforcing bar and waterproofing configurations Coastal faced. The blowpipe operation was key to keeping the rebound, overspray, and water out of the wall sections

The project's testing firm retained Consultant Ray Schallom to train their inspectors on the proper application of wet-mix shotcrete. Several meetings were required to establish and identify which ASTM test documents were to be used and who was paying for the tests specified by the structural engineer. Two different mockups were built with different wall layouts to evaluate shotcrete placement on lagging waterproofing. The mockups were set up to show the performance of waterproofing strips when shooting stopped for the day and commenced later. Another preconstruction test examined how much water could be sprayed on the waterproofing before it would activate. The mockups also allowed the owners to see what their foundation would look like after it was shot and finished.

One would think having most of the designers present in the weekly project meetings would have made getting the shotcrete submittals approved on a timely basis easy. Unfortunately, this wasn't the case, and approvals often took longer than expected. When the submittals were finally approved, Coastal shot and finished the preconstruction panels. The shotcrete crew had to wait to install the grade wires, check the tightness of the reinforcing bars, and set up the equipment while drain tile was installed under the new wall reinforcing steel. To make it even more difficult, the bentonite waterproofing could not be installed until the day of shooting wet-mix shotcrete. Wetting down the reinforcing bars was challenging because too much water would activate the bentonite waterproofing material.

There were hiccups along the way with concrete quality control (QC) issues including temporary shutdown of the shooting operation, much to the displeasure of Hensel Phelps' Superintendent. The ready mix concrete supplier's QC personnel, Hensel Phelps' Project Engineer, Coastal's Superintendent, and both inspectors drove to the concrete plant to try and determine what had gone wrong with the concrete. As it

Fig. 4: Large ballast rock caught on the grate. The smaller pieces that managed to slip through the grate caught in the reducer

Fig. 5(a) and 5(b): Congestion in front of the next wall sections to be shot

turned out, the loader operator had dug into the ballast rock below the sand with his bucket and contaminated the entire sand pile.

Thus, the concrete was delivered to the site with the large ballast rocks that caught on the wet-mix pump grate. The smaller rocks that made it through the grate hung up in Coastal's 2 in. (50 mm) shotcrete line. Other cast-in-place concrete projects going on down the street were using concrete buckets and didn't notice the problem. The batch plant concrete was quickly adjusted and a test load of concrete was batched for Coastal to shoot on the wall. When the concrete went through the system with no additional pumping issues, it was decided to bring the concrete from another plant for better QC of the concrete and safety of the shotcrete crew.

This now posed an issue of the 90-minute placement window. The plant with the contaminated sand pile was only 10 minutes away while the other plant was 30 to 45 minutes away without traffic. Master Builders (now BASF) was consulted to provide admixtures that could extend the truck delivery time and give Coastal the 90 minutes to shoot the shotcrete on-site without rejecting the truck. Master Builders supplied Delvo ESC pucks (hydration control additive) to delay hydration of the concrete to gain the extra concrete delivery time without jeopardizing the quality of the concrete. The Delvo ESC pucks made it easy to field-mix in the truck (one puck equates 1 hour for 1 yd^3 [0.76 m^3] of hydration control in the truck). This would cover the delivery time and give Coastal at least 90 minutes to empty the truck.

The next challenge on the project was to tie and anchor the reinforcing bars more securely. The first wall section Coastal shot broke the minimal anchors and ties, and the section bulged out 4 in. (100 mm) from the weight of the shotcrete. Fortunately, that wall section was at the stairwell and did not interfere with the building structure. By adjusting the grade wires, Coastal and Hensel Phelps were able to reshoot the section to take the bulge out of the wall. This is something that cast-in-place concrete could not do. It was apparent from the bulging problem that the reinforcing bars had to be tied at a much closer spacing as well as increasing the number of wall anchors and ties before the shotcrete operation could proceed (refer to Fig. 2(b)).

Once the shotcrete operation began in earnest, the crew planned to start in one area and work their way around the foundation so that the other trades could follow. Hensel Phelps moved

Coastal a couple of times to shoot in other areas that later would be the scaffold stairwell and the shear wall area. This made it difficult for the reinforcement placing crew and waterproofing installers to stay in front of the shotcrete crew (Fig. 1 shows three crews working side-by-side).

It was also found that the concrete quantities used were not matching the calculated quantities from the project drawings. The drawings detailed the wall as 14 in. (350 mm) thick, while the actual wall thickness measured between 16 and 19 in. (410 and 480 mm) thick on average. The shear wall measurement increased to 200 yd^3 (150 m^3). The transition into the second stairwell ranged from 1.33 to 5 ft (0.4 to 1.5 m) thick with only two rows of reinforcing steel. Adjusting cast-in-place form widths to accommodate these thickness changes would have been extremely difficult and costly. By using the wet-mix shotcrete process, these significant thickness variations were easily accommodated by adjusting the finish grade wires and using an alkali-free accelerator at the nozzle to shoot the thick sections with no sloughing.

Then Hensel Phelps began to push the shotcrete operation to make up time caused by the drilling and QC delays. All the contractors on the job had to work around the pile drilling company, which was still drilling piers and chipping down a few that were cast too high above the floor elevation. Vibration on the reinforcement from the chipping of the piles had to be monitored to prevent disturbing the freshly placed shotcrete.

All shotcrete placement and finishing was performed out of man lifts to stay ahead of the plumber who was installing the drain tile along

Fig. 6: Different operations on this project were trying to get in and work making it difficult to perform the shotcrete placement while staying out of everyone's way

Fig. 7: Keeping the walls and reinforcing steel wet in front of the shotcrete was a challenge so as not to activate the bentonite waterproofing or create a muddy mess for the equipment to drive on

Fig. 8: Tight working conditions Coastal had to work in daily to allow other trades to work. The wall waterproofing and reinforcing bar installation had to stop due to the dirt ramp that was in the way. Spraying water on the walls made a muddy mess and had to be dug out, replaced, and compacted before any equipment could be driven over it

(a)

Fig. 9(a) and (b): Finished wall with the floor waterproofing being installed, and the same wall after it was finished

(b)

the wall. Piping was also being installed into the floor area along with the floor drain pipes. This made pre-wetting the walls prior to shooting and water curing the newly placed shotcrete a problem for other site work. The exposed soil in front of the wall would hold the water, leaving a muddy mess and making it impassable for equipment and crews until it was drained or replaced.

Even with all the challenges and delays faced by Coastal on this wet-mix shotcrete project, they managed to gain back most of the excess time used by the pile drilling company and the QC issues. Overall, about 4 months of schedule time were recovered along with significant cost savings by using shotcrete instead of cast-in-place concrete construction.

In conclusion, logistics, schedule time, and costs played key roles in the selection of the wet-mix shotcrete process over conventional cast-in-place construction. You may also want to check out many previous articles in *Shotcrete* magazine's archives (**http://shotcrete.org/pages/archive-search/archive-search.asp**) on sustainability. Before selecting your contractor, make sure they are a qualified shotcrete contractor who has an experienced qualified crew with ACI Certified Nozzleman.

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Acknowledgments

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Fig. 10: Finished wall with other trades stockpiling gravel for the floor installation following right behind

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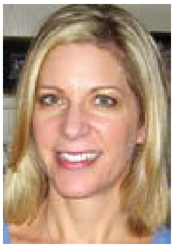

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Shotcrete Calendar

OCTOBER 1, 2015
ASA Outstanding Shotcrete Project Awards Program
2015 Entry Deadline
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OCTOBER 14-16, 2015
ICRI 2015 Fall Convention
Theme: "Modern Trends in the Repair Industry"
Hilton Fort Worth | Fort Worth, TX
www.icri.org

NOVEMBER 2, 2015
ASA Graduate Scholarship Program
2015-2016 Entry Deadline
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NOVEMBER 7, 2015
ASA Fall 2015 Committee Meetings
Sheraton | Denver, CO
www.shotcrete.org

NOVEMBER 8-12, 2015
The ACI Concrete Convention and Exposition
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Sheraton | Denver, CO
www.concrete.org

NOVEMBER 10-12, 2015
2015 Pool | Spa | Patio Expo
Mandalay Bay Convention Center | Las Vegas, NV
Visit ASA's Booth #452
www.poolspapatio.com

NOVEMBER 11, 2015
Shotcrete Nozzleman Education Class
Presenter: Bill Drakeley
9:00 a.m.-4:00 p.m.
2015 Pool | Spa | Patio Expo
Mandalay Bay Convention Center | Las Vegas, NV
www.poolspapatio.com/Attendee/Schedule/SessionDetails/34854

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
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FEBRUARY 2-5, 2016
World of Concrete 2016
Las Vegas Convention Center | Las Vegas, NV
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MARCH 16-18, 2016
ICRI 2016 Spring Convention
Theme: "Maintenance and Protection in Harsh Environments"
The Condado Plaza Hilton | San Juan, Puerto Rico
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APRIL 16, 2016
ASA Spring 2016 Committee Meetings
Hyatt & Frontier Airlines Center | Milwaukee, WI
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APRIL 17-21, 2016
The ACI Concrete Convention and Exposition
Hyatt & Frontier Airlines Center | Milwaukee, WI
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JUNE 26-29, 2016
ASTM International Committee C09, Concrete and Concrete Aggregates
Chicago Marriott Downtown | Chicago, IL
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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
Theme: "Revolutionary Concrete"
Marriott Philadelphia | Philadelphia, PA
www.concrete.org

NOVEMBER 9-11, 2016
ICRI 2016 Fall Convention
Theme: "Urban Reconstruction"
The Westin Cleveland Downtown | Cleveland, OH
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DECEMBER 4-9, 2016
ASTM International Committee C09, Concrete and Concrete Aggregates
Renaissance Orlando at SeaWorld | Orlando, FL
www.astm.org

Controlling Efflorescence

By Jonathan E. Dongell and Jerry B. Werner

Efflorescence typically manifests itself as a white salt deposit on the surface of a material. Its occurrence may be of little consequence or may be a sign of significant internal distress. It may appear as a white powdery dusting across the surface or as a thick hardened white crust exuding from cracks. It may intensify in wet periods and diminish in dry periods. It may encompass a large majority of the surface or may be confined to small areas of the surface.

This article is an introduction to the topic of efflorescence. Various mechanisms and factors that facilitate the formation of efflorescence and methods for reducing or eliminating its occurrence are introduced. Consideration for the aesthetic ramifications, and structural implications, of the presence of efflorescence is offered. Of course, every structure is unique. Therefore, having a thorough understanding of the facts and conditions for a specific project (mixture design, application, and placement environment) is necessary to determine a preferred course of action.

Mechanism

Assuming there is an evaporation front on at least one surface of the structure, three other factors must be present for efflorescence to form:

1. An available supply of soluble salt-forming components;
2. A sufficient supply of moisture to transport the salt-forming components in solution; and
3. Sufficient permeability, or spacial interconnectivity, within the structure to allow the transport of the salt-forming solution to the surface.

The mechanisms that create efflorescence are evaporation and precipitation. However, other transport mechanism(s) are typically present, allowing the overall process to proceed. These are the driving forces that move moisture into, through, and/or upward to the surface of the structure (a more detailed discussion on these transport mechanisms can be found in "Durability and Exposure Conditions of Cementitious Materials," *Shotcrete* magazine, Spring 2015).

Knowing that the aforementioned factors and mechanisms are necessary for efflorescence to form allows insight into measures that might be taken to reduce or stop its occurrence.

Salt-Forming Components

A primary source of efflorescence-forming material derives from the abundance of calcium hydroxide (CH) that is liberated during the hydration of cement. A majority of this CH is liberated early on, when a structure is young. CH formation

Fig. 1: Infinity edge (water-retaining wall) of swimming pool—2-year-old pool with no specific integral waterproofing or densifier controls

Fig. 2(a and b): Newly placed precast stone pavers

Fig. 3: Aged concrete slab deterioration

is a normal occurrence within hydraulic cement. Over time, ongoing hydration tends to densify the matrix of the structure, which seals shut much of the spacial interconnectivity and confines the CH. Carbonation of the upper surface also tends to densify and seal the surface of the structure over time. Prior to this, however, if sufficient moisture is introduced to the structure, CH can be taken into solution and transported from within the structure to the upper surface, forming efflorescence.

Alkalis (Na, K) may also be present in various components of the mixture design in minor amounts, but significantly more concentrated amounts of alkali (Na, K) are often found to originate from the soil, water, or other materials in contact with the structure.

Supply of Moisture

Efflorescence cannot form without sufficient moisture. It is important, during construction, to incorporate a means of removing or diverting moisture away from the structure whenever possible, allowing water to drain away from the structure quickly and unimpeded. Structures in constant water or saturated soil contact on one side, and an evaporation front on the other, are of primary concern. Such conditions often exist with retaining walls, negative edge or above-ground walls of swimming pools, basements, and tunnels. In this case, measures should be taken that essentially render the structure watertight (water resistant). Constant single-direct transport of water through cementitious materials increases the leaching of the calcium components, or the influx of deleterious ions into the structure from the saturated side, or a combination both, resulting in severe deterioration of the structure over time. Such structures, designed to be viewed on the "evaporation front" or "nega-

Fig. 4: Efflorescence buildup that caused delamination of tiles; more than just an aesthetic problem

Fig. 5: Efflorescence caused by water in transit

tive pressure" side and aesthetic appearance is of primary importance, should incorporate a method of densification or waterproofing of the structure that inhibits any moisture migration (moisture resistant).

Permeability

There are several effective ways to inhibit the mobility of water or moisture through a cementitious structure:

1. Solid waterproof membranes can be placed that inhibit water from entering into the cementitious structure;
2. Pozzolan can be incorporated into the mixture design, which combines with CH to form insoluble compounds and further densify the matrix;
3. Polymers can be incorporated into the mixture design to densify the matrix, or to form a co-matrix with cement;
4. Reducing the water-cement ratio (*w/c*), or the use of a water reducer, can reduce permeability;
5. Integral waterproofing or water-resistive additives can be incorporated into the mixture design;
6. Efflorescence-reducing additive (ERA) can be incorporated into the mixture design;
7. Integral waterproofing or other densifiers can be sprayed on, or applied as a slurry coat, to the surface of the cementitious structure; and
8. Incorporating methods of application, finishing, and curing that optimize consolidation of the matrix and produce a dense upper surface.

Each of these, whether individually or in combination, are effective at reducing or stopping the movement of water or moisture through the structure.

Fig. 6: Example of spray-applied densifier

Efflorescence and Durability

Typically, efflorescence is more of a cosmetic eyesore, and less of a durability concern. The intended finish is merely altered by the unsightly deposition of salts. In such cases, new efflorescence (also known as "bloom") can generally be removed from the structure with little to no damage to the surface. This efflorescence typically consists of many small individual grains or crystals. A bristle brush and water will often remove such efflorescence that is days old. However, these crystalline deposits can build up and carbonate from either CO_2 in air or CO_3 in water. If allowed to form into a hardened dense deposit, removal can be very difficult.

A similar buildup, known as sub-efflorescence, can develop at the interface of the structure surface and surface coatings, tile, or other coverings; or just below the upper finished surface of the structure. If this buildup continues unimpeded, a form of salt attack can cause the deterioration and weakening of the binder system. Ultimately, this may lead to a complete failure of the binder system, causing the debonding of the coating or covering from the substrate, or the delamination or peeling away of the upper surface of the cementitious structure. Structures such as swimming pool vanishing edges, retaining walls, basements, and tanks can be especially vulnerable. Methods of preventing the migration of moisture, as mentioned previously, should be considered in the initial design and construction.

Penetrations (for example, pipes, lights, or joints) or abnormalities (such as holes and cracks) within the structure can create open pathways, allowing the facilitated transport of salt-laden solutions to the surface. Small overlooked holes or gaps during application, or certain cracks (shrinkage, autogenous, or plastic), may often simply be plugged or patched. Structural movement cracks, or cracking due to some internal stress mechanism within the structure, require a more in-depth investigation be undertaken and evaluation as to cause and remedy be determined.

Applying non-breathable paints, sealers, and other coatings onto the surface of a surface experiencing efflorescence is to be avoided. Such coatings, which are less permeable than the cementitious structure, do not allow moisture to escape at the same rate. This impedance of moisture can create a buildup of moisture, pressure, and salts below at the structure/coating interface which, in turn, causes spalling or delamination of the coating and often spalling of the upper layer of the structure as well.

Conclusions

Early on, the appearance of efflorescence may be nothing more than an unsightly appearance on the surface of a structure. However, continued efflorescence growth or new efflorescence that develops on an aged structure may be a sign of a more serious issue. Avoiding the occurrence of efflorescence completely in all environments may not be possible. But with the implementation of certain construction practices, enhanced mixture designs, and/or the inclusion of a waterproofer/ERA/densifier, efflorescence can generally be controlled.

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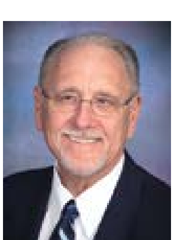

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In-Service Performance of Macrosynthetic Fiber-Reinforced Tunnel Linings

By Ralf Winterberg and Axel G. Nitschke

This article introduces macrosynthetic fiber-reinforced concrete (MSFRC) and shotcrete (MSFRS) for tunnel linings and provides an overview of state-of-the-art design and testing methodologies that currently exist. In addition to the structural load bearing capacity of fiber-reinforced linings, design considerations with regard to long-term performance are presented, which is getting more and more into the focus of project owners, as well as their designers and consultants. Actual projects and recent research are presented with this regard, together with best practice design principles, including crack width control, corrosion and durability, and sustainment of performance with age.

Introduction

MSFRC and MSFRS have reached maturity as an engineering process and is widely used in all forms of tunnel linings. The technology is now commonplace for temporary and permanent ground support in both mining and civil tunnel applications. It has for instance become the standard form of reinforcement in the Australian underground mining industry, where 2014 literally marked the end of steel fiber use in shotcrete,[1] and has been used for over 80% of permanent tunnel linings in recent tunnel construction in Norway. Similarly, macrosynthetic fibers are becoming a standard solution for initial (or primary) tunnel linings in the United States. Recent examples are the Devil's Slide Tunnel and Caldecott Fourth Bore Tunnel in California and the Anacostia River Tunnel Intershaft Connector Tunnel in Washington, DC. In addition, an increasing number of tunnels are adopting shotcrete permanent linings using macrosynthetic fibers. Examples include the A3 Hindhead tunnel near Guildford in the United Kingdom and the North Strathfield Rail Underpass in Sydney, Australia.[2,3] A recent example of a MSFRC cast-in-place permanent tunnel lining in the United States is the Euclid Creek Tunnel in Cleveland, OH.[4]

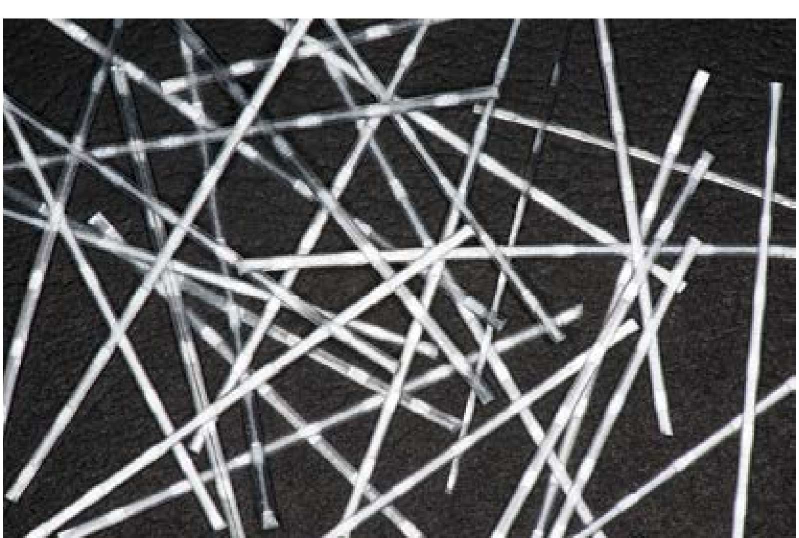

Fig. 1: EPC DucTil 57 Macrosynthetic Fiber

Macrosynthetic fibers have the same approximate size as steel fibers, but are not to be mistaken with monofilament microsynthetic fibers, which serve a completely different purpose, as these are nonstructural fibers. Macrosynthetic fibers have typical lengths between 0.8 and 2.6 in. (20 and 65 mm) and typical equivalent diameters of 0.016 to 0.039 in. (0.4 to 1.0 mm). Due to their flexibility, they are much easier to handle, pump, and shoot than steel fibers, which are more prone to formation of blockages and wear and tear of pumping lines. The tensile strength and the Young's modulus are typically around 45 to 100 ksi (300 to 700 MPa) and 725 to 2000 ksi (5 to 14 GPa), respectively. The base material of macrosynthetic fibers is usually polypropylene.

Typical dosages for shotcrete primary ground support and initial tunnel linings are in the range of 5 to 10 lb/yd^3 (3 to 6 kg/m^3). Typical dose rates for shotcrete or cast-in-place concrete final tunnel linings are in the range of 8.5 to 15 lb/yd^3 (5 to 9 kg/m^3).

The physical properties of different macrosynthetic fibers vary greatly. For tunnel applications, only highly engineered macrosynthetic fibers with a tensile strength greater than 90 ksi (600 MPa) and a Young's modulus greater than 1450 ksi (10 GPa) should be used. These fiber characteristics are required to achieve and maintain the required structural performance.

Structural Considerations for Initial Tunnel Linings

Initial tunnel linings are applied immediately after excavation, typically using shotcreting as the installation process. The initial tunnel lining acts as a temporary support in combination with other support measures where it is usually the only support system installed in mining applications. In civil tunneling projects, typically an additional lining is installed which can be either cast-in-place concrete or a further shotcrete layer, and is referred to as secondary or final lining.

Applications for tunnel linings with a long service life have required further research and study to confirm that macrosynthetic fiber reinforcement meets typical project performance criteria dictated by tunnel designers. Current research, as well as a number of major tunnel lining projects recently completed using macrosynthetic fiber reinforcement, confirm the very good performance of MSFRC and MSFRS for tunnel lining applications and a high potential for broader use.

Since the mid-1990s, multiple national bodies have developed guidelines for the use of fiber-reinforced concrete (FRC) and shotcrete (FRS); for example, in the United States and Canada by the American Concrete Institute and the American Shotcrete Association, or in Australia by the Concrete Institute of Australia and the Australian Shotcrete Society.[5] These documents provide guidance that is generally independent of the fiber material, whether it is steel or synthetic. However, design principles differ regionally or are owner specific, and depend on the support system required.

One simplified design approach for FRS for initial ground support in hard rock mining and tunneling uses Barton's Q-chart approach,[6] which is based on the energy absorption capacity of the composite as determined by means of the square panel test according to EN 14488-5.[7] However, the square panel test (also known as EFNARC test) used in conjunction with the Q-chart method is no longer used in many countries given the numerous problems associated with this test method. Instead, the ASTM C1550 round panel test[8] has become the primary means of assessing post-crack performance for FRS and is therefore

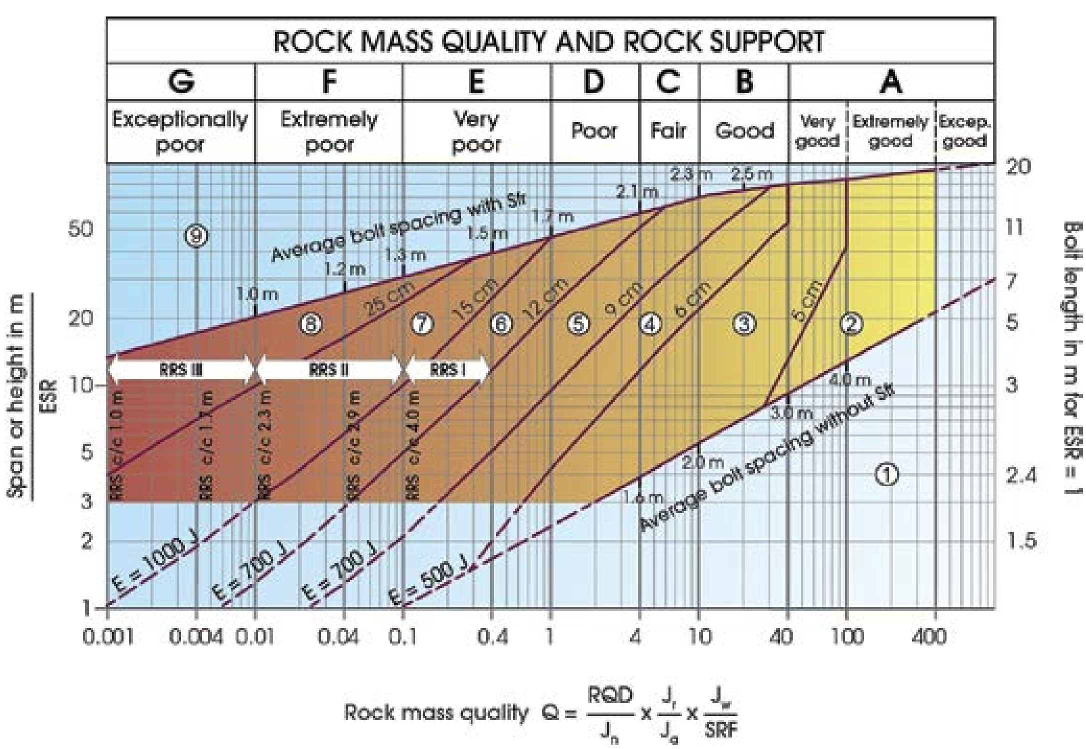

Fig. 2: Rock Mass Quality Chart or Q-Chart[6]

the preferred performance assessment tool used in the design of temporary tunnel linings based upon the Q-chart and other similar design approaches. The ASTM C1550 round panel test uses a 3 in. thick by 32 in. (75 mm thick by 800 mm) diameter round shotcreted specimen. A conversion factor of 2.5 was found to correlate the results from the different panel tests.[9] This means that, for example, a result of 740 ft-lb (1000 Joules) in an EFNARC panel relates to approximately 300 ft-lb (400 Joules) in an ASTM C1550 panel.

A classical design approach for fiber-reinforced concrete tunnel linings in civil tunneling applications is the use of Moment-Normal Force (M-N) interaction diagrams, which are obtained by equilibrium iterations on a given cross section.[10-12] The approach adopts and modifies classical design methods from unreinforced and reinforced concrete structures. The FRC material properties are herein derived from beam tests, which are eventually used as a basis to supplement the stress-strain relationship of the concrete on the tension side using defined procedures.[10-12]

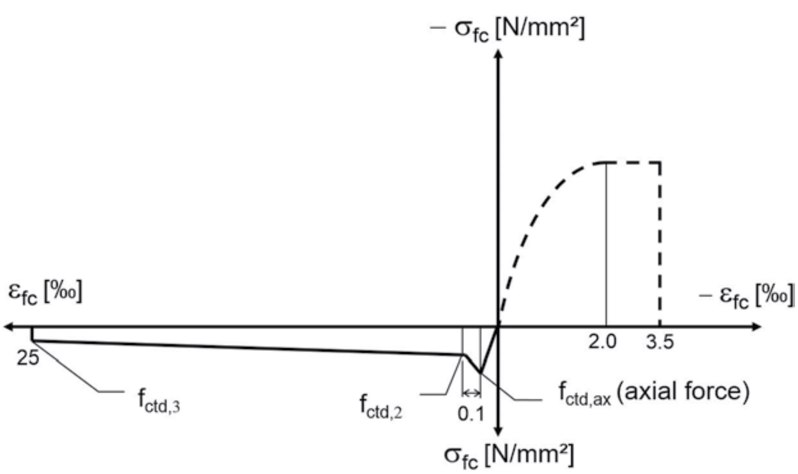

Fig. 3: Stress-strain curve of FRS

This approach generally provides structural gains for FRC and FRS versus unreinforced concrete, but typically the load-bearing capacity is less than the maximum reached in the elastic stage. The advantage of FRC versus unreinforced concrete is that it offers considerable loadbearing capacity in the post-cracking phase due to the elasto-plastic or ductile failure behavior of FRC, [10-12] which is similar to steel welded-wire-reinforced shotcrete. In tunnel linings, which are statically highly indeterminate, this ductile behavior allows for load redistribution, thereby increasing the structural capacity of the structure as a whole.

An economic, state-of-the-art tunnel lining design considers the load redistribution in the ground and the ground-support interaction. Load redistribution induces deformations and a ground support that is flexible enough to withstand this deformation. Historic lining designs were structurally stiff and attracted a lot of loading, which in return required heavy reinforcement. Modern designs allow for controlled deformations resulting in much thinner and softer linings. However, the structural integrity of the deformed lining has to be considered. To take full advantage of the material properties of FRC, the design approach of tunnel linings has to move from an elastic to an elasto-plastic approach, similar to the consideration of plastic moments commonly used in steel-structure design. After reaching the elastic capacity of the lining, the lining cracks but is still able to provide plastic bearing capacity. The load is hereby redistributed within the tunnel lining by

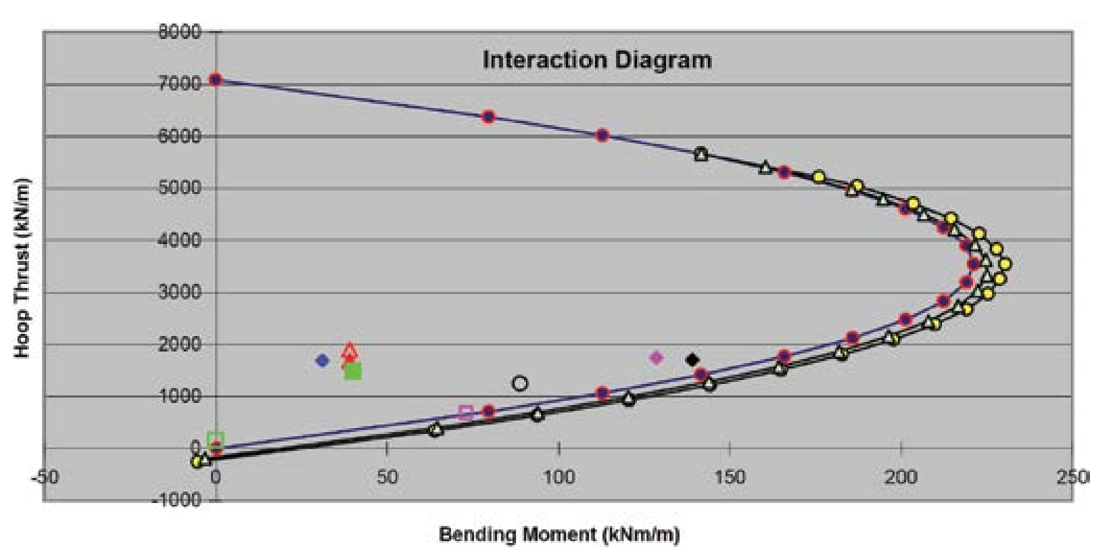

Fig. 4: M-N interaction diagram of FRS

increasing the bearing capacity of the structural system as a whole. The driving design factor is hereby moved from the maximum bearable load to a maximum allowable deformation or rotation capacity of a plastic joint (crack), which is provided by the fiber reinforcement.

Structural Considerations for Final Tunnel Linings

For the structural design of final (or permanent) tunnel linings similar methods to the above may be applied. However, for final lining applications there are a number of additional factors design engineers must consider. While cracking and deformations may well be acceptable for the initial lining or short term ground support, they may be undesirable for final linings. Apart from the structural capacity, the long-term structural behavior becomes more important for final lining applications. The driving factors herein are durability and corrosion, crack width control, embrittlement, and retaining the load-bearing capacity with age as well as creep.

Durability and Corrosion

The durability of a tunnel final lining encompasses a number of factors including the permeability of the concrete, concrete strength, durability of the reinforcement, and control of cracks. The durability of the concrete matrix in FRC is affected by the same parameters governing plain concrete when subject to the exposure conditions typical of an underground environment. However, macrosynthetic fibers are not subject to corrosion. Typical issues like chloride ion penetration, carbonation, and to a lesser degree, water impermeability are therefore of no concern. This simplifies the design approach by reducing the number of critical durability problems, thereby allowing much greater flexibility in design.

Maximum allowable crack widths when using steel bars or steel fibers are small, because cracks act as points of rapid salt ingress to the reinforcement. Maximum acceptable crack widths are about 0.006 in. (0.15 mm) or just 0.004 in. (0.10 mm) as shown by recent in-place tests by Nordström[13,14] and Bernard.[15] In contrast, crack width control is not critical for durability when using macrosynthetic fibers since they are not susceptible to corrosion. Crack width limits might have to be considered though for water-tightness or structural capacity.

Embrittlement

Most shotcrete mixture designs focus on durability and corrosion protection to provide high resistance against chemical attack over their service life, which in tunneling is typically between 80 to 120 years. To achieve this goal, the mix design often contains large proportions of pozzolanic binders, which can develop significant post-hardening of the concrete over time. This leads to embrittlement of the fiber-concrete matrix, which is responsible for post-crack performance loss when using steel fibers.[15,16]

Embrittlement of FRC with age due to post-hardening and its detrimental effect on the post-crack performance of steel FRC has been known for nearly 20 years. Numerous research works have indicated that aging can lead to a significant loss of post-crack performance for steel FRC.[15-17] The change in behavior with age is due to a change from a ductile high-energy pull-out mode of post-crack fiber behavior into a brittle low-energy rupture mode of the fiber itself, because of rup-

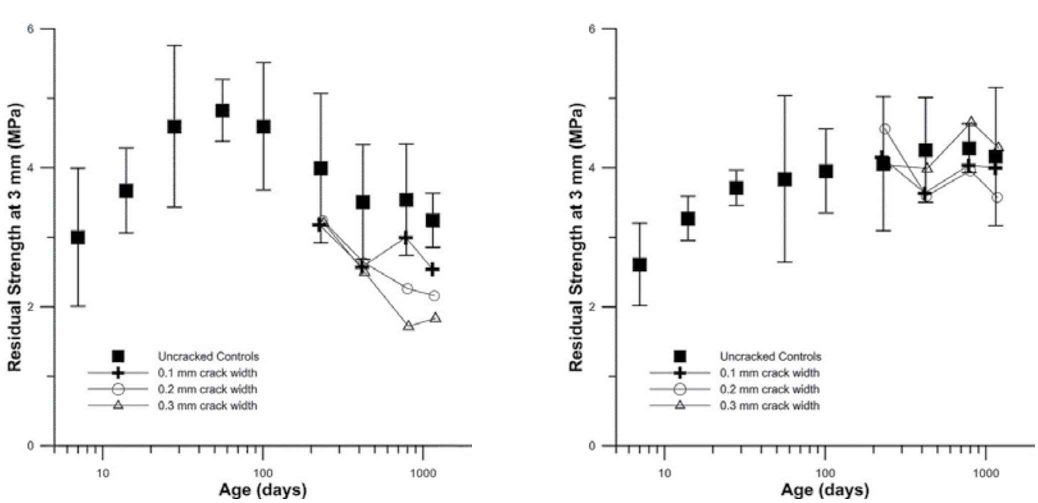

Fig. 5a,b: Corrosion and embrittlement leading to post-crack performance loss in steel FRC with age (left); where neither corrosion nor embrittlement effects occur in MSFRC (right)[16] turing of steel fibers at crack widths, which exceed the elongation capacity of the fiber. The fibers break rather than being pulled out of the concrete matrix. This effect leads to performance degradation by primarily affecting the capability to react to a change of loading conditions while the structure is aging. Typical examples for changed loading conditions in tunneling are nearby underground or subsurface construction, seismic loading, or changes in hydrological conditions or tidal effects. For this reason, satisfactory performance at early ages (around 28 days) does not guarantee an acceptable performance of the aging steel FRC. The performance of steel FRC at crack widths in excess of 0.04 in. (1.0 mm) can decrease by as much as 50% compared to the optimum exhibited at early ages; thus, a performance-reduction factor should be applied to the long-term flexural resistance of steel FRC.[15,16]

MSFRC is largely unaffected by this phenomenon because post-hardening or changes in paste hardness make little difference to the behavior of the fiber within the composite beyond the first few days of hardening. The performance of MSFRC evident at 28 days is therefore unaffected over time.

Creep Considerations

In general, the magnitude of creep deformation in uncracked shotcrete does not depend on the type of reinforcement and is similar for a centrally layered light steel welded-wire reinforcement, steel fibers, or macrosynthetic fibers.[18] In cracked concrete, however, the load ratio (applied creep load over static capacity) governs creep deformation. There is only a minor difference in the performance of FRC in combination with reinforcement with a light steel welded-wire reinforcement or macrosynthetic fibers up to load ratios of 50% during a loading period of 100 days.

The requirement for long-term testing of MSFRC is only necessary when long-term tensile stress is expected to be imposed on a cracked section in service. However, this loading regime seldom exists in tunnel linings, which are typically loaded under compression. Thus, the concerns which have been raised about the long-term performance of macrosynthetic fibers in respect of creep and the associated consequences for crack width development with time under sustained flexural loads appear to be significantly overstated. The results of recent research[19] show that the inclusion of macrosynthetic fibers in the concrete has only a minor effect on the flexural strength of the cross section, but the fibers reduce time-dependent in-service deformations and significantly reduce maximum crack widths when used in combination with conventional reinforcing bars.

Conclusions

The structural performance of MSFRC or MSFRS is able to meet or exceed that of welded-wire reinforcement or steel fiber-reinforced concrete for tunnel lining applications. Design methods for the structural load-bearing capacity are similar.

Macrosynthetic fibers are easy to pump and apply using the shotcrete process, reduce the wear and tear on pumps and slick lines and are easier and safer to handle than steel fibers.

Macrosynthetic fibers are not susceptible to corrosion and do not have to meet stringent crack width limitations for durability. High-performance macrosynthetic fiber reinforcement is ideal for aggressive exposure conditions and guarantees durable performance over the design life cycle without suffering matrix embrittlement and performance loss with age.

The inherent isolated creep properties of macrosynthetic fiber reinforcement play a subordinate role in the long-term performance of tunnel linings because compression forces typically govern overall behavior. Due to the advantages discussed in this article, it is to be expected that macrosynthetic fibers will become more common in tunnel shotcrete and cast-in-place tunnel linings in the near future.

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Pre-Job Safety Checks

By Mark Corner

Today's shotcrete placement, equipment, and personnel have evolved over the years, bringing a number of new safety items and topics. Every project is unique and possesses unique hazards that need to be addressed. Even before the shotcrete machine is started, we are responsible, as professional shotcrete nozzlemen, to plan for placing quality shotcrete and maintaining safety at all times while working on jobsites. One of the most important aspects is pre-job safety planning for the project to mitigate injury or damage to your equipment and to protect the worker.

Job organization is an essential part of the pre-job safety process. The responsibility falls to the foreman of the job to correctly identify the hazards and communicate them to the crew and workers on-site. He should lay out the equipment and shooting operations on the job to meet the safety requirements. The foreman should also ensure that all equipment is properly maintained and will work smoothly, while being aware of necessary precautions and providing for unseen eventualities.

Pre-Job Safety

As we know, safety starts with the individual. In shotcrete processes, we have to consider many aspects of planning jobs and keeping safe. The following are some key points in my Pre-Job Safety checklist.

- Before operating any type of machinery, the crewman should be very clear on how the machinery operates. Sure, reading manuals can be boring, but you know what's worse? Lying in a hospital bed because you used a shotcrete pump with no training. STAY SAFE, READ MANUALS.
- Communicate with key personnel such as the Project Contractor and other subcontractors, making sure everyone is aware who is responsible for identifying hazards. Also, we must always be informed of and follow local laws and regulations. All shotcrete projects are unique and have their own set of hazards that must be addressed. These discussions should take place before the start of the project. They can include procedures to respond to weather

Fig. 1: On-site safety talks provide timely communication during a project

limitations, special site conditions, and work limitations (for example; evening work should ensure that proper lighting is provided). Restrictions that local laws place on noise and hours of work need to be communicated clearly and work planned accordingly. Even the physical setup of the equipment should be planned to allow the pump operator a visual line of sight with nozzlemen or radio communication provided when visual access is not feasible.

- Safety talks or tailgate meetings are a key element in the daily operations. This is the opportunity to pinpoint hazards for the day. This may include potential hazards that may have changed due to changes in weather or other trades working close to the shotcrete placement. Let everyone ask questions and ensure everyone understands the answers and the potential hazards you address. Ensure employees are aware of the location of safety stations and know how to use them in the event of an emergency. A safety plan is a great idea for the work crew as well as a daily reminder of procedures in the event of an emergency. On most commercial jobsites or in mining, you are required to participate in a "line-up" or meeting to go over the day's production processes and discuss who is working in the area and potential hazards. Hazards are identified before work starts and documented. Each employee will record the day's events and any hazards encountered that is turned into a report at the end of the shift (refer to Fig. 1).
- Ensure each worker is competent. More and more project owners are now requiring certification for shotcrete nozzlemen.
- Equipment arrival on-site: During initial setup, the equipment should be checked for any defects and verify that all safeguards are in place. Inspect all components before startup and confirm the proper hose and fitting are being used with special attention to the level of wear in the fittings or hoses which could be a potential hazard during operations. Identifying the hazard early can eliminate injury and lost time.
- Jobsite production may require using equipment such as scissor lifts, man lifts, or scaffolding. Ensure this equipment is adequate for the job, is in compliance with local laws and regulations, and is serviced according to manufacturer's recommendations. Ensure your shotcrete equipment is adequate for the job and properly serviced. Prompt service is essential to keep expenses down time to a minimum (refer to Fig. 2)!

Fig. 2: Man lifts allow for quick, convenient access to hard-to-reach spaces

In summary, a well-planned job with a focus on safety will bring profit to your company and your customers will appreciate a job done on-time and on-budget. Spending the proper time pre-planning and ensuring the job is safe will benefit all.

Resources

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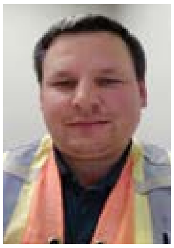

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The Quikrete® Companies Celebrates 75th Anniversary

Iconic Yellow Bag Represents Much More than Just Cement and Concrete

The QUIKRETE® Companies, a leading manufacturer of packaged cement and concrete products for construction, repair, and home improvement projects, turns 75 this summer. Widely recognized for establishing the pre-mixed packaged concrete category, QUIKRETE helped shape the building and do-it-yourself (DIY) home improvement industries with thoughtful product innovations, unmatched customer service, and a dedicated staff of associates. The company's evolution from small building materials business in Columbus, OH, to multi-brand conglomerate catering to the needs of millions of homeowners and professionals annually is available at **www.QUIKRETE.com/75**.

"We're proud of our heritage as an American, family-run company that has helped revolutionize the building and home improvement industries during the past 75 years," said James E. Winchester Jr., CEO for The QUIKRETE Companies. "From day one, my father, Gene Winchester, was driven to meet the needs of both contractors and homeowners with the highest-quality products at fair market value, and that commitment remains a core value of QUIKRETE today. It's been quite the journey from a single plant in Columbus, OH, manufacturing three products to plants across the country manufacturing hundreds of products, but a journey made possible thanks to our hardworking employees and loyal customers."

The QUIKRETE Companies offers professional-grade and consumer products including concrete mixtures, mortar mixtures, cements, shotcrete, concrete repair products, stuccos, waterproofing products, tile setting systems, hardscapes, blacktop products, floor underlayments, sand and aggregates, and other seasonal items. Today, the QUIKRETE family of companies also features leaders from related industries, including Pavestone®, Custom Building Products®, SPEC MIX®, Target Technologies®, Daubois and QPR®, which provides customers with a single source for unsurpassed product and service support. Collectively, QUIKRETE manufactures and distributes products from nearly 150 facilities in the United States, Canada, Puerto Rico, Panama, and Peru. Supporting technical centers across the QUIKRETE network also ensure that professionals and homeowners receive the most innovative and highest quality products available.

In addition to introducing the iconic yellow bag of pre-mixed packaged concrete, QUIKRETE is credited with a number of other industry firsts, including Vinyl Concrete Patcher, QUIKWALL Surface Bonding Cement, Fast-Setting Concrete, Concrete Resurfacer, and Green Concrete. QUIKRETE also proudly boasts a portfolio of high-profile, landmark building and restoration projects including the Statue of Liberty, Frank Lloyd Wright House, National Museum of the American Indian, The U.S. Capital, George W. Bush Presidential Center, San Francisco Bay Bridge, and Alcatraz Island.

"Long before the term do-it-yourself was coined or HGTV existed, QUIKRETE was helping homeowners with easy, affordable projects around the house. However, we've also stayed true to our core customers in the building industry by providing heavy-duty products that meet the needs of even the most challenging projects," said Winchester. "QUIKRETE has truly evolved from concrete in a bag into an iconic brand that lives up to its mantra, 'What America's Made Of™' every day. We're extremely grateful for the success and look forward to writing the next chapter in the company's history."

More QUIKRETE product and project information is available at **www.quikrete.com**, Facebook, Twitter, Pinterest, and YouTube.

OSHA Issues Temporary Enforcement Policy for Confined Spaces in Construction

The U.S. Department of Labor's Occupational Safety and Health Administration (OSHA) recently announced a 60-day temporary enforcement policy of its Confined Spaces in Construction standard, which becomes effective August 3, 2015. The agency is postponing full enforcement of the new standard to October 2, 2015, in response to requests for additional time to train and acquire the equipment necessary to comply with the new standard.

During this 60-day temporary enforcement period, OSHA will not issue citations to employers who make good faith efforts to comply with the new standard. Employers must be in compliance with either the training requirements of the new standard or the previous standard. Employers who fail to train their employees consistent with either of these two standards will be cited.

Factors that indicate employers are making good faith efforts to comply include: scheduling training for employees as required by the new standard; ordering the equipment necessary to comply with the new standard; and taking alternative measures to educate and protect employees from confined space hazards.

OSHA issued the Confined Spaces in Construction final rule on May 4, 2015. The rule provides construction workers with protections similar to those manufacturing and general industry workers have, with some differences tailored to the construction industry. These include requirements to ensure that multiple employers share vital safety information and to continuously monitor hazards—a safety option made possible by technological advances after the manufacturing and general industry standards were created.

OSHA estimates the confined spaces rule could protect nearly 800 construction workers a year from serious injuries and reduce life-threatening hazards. For more information, visit **www.osha.gov**.

U.S. Department of Transportation—Road and Bridge Data by State

The U.S. Department of Transportation recently released a table about the road and bridge conditions for each state. Indiana takes top honors for the best road conditions, while Illinois and Connecticut are tied for the last place. The nation's poor road and bridge conditions cost each motorist an average of $300 annually with some state motorists paying nearly twice that per year. Nearly half the country's roads and more than 25% of its bridges are in "poor" condition.

The U.S. Department of Transportation says "The Highway Trust Fund is set to expire on July 31. Without action from Congress, federal funding for transportation will come to a screeching halt—and with it, so will traffic in many places. Over the last 6 years, Congress has passed 33 short-term measures rather than funding transportation for the long term. And our transportation system—our roads and bridges, especially—is in a dire state of disrepair because of it. Experts agree: The only way to prepare our transportation system for the next generation is to stop this cycle of short-term measures and pass a long-term transportation bill."

ASCC and ACI Publish Revised "The Contractor's Guide to Quality Concrete Construction"

This revised edition of "The Contractor's Guide to Quality Concrete Construction—Third Edition" provides insight into proven construction practices that will produce quality concrete construction. Contents include how to organize for quality, concrete mixture designs, foundations, formwork, reinforcement and embedments in structures, joints and reinforcement for slabs-on-ground, preparing for concreting, concrete placing and finishing common field problems, and safety. It is also a required or suggested document for contractor licensing programs in 11 states.

The CD and MP3 audio formats are accompanied by a printed supplement containing the figures, tables, and checklists from the document. The audio version allows contractors and engineers to educate themselves or their employees on quality concrete construction practices while waiting in a vehicle, traveling to and from work, or running between projects.

Available in hard copy, CD, or MP3 format and a Spanish version is also available in hard copy format. Visit the ACI website, **www.concrete.org**, for ordering information.

ACI SDC Holding its Fall Meeting in Michigan

The upcoming ACI Strategic Development Council (SDC) Technology Forum #38 to be held in southeast Michigan focuses on accelerating the acceptance of concrete technologies and will feature topics on alternative cementitious materials, with an emphasis on how to move the theoretical knowledge of these materials to their practical use. The Forum will also include Technology Showcases, sessions on research repair, and a planning session on Contractors Visioning for the Future, plus other updates on industry critical technologies/issues.

The Forum includes a special tour of the Ford Rouge Factory—a unique perspective on innovation within another industry—might there be examples for the concrete industry in the use of materials, methods, equipment, and human factors? A reception and dinner follows at ACI headquarters.

SDC was formed in 1997 and is a council of the ACI Foundation. SDC provides to the concrete industry an in-house forum where the concrete industry, including government and academia, can come together with companies and entrepreneurs with new technologies at senior levels to discuss strategic issues and tactics including support of practical research to the benefit of all. For entrepreneurs, SDC provides a showcase for their technologies and an opportunity to work with concrete industry leaders to find pathways to accelerate technology acceptance. This supports the ACI Foundation's mission to increase the understanding of concrete materials and to support programs that improve the quality and potential competitiveness of concrete design and construction.

The SDC comprises member organizations that include suppliers, manufacturers, architectural/engineer firms, contractors, trade associations, and owners.

To facilitate advancement of concrete technology, the SDC is currently engaged in a number of initiatives/projects dealing with accelerating technology acceptance: identifying critical industry technologies that most impact the concrete industry; identifying barriers to technology acceptance and implementation; and acting as a catalyst to remove barriers.

Current industry critical technologies being addressed by SDC include:

- Alternative Cementitious Materials;
- Building Information Modeling;
- Concrete for Nuclear Structures;
- Concrete Wind Turbine Towers;
- Crack Reduction;
- Prepackaged Powdered Construction Product;
- Self-Consolidating Concrete;
- Strategic Repair Research Council; and
- Vision 2020.

The SDC also provides its members with a vehicle to form and participate in collaborative research and development efforts to accelerate acceptance of concrete systems and technologies.

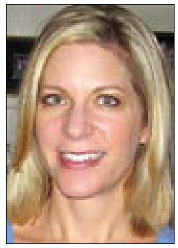
The organization is emerging as the leadership and voice for the concrete industry on issues involving the entire industry. It provides the objective voice that advocates improvements to industry efficiency and quality.

Join other concrete industry leaders to help shape the future of the concrete industry by attending SDC's Technology Forum #38, October 8-9, 2015, in Novi, MI.

For more information about SDC, and to register for the meeting and to reserve a hotel room, visit **www.concretesdc.org**.

View from catwalk inside Ford Rouge Factory Tour

Nozzleman-In-Training Program Update


Randle Emmrich

In May and June, ASA staff worked with Randle Emmrich, Chair of ACI's Committee for Nozzleman Certification (C660), and members and staff of ACI's Certification Programs Committee (CPC) to finalize the details for a nozzleman-in-training (NIT) program. ASA has committed to providing NITs with a log to allow them to track the required shooting hours. The final details were approved by mid-July. ASA is considering both a physical log and an online system. Hopefully, details will be available before our next issue of *Shotcrete* magazine.

Shotcrete Inspector Certification Update


Oscar Duckworth

Board member Oscar Duckworth, along with ASA's Executive Director, met with the California State Architect's office and DOT to discuss ASA's shotcrete inspectors' education program, as well as ACI's upcoming shotcrete inspector certification. This day-long meeting provided great feedback on the needs of the agencies, and how ASA education (and ACI certification) could best benefit the use of shotcrete in their state. With that feedback we can now refine our shotcrete inspector education program, and start to promote it in the industry.

ACI 506R "Guide to Shotcrete" Update

ASA actively consulted with ACI 506 committee members and ACI staff on the ACI Technical Activities Committee (TAC) review of the upcoming revision of the ACI 506R, "Guide to Shotcrete." ACI 506R was reviewed by TAC at their July meeting in Savannah, GA. ASA Past President and 506 Subcommittee Chair Lars Balck attended the TAC review and helped the TAC review group understand the changes to the Guide. After the review group meeting with Balck, TAC approved the Guide subject to proper response to TAC comments by the committee. Hopefully, ACI 506 can respond to TAC comments by the Fall ACI meeting and the next version of the Guide can be available for publication. The Guide has been reformatted in this version to complement the layout of the ACI 506.2, "Specification for Shotcrete." In many ways, the Guide will serve as the commentary for the specific, concise provisions of the specification.


Lars Balck

Certification Session in Australia

Melbourne, Australia

ASA is working with the Concrete Pumping Association of Australia (CPAA) and the Australian Shotcrete Society (AuSS) to co-sponsor and conduct an ASA education and ACI shotcrete nozzleman certification session in Australia. The first session in Australia is scheduled to follow the Concrete Institute of Australia's Concrete 2015 in Melbourne, Australia. This is the Concrete Institute of Australia's 27th Biennial National Conference, and draws owners, engineers, architects, inspectors, and contractors from around the world. We hope that in working together in promoting quality and certification, we can develop a stronger image for shotcrete around the world. ASA looks forward to the opportunity to raise the standards for shotcrete nozzlemen and the shotcrete industry by providing quality education and certification opportunities that have served us so well here in North America.

PCA Professors' Workshop

Skokie, IL

For the first time, ASA co-sponsored and actively participated in the Portland Cement Association's Professors' Workshop. ASA Executive Director Charles Hanskat presented a morning session on shotcrete theory and practical applications to the group. The Professors' Workshop is designed to provide faculty in engineering, architecture, and construction management programs the tools to teach the latest developments in concrete design, construction, and materials. The week-long session included networking opportunities to exchange ideas with professors from many universities, demonstrations by software vendors, and more than $2500 of free resource materials. ASA believes that exposing the professors to shotcrete is an important aspect of raising the visibility and ultimately the routine acceptance of shotcrete. It is hoped they will develop a keen interest in teaching a segment of their course on shotcrete using ASA as a resource, and thus exposing future engineers to the benefits we can provide using shotcrete in concrete construction.

32nd Annual International Bridge Conference

Pittsburgh, PA

ASA Executive Director Charles Hanskat presented an hour-long seminar on "Shotcrete for Bridge Repair" at the Bridge Preservation workshop held in Pittsburgh at the 32nd Annual International Bridge Conference. The shotcrete seminar had great attendance and interest from a wide cross section of owners (primarily DOTs), specifiers, and contractors. Other topics in the workshop included a segment on "Bridge Deck Waterproofing and Bonding Asphalt Systems," "Rapid Bridge Deck Rehabilitation Utilizing Hydrodemolition," and "Bridge Preservation thru Cathodic Protection." Presenters included consulting engineers, DOT materials engineers, and international material suppliers.

ASTM International Committee C09, Congregate and Concrete Aggregates

Anaheim, CA

Many ASA members, including ASA's Executive Director, attended the ASTM Committee C09 meetings in Anaheim, CA, in June. Of particular interest to ASA is the work of Subcommittee C09.46, which deals specifically with shotcrete and is currently chaired by Richard Schwartz, Laboratory Manager with The QUIKRETE® Companies. The C09.46 Shotcrete Committee is looking at revisions to C1604, "Standard Test Method for Obtaining and Testing Drilled Cores of Shotcrete," and C1140, "Standard Practice for Preparing and Testing Specimens from Shotcrete Test Panels," as well as several other standards maintained by the committee. Of note is an effort to coordinate the test panel sizes and configurations with the ACI 506 documents. The C09.46 Committee is also considering developing a standard for early-age testing of accelerated shotcrete, which would be useful in many underground applications.

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: *What is the standard materials delivery rate velocity for shotcrete applications?*

Answer: Recent research into velocity of the material stream shot from the nozzle is approximately 60 to 80 mph (97 to 129 km/h) in the middle of the stream. Outer portions of the stream are slowed and show speeds of about 45 mph (72 km/h).

Here's a link to the Technical Tip published in the Fall 2013 *Shotcrete* magazine that provides more complete documentation of the research: **www.shotcrete.org/media/Archive/2013Fal_TechnicalTip.pdf**.

Question: *We are planning on placing shotcrete over rock face and are concerned about water seeping out of the rock and forming ice behind the shotcrete. Could you please offer some insight?*

Answer: Shotcrete is a functionally impermeable material when properly designed and placed. Thus, if water accumulates between the rock substrate and shotcrete, depending on temperatures and thickness of the shotcrete, it may freeze. As with all concrete, shotcrete material can be air-entrained to enhance resistance to freezing-and-thawing exposure. You should consult with an experienced engineer to determine whether the type of rock, geometry of the sections, and anchoring of the shotcrete (such as with soil nails or rock bolts), along with the bond of shotcrete to the rock, will provide the desired performance.

Question: *I have a very small job to do that would normally be handled by a gunite or sprayed-on application. I need to form the inside of a concrete box into a cylindrical shape. I would like to get a few hints or suggestions on how I might accomplish the "gunite" solution using my hands/tools only. Does this require a special mix of the mortar mixture?*

Answer: Shotcrete is concrete placed at high velocity to achieve compaction. It is dependent on the projection of material with air velocity of 60 to 80 mph (97 to 129 km/h) from the nozzle to consolidate the concrete material in place. It cannot be hand-applied. You may consider hand-applied prepackaged mortar mixtures to achieve your results, although strength and durability may be less than a similar section with shotcrete because the hand-applied material is not fully compacted. Another alternative is to create an inner cylinder and cast concrete in the space between the box and the form. The concrete could then be vibrated for consolidation.

Question: *Lately, I've been testing shotcrete cores for compression strength according ACI 506, ASTM 1604, and ASTM 1385. The only thing that we have been doing out of specifications is the panel. Our panels are done: 18 x 18 in. (457 x 457 mm). We have been coring at the center of the panel 2 days after casting. We test the cores at 7 and 28 days and the strength of cores reflects passing at 7 days but failing at 28 days.*

Can you please tell me what could be the cause of this?

Answer: ASTM 1140/1140M-11, "Standard Practice for Preparing and Testing Specimens from Shotcrete Test Panels," is the appropriate ASTM standard for producing and coring test panels. ASTM C1140 specifies panel size as a minimum of 24 x 24 in. (610 x 610 mm) with a minimum 3.5 in. (89 mm) depth. Without more information on the materials used in the shotcrete, and the type of shotcrete, it is impossible to identify what may be causing the lower compressive strength tests.

The compressive strength should increase between 7 and 28 days on a curve equivalent to cast concrete. A strength degradation between 7 and 28 days may be a result of poor shotcrete application or problems with coring or curing of the samples.

Question: *Is there a reference where I can obtain some guide regarding the tensile strength of fiber-reinforced shotcrete (steel and poly)?*

Answer: ACI 506.1R-08, "Guide to Fiber-Reinforced Shotcrete," is a good reference for general use of fibers in shotcrete. If looking at underground applications for shotcrete, ACI 506.5R-09, "Guide to Specifying Underground Shotcrete," will also offer guidance. The ACI 506 documents are available in hard copy format on our bookstore website with ASA member discounts (**www.shotcrete.org**) or on the ACI website (**www.concrete.org**) in hard copy or PDF formats.

Because shotcrete is a method for placing concrete, many, if not most, of the properties of fiber-reinforced concrete, as found in ACI 544 committee documents, are applicable to shotcrete.

Question: *We have a concrete tunnel repair project, where expansion joints in a 10 x 10 ft (3 x 3 m) tunnel need to be repaired. The joints are on the top, bottom, and both sides of the tunnel; therefore, we have vertical and overhead applications. The detail calls for deteriorated concrete to be removed to a depth of about 6 in. (152 mm), existing reinforcing steel to be cleaned and preserved, and old waterstop removed and new PVC waterstop installed. How far can shotcrete be pumped for an application in a tunnel? We are looking at about 200 ft (61 m) for the shotcrete to be pumped from the supply to the repairs. Is this constructible?*

Answer: Yes, this is definitely a great application for shotcrete. Either wet- or dry-mix shotcrete can easily be used in tunnels with hose lengths of 200 ft (61 m). An experienced shotcrete contractor will be able to select the appropriate process based on the site, availability of material, and their particular equipment and trained shotcrete crews.

BASF Launches MasterEase

A new groundbreaking admixture range for low-viscosity concrete

As global leader in concrete admixtures, the Master Builders Solutions® experts have developed a new generation of polymers bringing a significant improvement in the rheological properties of concrete. Advanced concrete mixtures often demonstrate a higher viscosity due to their low water contents. Although having a high level of workability, the concrete often appears harsh, sticky, and therefore difficult to pump and process. This is especially true for engineering concrete with low water-cement ratios (*w*/*c*) optimized towards having a low environmental impact.

- New MasterEase product range for superior rheology of high-performance concrete
- Low viscosity and concrete mixture stability facilitate pumping and placing of concrete
- Optimizes the concrete mixture design and allows reduction of CO_2 footprint

To overcome these challenges, BASF has developed MasterEase, a new admixture range developed for low-viscosity concrete, and will present this innovation at the ERMCO (European Ready Mix Concrete Organization) Congress in Istanbul, Turkey.

With the new technology, plastic viscosity can be reduced by up to 30%, which results in a substantial reduction of pumping pressure required to pump the concrete on the construction site. Placing and finishing of the concrete is much easier, faster, and hence more economic than using standard concrete. "Innovation is what drives our business. With our new products we want to meet our customers' needs, contribute to their success, and strengthen our connectedness. This is the force behind MasterEase," said Ralf Spettmann, President, Construction Chemicals.

"The new admixture technology enabling these properties is being made available globally under the brand of MasterEase," explains David Bowerman, Regional Business Segment Manager for Orient, Russia, and Africa. "Ease stands for easiness of mixing, pumping, placing, leveling, and finishing of concrete. After pioneering concrete technology with market leading products, such as MasterGlenium and Master X-Seed we are proud to present another groundbreaking innovation from Master Builders Solutions to the concrete industry."

Concrete producers and users benefit in many ways from the new technology: it is flexible and can be adapted to challenging situations such as temperature variations. Moreover, the high level of rheology and workability retention minimizes the risk of jobsite addition of water: "This is a real added value for the contractors in terms of concrete durability," explained Jan Klügge, Head of Marketing, Ready Mix Europe. "The concrete is easy to place, trowel, and pump. Using this concrete saves time and cost in every single construction project, it improves the utilization of the transportation fleet and equipment and reduces the wear of mixers, pumps and pipelines." In addition, the possibility to reduce mix water even further without impacting the concrete rheology opens new possibilities for improvement in concrete mixture designs: less water in concrete mixtures implies higher performance and better durability.

"We already started to supply the new technology to the first construction projects. The feedback from the field is overwhelming," said Klügge.

The new technology is particularly suitable for concrete mixtures which are optimized for advanced engineering properties and sustainability: the Green Sense Concrete concept from Master Builders Solutions. High-strength concrete with low *w*/*c*, as well as mixtures with higher levels of secondary cementitious materials, reduce the CO_2 footprint and are easier to produce and place. This helps engineers and investors to improve sustainability ratings of their projects.

Starting in Europe and the Middle East, this technology will be globally available as MasterEase 3000 series for ready mix and site mix concrete applications.

For further information on innovative BASF products for the construction industry, please go to **www.master-builders-solutions.basf.com.**

With innovative MasterEase, placing and finishing of concrete is much easier and faster than using standard concrete

Putzmeister's New Tommy Gun A3 Series Fireproofing Pump Put to Work

Tennessee assisted living center gets fireproofed using innovative Putzmeister pump

One of the most important considerations in designing and constructing a healthcare facility is the safety of its future staff and guests. Thus, one of the major building elements for the new $38 million assisted living and skilled nursing center being constructed in Bellevue, TN, called NHC Place at the Trace (NHC), consists of fireproofing the facility from top to bottom. That phase of the three-story center, totaling more than 137,160 ft^2 (41,806 m^2), is being completed with the help of a brand-new Putzmeister Tommy Gun® A3 Series Fireproofing Pump.

The project's general contractor, Nashville, TN-based American Constructors, turned to the expertise of Safway Services (Safway), a diverse, international company offering a variety of services, including insulation solutions, to execute the fireproofing work and attic insulation required at the site.

Coordinating Logistics

On this project, after the elevated slabs are placed, the drywall contractors installed "Z" clips on all beams that will have a wall attached to them. Next, Safway sprays fireproofing using a Putzmeister Tommy Gun A3 Series Fireproofing Pump on

The Tommy Gun's mixer has been lowered closer to the ground to help reduce operator fatigue

The machine ensured consistent spraying of 1300 bags of MK-6/HY SFRM required for the job all the beams to the UL-required thickness of 1 in. (25 mm) and cleans and disposes of any overspray from the floor.

The newly redesigned Tommy Gun, which features a 13 ft^3 (4 m^3) hydraulic lift and dump paddle mixer, is being used to spray approximately 45,000 ft^2 (14,000 m^2) of spray-applied fire-resistive material (SFRM) for the project.

"The new Tommy Gun model has made huge improvements for our operators," said Wendell Kimbrough, Regional Manager for Safway. "The hydraulic lift has reduced the footprint required for setup, which is a great benefit when working around other teams of subcontractors. And the mixer that has been lowered closer to the ground reduces operator fatigue."

Consistency is Key

With Safway's fireproofing responsibilities on the project lasting for up to 40 days, it is important for the company to ensure consistent spraying of the 1300 bags of MK-6/HY SFRM required. The new blade design of the Tommy Gun is helping to make that happen.

"Not only does the new blade improve the thoroughness of the mixture and reduces the amount of dry material buildup on the walls of the drum, but it also ensures material is mixed well in the time frame set forth by the various manufacturers," explained Kimbrough. "We've been really impressed with the new model's performance."

Specifications

- Owner/Developer: National HealthCare Corporation, Murfreesboro, TN
- General Contractor: American Constructors, Nashville, TN
- Equipment Owner: Safway Services, West Allis, WI
- Spray-Applied Fire-Resistive Material Provider: W.R. Grace & Co. Construction Products, Bedford Park, IL
- Equipment: One (1) Putzmeister Tommy Gun® A3 Series Fireproofing Pump

The newly redesigned Tommy Gun features a 13 ft^3 (4 m^3) hydraulic lift and dump paddle mixer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HCM SHOTCRETE a Div. of HC MATCON INC.

HC Matcon Inc. specializes in concrete placement using the shotcrete process (wet and dry). We are a multi-disciplinary group of engineers, technologists, and skilled tradespeople with backgrounds in design, capital planning, project management, and construction. We service clients in residential, recreational, commercial, industrial, and institutional markets across Canada.

HCM Shotcrete is a specialized division of HC Matcon Inc. HCM Shotcrete is focused on structural and architectural shotcrete, restoration, and specialty coatings while HC Matcon is focused on soil stabilization, deep foundations, excavation support, and underpinning. Both HCM Shotcrete and HC Matcon use the shotcrete process to simplify concrete placement related to a wide range of applications.

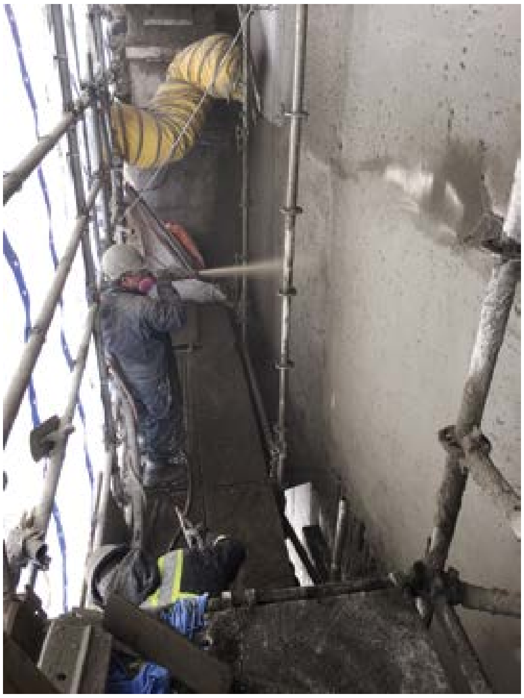
Structural and Architectural

HCM Shotcrete uses shotcrete placement methods as a substitute for formed construction methods. Typical applications include below-grade foundation walls, backformed interior elements, columns, and exposed architectural elements. HCM leverages the versatility of shotcrete to accelerate schedule and simplify atypical geometry and finishing requirements. HCM employs a number of ACI-certified nozzlemen with specific training in structural shotcrete placement.

Concrete Repair and Restoration

Many structures in Canada are faced with aggressive environmental conditions and exposure to deicing salts which can lead to accelerated deterioration of reinforced concrete. HCM Shotcrete uses shotcrete placement methods to reduce time and material required to complete repairs to existing structures. In Ontario, stringent certification requirements for dry process nozzlemen are used to verify skill and quality of workmanship before shotcrete nozzlemen are

MTO bridge pier repair for Toronto Transit Commission using dry-process shotcrete



Salt mine storage bin repairs using dry-process shotcrete

4 in. (102 mm) shotcrete liner to address microbial induced corrosion for aerobic reactor at wastewater treatment plant using dry-process shotcrete

permitted to place concrete related to infrastructure repair projects. HCM Shotcrete employs a number of Ministry of Transportation (MTO) certified nozzlemen to service this market. In addition to shotcrete repair methods, HCM Shotcrete is also equipped to complete traditional formed repairs—we choose the best technology for each project.

Soil/Rock Stabilization, Excavation Support, and Underpinning

HC Matcon is an industry leader in the application of shotcrete to soil/rock stabilization, excavation support, and underpinning. Engineering support provided by RWH Engineering allows HC Matcon to deliver design-build solutions for all kinds of stabilization, shoring, and underpinning challenges. Recently, HC Matcon completed excavation support for one of the deepest excavations in Calgary using a mixture of caisson wall elements and conventional shotcrete shoring.

Engineering Advantage

Due to the technical nature of shotcrete placement, HCM staffs projects with a field engineer to assist with quality assurance, technical communication, and continuing innovation. HCM also employs several professional engineers who are available to troubleshoot project-related issues or to discuss prospective projects. Call our shotcrete engineering specialists today to discuss your project.

25 ft (8 m) high architectural stairwell walls for institutional building using wet-process shotcrete

Perched caisson wall over conventional shotcrete in Calgary, AB, Canada. The caisson wall is installed in weak soil stratum and shotcrete is installed in competent soil/rock stratum

For more information on HC Matcon Inc. and HCM Shotcrete's offerings, visit our websites:
HC Matcon: **www.hcgroup.ca** | HCM Shotcrete: **www.hcmshotcrete.ca** | RWH Engineering: **www.rwhengineering.ca**

HCM SHOTCRETE a Div. of HC MATCON INC. "Specialized Concrete Solutions"

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