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shotcrete MAGAZINE

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Pools

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20th anniversary

1998-2018

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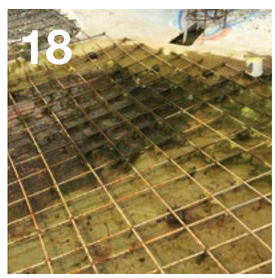
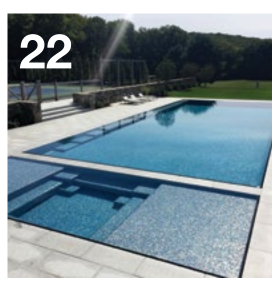
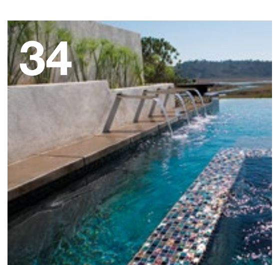
FEATURES







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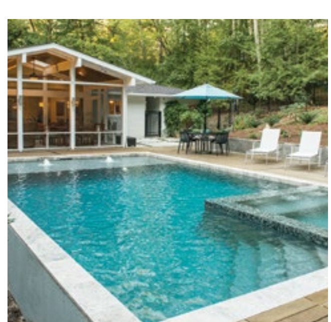
Editor's Note: Shotcrete is a placement method for concrete. However, for the sake of readability, the word "shotcrete" is often used either to identify the shotcrete process (method of placement) or the shotcrete mixture (product materials).

DEPARTMENTS



On the cover: Pool by Clearwater Construction Group
Photographer: Exum Photograph

A Prosperous Year for the Shotcrete Industry

By John (Lihe) Zhang

Working in the shotcrete industry, it is hard to not be busy during this time of the year. No matter where you reside, whether in Florida, Toronto, Houston, or Calgary, shotcrete professionals, including contractors, suppliers, consultants, owners, and researchers, are staying very busy in 2018.

From January 1 to July 31, ASA has conducted 64 ASA/ACI Shotcrete Nozzlemen Certification sessions. In addition, 432 nozzlemen and nozzlemen-in-training have been certified, recertified, or retested. This is a record number of certifications for this point in the year, and nearly equals our previous annual record of 450! Of these sessions, one session was held halfway around the world in Australia. ASA has had other international inquiries for certifications in Mexico and Argentina.

Civil tunnels are one of the major booming markets for the shotcrete industry. With several major subway projects in North America, including Los Angeles, CA; Washington, DC; and Toronto, ON, Canada, shotcrete is being used more and more in major metropolitan areas in the United States and Canada.

ASA has been putting considerable time and effort into keeping up with the rapidly growing pace of the shotcrete industry. Our Association is scheduling frequent ACI Shotcrete Nozzleman Certification sessions to meet the demands for certified nozzlemen. On average, about nine certification sessions with six to seven nozzlemen are being conducted every month. Charles Hanskat, ASA Executive Director, has been providing on-site seminars and presentations at technical conferences and to owners, specifiers, and private companies. As a result of the increased workload, ASA staff has increased to three full-time positions. ASA officers, board, and active committee members, along with staff, have been working diligently to meet industry needs for outreach, education, nozzlemen certification, and publications.

The shotcrete industry is growing in a healthy way. We look forward to a prosperous year in 2018 and are optimistic that we have structured our Association to serve the industry well into the future.

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Pool & Recreational Shotcrete Committee

By Bill Drakeley

As a pool builder, I wanted to share some observations on this 2018 season as well as a rather important recommendation. First, my observations on what condition the pool shotcrete industry is in and some interesting trends. Overall, I believe the pool shotcrete process has never been in a better place than it is currently. I say this because it has never been more analyzed, reviewed, and critiqued than it has in the past. We get calls every day from engineers, specifiers, and design consultants asking what quality shotcrete should look like and how should it be called out. The ASA website Technical Questions and Answers page fields more pool application questions than any other single portion of our industry. There is a very real need for education, or better yet an understanding of the shotcrete process than ever before.

So, why do I feel that this is good for the shotcrete pool builders? Simply put, the buying public knows better. This necessitates every pool "guy" to up his or her game. With ACI having an ACI 506 Subcommittee dedicated to pool shotcrete, a shotcrete nozzleman certification, and an upcoming shotcrete inspector certification, professionals involved with quality shotcreted installations are referencing these important resources. Equally important, ASA has been pounding the drums of quality pool concrete for some time now. *Shotcrete* magazine has numerous pool specific articles, there are educational opportunities at industry shows, and ASA position papers have thrust scientifically proven data onto the construction and buying public.

If you are still one who does not recognize and adopt in your work the advances in shotcrete technology and quality readily available today, you need to wake up and recognize our industry needs the durability and serviceability that quality shotcrete can provide. Move your business forward. Review our Pool & Recreational Shotcrete Committee position statements at **www.shotcrete.org/pages/products-services/shotcrete-resources.htm**. Get your nozzlemen ASA/ACI-certified.

We are being pushed to do better every day. This is a good thing. With new trends such as acrylic glass panels in high-end mixtures, we builders have to understand and have a critical, thorough knowledge of our installed product. Concerns about water-cementitious materials ratios and thermal stresses, as they relate to glass tile or acrylic panels, and the bond between materials are serious issues. Pool structures are not getting easier. We need to become smarter. The buying public is becoming more and more informed. We shotcrete installers need to understand that fact and stay ahead of the knowledge curve.

The next step in differentiation and acceptance is the status of being a qualified shotcrete pool contractor. ASA

ASA POOL & RECREATIONAL SHOTCRETE COMMITTEE

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Lihe (John) Zhang | LZhang Consulting & Testing Ltd.

has developed a program that reviews your company's past performance including verification of references on specific shotcrete projects. Those who meet the successful experience and shotcrete contractor requirements, along with a written exam, can then become an ASA Qualified Shotcrete Contractor. When ASA worked with ACI to implement the ACI shotcrete nozzleman certification in 2000, we did not realize that nozzleman certification may become the de facto standard for identifying quality shotcrete installers. In reality, the entire shotcrete team, being a qualified contractor, carries a lot more weight and credibility. Anybody can hire a certified nozzleman, but does that mean the project has the correct mixture design, well maintained equipment, adequately sized air compressors, proper formwork, experienced supervisors, and crew? It does not! A key to quality shotcrete on project after project is the shotcrete contractor.

Our product is technologically and structurally more sophisticated. The nozzleman alone does not make the shotcrete team. The entire field crew and management team needs to be knowledgeable and competent. Our ASA program is that educational and evaluation tool needed to keep pace and help differentiate those who are committed to quality, durable shotcrete installations. Everyone involved in placing quality pool shotcrete needs this credential. There is already a push on the design side to include ASA Contractor Qualification as a requirement in the bidding process. Our first class offered specifically for the pool industry is scheduled for November 1, 2018, in Las Vegas, NV, at this year's International Pool | Spa | Patio Expo. My strong recommendation is to attend this class and apply for the qualification process to demonstrate your commitment to quality shotcrete placement, and in turn, substantially enhance your credibility among the increasingly sophisticated owners of our pools.

Summertime and the Livin' is Easy (or at least very busy for ASA)

By Charles Hanskat, PE, FACI, FASCE, ASA Executive Director

Getting the bad news out of the way first, Beth Hinman, our part-time *Shotcrete* magazine facilitator and customer service staff, retired from ASA on June 15. Beth was a positive addition to our staff, joining ASA in July 2017. She got to know many of our members through phone conversations and e-mails when following up on magazine or customer service issues. Beth was wonderful to work with and always had an optimistic outlook. We certainly wish her the best, and hope she enjoys retired life.

But now for the good news! On June 18, we contracted with our association management firm, AOE, formerly CAM, to provide increased staffing to fill both Beth's duties and expand our social media outreach and marketing. Lacey Stachel comes on board part-time to handle the *Shotcrete* magazine-related duties, as well as social media and other marketing efforts. Lacey, in her spare time, works with ACI on *Concrete International* magazine. Karen Smith joins us from ACI's Customer Service department in a part-time position to handle membership and customer service duties. Please welcome Lacey and Karen to the "ASA team." You will find a little more about each of them in our Association News section of this issue.

SHOTCRETE NOZZLEMAN CERTIFICATION IS "HOT"

I often get questions during my seminars on the total ACI certified nozzleman population and the distribution of process, orientation, and nozzlemen-in-training (NIT) certifications. Using the ACI certification website to compile the data in mid-July, the overall status of ACI Shotcrete Nozzleman certifications were as shown in Table 1.

You will see though wet-mix has by far the largest number with 75% of the overall nozzlemen, dry-mix still enjoys a 25% share. Of note, 61% of dry-mix nozzlemen are certified in both vertical and overhead orientations, while only 26% of wet-mix nozzlemen are certified in both orientations. This is likely because dry-mix is more widely used in repair applications that will often include both vertical and overhead work. The NIT percentage of 7% is a sign we are attracting many new entry-level nozzlemen with less than the required 500 hours of nozzling time. The NIT category has only been available for 2 years, so we hope to see the number of NITs and those converting to full certifications increasing.

Table 1: ACI Shotcrete Nozzleman Certification

Certification Type	Nozzlemen
Dry - Vertical	175
Dry- Vertical + OH	276
Dry - NIT	24
Wet - Vertical	992
Wet - Vertical + OH	356
Wet - NIT	98
Total Fully Certified	1799
Total NIT	122
Dry %	25%
Wet %	75%
NIT % of full certs	7%

NIT = Nozzleman-in-Training, OH = Overhead

But what makes our sessions this year "hot"? Just looking at the number of sessions and certifications we have processed this year, you will see shotcrete nozzleman certification is blistering hot. Through July, we have held 64 sessions that have certified 232 new nozzlemen, 28 NITs, 133 recertifications, and 39 retests for a total of 432 overall nozzlemen. These numbers are running about 50% higher than last year at this same time. And last year was a record year with a 25% increase over our previous high. The total of 432 through July is nearly up to the 450 certifications we held in the entire year of 2017. Keeping up with the huge increase entails a lot of work and Alice McComas, our Program Coordinator, is doing a super job. Thanks to her, and all our ASA/ACI shotcrete nozzleman examiners who have allowed us to meet this high demand.

ASA CONVENTION—ROUND 2

In April, the ASA Executive Committee and a Marketing Task Group reviewed the results of our first convention, held in March. They found the convention was not only financially a gain for the Association but was more importantly a prominent event showcasing for the attendees what ASA offers the shotcrete industry. Our attendees enjoyed a sense of community with fellow shotcreters, and most found a renewed optimism about the future acceptance and growth of both ASA and the shotcrete industry.

With this positive feedback, the Executive Committee decided we needed another convention in 2019, and asked staff to evaluate East Coast venues for a late February to early March 2019 convention. Working with ACI Event Services, our staff reviewed five venues in Georgia and North Florida. The location selected is the Omni Amelia Island Plantation Resort in Fernandina Beach, FL. We are planning a 2-day convention on February 25-26, 2019. We will use a similar format as the 2018 Convention—a technical conference with shotcrete presentations, our Board and committee meetings, and the annual Outstanding Project Awards banquet. The day before the convention, Sunday, February 24, has scheduled optional events, including an ASA Shotcrete Contractor seminar, as well as local tours and recreational events. Check out **www.shotcrete.org/convention** for more information.

CALL FOR PRESENTATIONS DUE SEPTEMBER 7, 2018

As an essential part of our 2019 Convention, we will continue to have expert speakers explore shotcrete applications and innovations, as well as future advancements. We are seeking those active in shotcrete construction, engineering, education, equipment, materials, and R&D who are interested in sharing their expertise, insights, and accomplishments in the wide variety of shotcreted applications to submit presentations for consideration. Individual presentations are scheduled for a 50-minute duration including a short Q&A opportunity for the audience.

Topic areas include (but are not limited to):

- Water features
- Value engineering
- New construction
- Repair, rehabilitation, and repurposing
- Geotechnical and underground
- Architectural
- Advances in materials and equipment
- Sustainability

Title of the proposed presentation, speaker information, and a short (less than 100 word) abstract should be received by September 7, 2018, to be reviewed by the ASA Technical Committee. Submissions and questions should be directed to me at +1.248.848.3742 or Charles.Hanskat@Shotcrete.org.

ASA OUTREACH IS HEATING UP

ASA has seen a substantial increase in requests for our programs. The new Shotcrete Inspector education full-day seminar has been presented at the New York DOT, Tennessee DOT, North Carolina DOT, and in two locations for CalTrans in California. With over 250 attendees for the seminar overall, we have had great feedback, and acceptance by the DOTs that modern shotcrete technology can produce high-quality, durable concrete structures and repairs. The seminars have been attended by not only inspectors, but materials specialists, structures groups, and new construction and maintenance staff within the DOTs.

The ASA informational seminar "Introduction to Shotcrete" has been presented to many different groups, including national consulting engineering firms, ACI local chapters, regional concrete technology conferences, PCA's annual professor's workshop, concrete producer groups, and even the U.S. Army Corps of Engineers. These sessions are usually only 1-hour long but give a valuable overview on how shotcrete is a quality way of placing durable concrete. The seminar also opens the doors for later communication with attendees about how to best use shotcrete on their projects.

ASA has strong involvement in technical standards writing groups including ACI, ASTM, and AREMA, and we are showing substantial gains in recognition and acceptance of shotcrete. We have worked with various committees in all three groups to have codes, standards, and manuals directly cover shotcrete in a way that recognizes our current state-of-the-art.

Finally, our ASA Shotcrete Contractor Qualification program is fully available. A description of the program and online application are available at **www.shotcrete.org/pages/education-certification/cq-program.htm**. An article by Past President and Board member Marcus von der Hofen in our Winter 2018 issue provides an excellent overview (**www.shotcrete.org/media/Archive/2018Win_vonderHofen.pdf**). Also, you will find Past President and Officer Bill Drakeley, in the Committee Chair Memo in this issue, challenge those in the pool industry to step up and become ASA Shotcrete Qualified Contractors.

We have certainly been busy here at ASA this summer, and it does not appear to be slowing down. Fall will be here before we know it. I hope you have been able to enjoy the summer. As always, if you have any questions about ASA, or shotcrete in general, please feel free to contact me (+1.248.848.3742 or charles.hanskat@shotcrete.org).

Gunite Versus Shotcrete in Swimming Pool Construction

By Mason Guarino and Ryan Oakes

The term "gunite pools" has been used for decades in the swimming pool industry and is commonly used to describe a pool using shotcrete placement, whether it is the wet-mix process or the dry-mix process. Pool builders and designers have often debated whether a pool should be "made from gunite or from shotcrete." In this article, we clarify the terminology that leads to the debate and then provide arguments for both sides of the discussion.

Gunite and shotcrete are not materials, but rather are placement methods for pneumatically placing (shooting) concrete materials at high velocity. In the history of shotcrete, the term "Gunite" was a tradename used for the dry sand-cement mixture pneumatically shot from the Cement Gun Company's equipment and hydrated at the nozzle. When ACI started writing standards for pneumatically placed mortar in 1951, it adopted the term "shotcrete," as proprietary tradenames were frowned upon in technical standards. When reliable concrete pumping equipment allowed pneumatic placement of ready mixed concrete, the terminology was modified to include "wet-mix shotcrete," while the original dry process became termed "dry-mix shotcrete." Many companies still use the original term "gunite" to refer to dry-mix shotcrete. Thus, the term "shotcrete" can really be applied to either the dry-mix or wet-mix process.

It has long been considered that shotcrete is the best way to place quality concrete for a swimming pool structure. Shotcrete requires less formwork, fewer touchups after form stripping, provides excellent strength and durability, and can be installed far more quickly than form-and-pour pool construction. Along with many other benefits of shotcrete, there is no question that shotcrete is how concrete pools should be constructed. However, with two shotcrete processes, which one is the best for swimming pool construction? The short answer is that both processes work exceptionally well when correctly placed with a well-trained crew using the proper materials, equipment, and placement techniques employed by experienced shotcrete companies.

THE DRY-MIX VERSUS WET-MIX DEBATE

Common points of debate are whether one method is stronger than the other and whether one method cracks more than the other. There are many variables that influence these points, including the mixture design and the placement of that mixture. If dry-mix shotcrete has a 5000 psi (35 MPa) compressive strength and wet-mix shotcrete has a 5000 psi compressive strength, they are indeed the same strength. This seems elementary, but actual compressive strength as measured by compressive values is often ignored during arguments of one method being stronger than the other.

Though many pool builders feel a 2500 psi (17 MPa) 28-day compressive strength is adequate for pool construction, ASA's position is that shotcrete must have a minimum 4000 psi (28 MPa) to allow proper encasement of reinforcement, low permeability, and long-term durability. This is especially important in shotcreted pool shells that are expected to be watertight and provide decades of trouble-free service. This topic is covered in more detail in the "Overview of ASA Position Statements" article on p. 28 of this issue and online in Pool and Recreational Shotcrete Committee Position Statement #1 (**www.shotcrete.org/media/pdf/ASAPositionPaper_PoolRec_1.pdf**).

When it comes to cracking, the debate becomes more difficult. There are many reasons why pool shells crack. Common reasons include inadequate reinforcing bars, construction on poor soil, poor curing practices, seasonal temperature changes, concrete shrinkage, and even whether rebound is left in the pool rather than being removed during the installation. Aside from not removing the rebound, most of the pool cracks that occur have nothing to do with the shotcrete placement. Shrinkage (autogenous, early-age plastic, and long-term drying) takes place in all concrete whether cast or shotcreted. We will only be covering shrinkage cracking in this article.

The wet-mix process typically uses a water-cementitious materials ratio (*w/cm*) range of 0.40 to 0.45 and the dry-mix process typically uses a lower *w/cm* range of 0.35 to 0.40. This lower *w/cm* reduces water in the concrete mixture and can reduce shrinkage cracking. Moreover, when wet-mix concrete leaves the plant or arrives to the jobsite with a 0.40 *w/cm*, it may have more water added if it has been aging and needs more fluidity to be pumped down the line. Unfortunately, adding additional water to the concrete mixture after the mixture has stiffened is a common practice in the pool industry, resulting in concrete placed in many pools having a *w/cm* higher than 0.50. This higher water content not only reduces the strength of the shell and increases the permeability but also creates the potential for more shrinkage.

The negative effects of a too-high *w/cm* cannot be over emphasized in creating watertight pool shells. ASA Position Statement #4, "Watertight Shotcrete for Swimming Pools," explains that ACI 350, "Code Requirements for

Environmental Engineering Concrete Structures," mandates a maximum *w/cm* of 0.45 with a minimum 4000 psi for concrete intended to have low permeability when exposed to water. If concrete water-containing structures are exposed to freezing and thawing while saturated (a common occurrence in northern climates), an even lower maximum *w/cm* of 0.42, with a minimum 4500 psi (31 MPa) is required.

A well-trained crew can mitigate this by using water-reducing admixtures rather than adding water. Strength is not an argument for one shotcrete process over the other, as both, with the proper concrete mixture designs, can produce strong, functionally impermeable concrete shells. With proper attention to shrinkage, cracking is typically not an argument for one process over the other.

WHAT IS THE DIFFERENCE BETWEEN DRY-MIX AND WET-MIX?

Dry-mix is the process of conveying dry concrete materials, often just a coarse sand and cement mixture, through a delivery hose, injecting the majority of water at the nozzle, then shooting the newly hydrated concrete at high velocity onto the receiving surface. The wet-mix process pumps premixed concrete (usually a coarse sand, 3/8 in. [10 mm] or less coarse aggregate, and cement mixture) down the delivery line and adds air at the nozzle to accelerate the concrete to a high velocity.

Benefits of Dry-Mix Shotcrete

The benefits of dry-mix shotcrete make it an exceptional method for all pool construction. Dry-mix really excels in pools with less than 1000 ft^2 (90 m^2) of water surface area and pools with a high level of detail such as perimeter overflow pools or vanishing-edge pools. Pools in this size range typically can be finished in a day barring any extravagant features that could delay the crew into a second or third day.

Pools this size are often found in backyards where there is very little area to work in and limited space for a concrete truck to clean out. Dry-mix shotcrete creates minimal mess and can be easily cleaned up, and that helps get crews in and out in a day. A wet-mix crew must provide a way for concrete delivery trucks to clean their chutes while a dry-mix crew simply shovels up any leftover materials at the end of the day. Additionally, these size pools often have only one curtain of reinforcing bars, making the shooting process and managing rebound easier for the nozzlemen.

The cleanup process after shooting dry-mix is easier than wet-mix. There are only dry concrete materials to scoop or vacuum up—no concrete wash water or leftover concrete to worry about, especially when having to shoot from city streets (Fig. 1, such as Commonwealth Ave. in Boston). Wet-mix would have added hours of cleanup to the job; even a good plastic washout pan can fail and then you are cleaning up wet concrete with nowhere to wash it to.

Residential pools commonly have a lot of intricate detail. This detail work is typically easier to place and finish with a mixture that only contains cement and concrete sand without a coarse aggregate. Many dry-mix shotcrete pool contractors use volumetric mixer trucks to produce their concrete mixtures. This allows the crew to stop and start as necessary to ensure a quality placement and finish, while eliminating the concern of set time of premixed concrete material not yet placed. The concrete materials in the volumetric mixer truck are dry and can sit as long as needed until the crew is ready to start shotcreting again. A great advantage to dry-mix shotcrete is that with the correct mixture and placement, the in-place material can handle foot traffic immediately, leaving little more than a footprint (Fig. 2).

Fig. 1: Volumetric mixer truck on a pool shoot

Fig. 2: The crew is able to walk on recently shot dry-mix material without sinking into the surface

Unless a wet-mix concrete design uses a retarder or hydration control admixture, the batched concrete needs to be placed within 90 minutes of batching. By the time the concrete truck drives to the jobsite (hopefully not stuck in traffic), waits their turn to pump, and then is shotcreted, it is often difficult to meet the 90-minute time frame.

Using volumetric mixer trucks for creating wet-mix concrete on site can help mitigate this problem. However, it still leaves the problem of walking on the freshly placed, relatively fluid concrete mixture and disrupting the surface.

Benefits of Wet-Mix Shotcrete

Wet-mix shotcrete has significant benefits for pools larger than 1000 ft^2 (90 m^2) of water surface area and when more than 1 day is required to complete a pool structure. Wet-mix shotcrete has substantial production advantages over dry-mix. At South Shore Gunite (SSG), a volumetric mixer truck is used to produce both dry-mix and wet-mix shotcrete. With dry-mix production, the mixer truck runs at about 8 to 12 rpm, whereas in producing wet-mix concrete, the truck runs between 20 and 25 rpm—both with similar output per rpm. Thus, using wet-mix can double the production rate of concrete as compared to dry-mix… when the job allows. Wet-mix shotcrete can be easier to place, especially when jobs have high amounts of reinforcing bars with multiple curtains of reinforcing bars to shoot through (Fig. 3 and 4). The wet-mix process typically has less rebound than dry-mix, making areas with complicated layouts easier to manage with an experienced nozzleman and blow pipe operator. In similar circumstances with dry-mix shotcrete, the speed that rebound collects can be more challenging for the blow pipe operator to control.

Fig. 3: Wet-mix shotcrete was used on this pool because of the congested reinforcing bar layout, as well as requiring about 300 yd^3 (230 m^3)

Fig. 4: The same pool shown in Fig. 3 contained over 55 tons (50 tonnes) of reinforcing bars. With an extremely tight schedule, wet-mix easily allowed placement of concrete in 5 days

Wet-mix shotcrete also allows the use of more complicated concrete mixtures than dry-mix. Wet-mix shotcrete is readily available from ready mixed plants with fibers, air entrainment, high-range water-reducing admixtures, accelerators, and other forms of concrete admixtures. Dry-mix can include supplemental materials or admixtures, but it involves a more advanced setup, or use of prebagged, plant-produced materials. Revolution Gunite (RG) has used supplementary cementitious materials (SCMs) such as silica fume and has added color or fiber to its mixture design when required for the job. However, it takes more planning and setup on the job, and is more difficult than simply ordering ready mixed concrete from a concrete plant.

SELECTING A PROCESS

SSG installs pools smaller than 1000 ft^2 (90 m^2) of surface area with dry-mix shotcrete (Fig. 5) and pools over 1000 ft^2 (90 m^2) with either method. SSG does not use wet-mix shotcrete for pools under 1000 ft^2 (90 m^2) because these pools can be done in 1 day, and thus require crews to walk on freshly placed concrete in the floor. With dry-mix shotcrete, the placed material is very stiff and walking on freshly shot material disturbs just the top surface (minor footprints) without disturbing the embedded reinforcing bars. Wet-mix shotcrete tends to be more plastic when shot and walking prematurely on the surface can disturb and displace the embedded reinforcing steel in the floor.

Some finishing takes a lot of time, meaning that the shotcrete crew often chooses between one of two methods:

1. Shooting the walls first and cutting the excess shotcreted wall material into the floor/wall cove and then attempting to clean this undesirable material out from under the reinforcing steel; or
2. Shooting the cove in first and then walking through the wet, freshly placed material, potentially disturbing the concrete well into its initial set time.

However, neither method is advised. It is especially difficult to properly remove ALL the shavings, rebound, and excess concrete from under the reinforcing steel in the floor/wall cove. For strength and watertightness of the concrete pool shell, it is essential that all concrete is well placed with high velocity from the nozzle, providing thorough compaction of the material. This is equally important for both wet-mix and dry-mix. Tight spaces with a lot of congestion in formwork, embeds, pipe penetrations, or reinforcing steel—such as a spa—can create excessive rebound and in most cases the floor should be shot or cast first.

SSG mostly uses its wet-mix equipment for larger jobs starting at around 200 yd^3 (150 m^3) and going up to 600 yd^3 (460 m^3) (Fig. 6). SSG typically works under tight schedules, so the ability to install a pool structure a week faster than with dry-mix is a huge advantage. However, before SSG started using the wet-mix process, it shot many large pools, including a 50 m (160 ft) pool for Brown University with

Fig. 5: SSG used dry-mix shotcrete for this smaller pool with about 50 yd³ (38 m³) of concrete and easily completed in 1 day with dry mix. Additionally, the steel schedule was light and with a tight jobsite it is easier to clean up a dry-mix setup than a wet-mix setup

Fig. 6: Wet-mix shotcrete pump and on-site volumetric mixer allowed for faster production, as there was no swapping out of concrete trucks

dry-mix equipment. This pool had multiple layers of reinforcing bars and tricky areas. Having an experienced ACI-certified shotcrete nozzleman and an experienced blow pipe operator, SSG was able to build an exceptional structure that easily passed the watertightness test.

RG shoots every pool, large or small, with the dry-mix process. RG found that when working on multiple-day shoots, using the dry-mix process has the added advantage of having a delivery hose that, when not conveying concrete material, can provide high-volume air and water.

This high-volume air-water blast allows crews to easily prepare the previous days' placement, creating an optimum clean, saturated surface-dry (SSD) surface before applying the new concrete. RG uses on-site volumetric mixers for continuous batching of dry concrete materials. RG has achieved rates as high as 110 yd^3 (84 m^3) per day with one gun. Though admittedly not as high a production rate as wet-mix, it is fast enough for one crew to keep up. When a higher placement rate is needed, RG simply adds another gun and finish crew to double the production. High production is important in large commercial pools; however, most residential pools average 50 to 60 yd^3 (38 to 46 m^3) in North Carolina and 25 yd^3 (19 m^3) in Florida, so the region may dictate the installation method as well.

RG recently transported its volumetric mixer, compressor truck, and a cement silo along with multiple loads of aggregate and cement by barge to a remote island, off the

Table 1: Dry-Mix Process

Pros	Cons
Low *w/cm* ratio (high strength and low shrinkage)	High investment cost to get started or add experienced crews
Finishers can walk on material without disturbing the placed material	Higher level of experience needed from the nozzleman and crew
Finishers can work more easily with the material	High level of maintenance for equipment and trucks when using volumetric mixers
Volumetric on-site batching facilitates logistics	Requires specialized equipment to meter the material deliveries and water must be available on site or trucked in
Hydration at the nozzle ensures that the concrete mixture is fresh	Lower production rates compared to wet-mix
Hoses are lighter and easier to manage for the crew	Procuring dry aggregate and cement in remote areas where batching facilities are not owned by the contractor can be extremely difficult
Hoses do not surge, making the delivery hose layout more flexible	
Running long distance (up to 500 ft [150 m]) does not require additional procedures or concerns	
Dry materials are easier to clean up and dispose of than wet-mix concrete	
All job logistics are typically handled by the Shotcrete Contractor	

Table 2: Wet-Mix Process

Pros	Cons
Higher production rates compared to dry-mix	Can be more difficult to coordinate timely deliveries to place material within allowed timeline
Easier to get material in most locales	If problems arise on the job, stopping batching of subsequent trucks is difficult
Easier to use specialized admixtures in the mixture	If lines plug, they are difficult to clear and provide an added risk to property and crew
Mixture comes ready to pump; no on-site water needed	Contractors are typically at the mercy of the concrete supplier and their schedules
Can also use on-site volumetric mixer rather than ready mixed	Tends to have a higher *w/cm* for pumpability
Low start-up cost relative to dry-mix process using volumetric mixers	Adding water to the mixture to facilitate pumping is often a problem
	Walking on previously placed material can disturb the concrete and embedded reinforcement
	Contractor must provide a place for cleanout of concrete trucks
	Hoses are heavy and require more strength and endurance from the nozzlemen and crew
	Coarse stone in the mixture makes it more difficult on the finishers to achieve required finishes
	Distances from the pump to nozzle are limited by line type and size, often requiring steel pipe or larger lines to pump as far as a dry-mix hose can deliver with ease

coast of North Carolina, to shoot three commercial pools. The winds that could result in barge closings, and ability to coordinate placement on the jobsite made dry-mix shotcrete ideal, even though these were larger pools with congested reinforcing steel layouts.

Another example where dry-mix excelled for RG was on a residential project where the delivery lines had to be routed through the home—and the nearly completed home was worth approximately $20 million! Because dry-mix delivery hoses are relatively low pressure and not surging from the stroke of the concrete pump swing tube, the crew felt more comfortable using dry-mix. Water hoses ran through the home too, requiring RG to take special care to assure the connections were not leaking. This job could theoretically have been done with a wet-mix shotcrete line; however, it would be precarious to say the least just to protect the floors from the surging lines and in the event of a plug and the hose break or a simple cleanout, things could quickly become scary and expensive.

Past arguments against dry-mix shotcrete for a pool have included the fact that the *w/cm* is not precisely measured, and injecting water with the concrete materials so soon before placement cannot adequately mix the concrete. However, injecting water at high pressure while the dry materials pass through the water body completely saturates the materials. RG assures a constant flow of high-pressure water to our dry-mix nozzles by using on-board hydraulic water pumps pulling from our water tanks to get uniform water pressure. Although RG uses flow meters to determine actual *w/cm*, those concerned with the precise *w/cm* will find if you shoot dry-mix too wet, it simply won't stand up. Generally, dry-mix used vertically (or overhead) has a lower *w/cm* than wet-mix because pumpability is not a concern. Another common argument against the dry-mix process is that the builder paying for the material does not really know how much is being delivered. At RG with its volumetric mixer trucks they can accurately meter and document the materials being delivered.

From the shotcrete contractor's standpoint, dry-mix has its disadvantages, too.

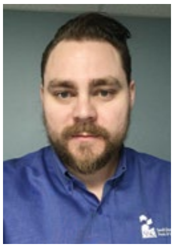
1. Because water addition to the concrete is controlled at the nozzle, dry-mix requires a more skilled nozzleman to place the material at the proper consistency.
2. Depending on the nozzleman, a job can experience more or less rebound, although the same can be said for the wet-mix process.
3. Finding water on site can be challenging, sometimes requiring water to be delivered to the job for the dry-mix placement.
4. The overall investment for a complete dry-mix operation with volumetric mixers can be 15 to 20 times (or greater) than that of a wet-mix setup. With the barrier of entry from an investment standpoint so high, it leaves the new startups competing with established giants in the industry.

Wet-mix also has a few drawbacks for the shotcrete contractor.

1. Unless site batching, they are relegated to working with the local ready mixed concrete companies and being constrained by their concrete availability and delivery schedules.
2. The overall pool builder, not the shotcrete contractor, often coordinates the concrete deliveries, adding a third party into the logistics.
3. The wet-mix delivery hoses are much heavier and must carry 10 times the internal pressure, making them not only more tiring for the nozzleman but also more dangerous for everyone on the project if there are plugs in the line.
4. The coarse aggregate typically used in the concrete mixture makes finishing harder on the crew.

Conclusions

In summary, both the dry-mix and the wet-mix process, when using quality materials, well-maintained and properly sized equipment, and placed by experienced shotcrete crews, are great for creating high-quality, durable, watertight swimming pools. Table 1 (Dry-Mix) and Table 2 (Wet-Mix) summarize our commentary on the advantages and disadvantages of both the dry-mix and wet-mix shotcrete processes.



Mason Guarino *started in the pool industry when he was 14, learning how to install reinforcing bars. 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 Directors and is an ACI Certified Nozzleman.*

Ryan Oakes *is a Managing Partner at Revolution Gunite and is a licensed pool contractor in North Carolina and Virginia. Oakes has been designing and building watershapes in the United States and abroad, from swimming pools to art pieces and even aquaculture systems, for the past 20 years. With a mission to change the way gunite is perceived and applied, Oakes started down a path of education for himself as well as their staff. He is an active member in the National Swimming Pool Foundation's Genesis University, which educates contractors around the world in various aspects of the pool building process, including the shotcrete process. Oakes is an SWD Master (Society of Watershape Designers) and an Allied member of the American Institute of Architects and member of the American Pool & Spa Association. In 2017, Oakes was appointed by the ACI Technical Activities Committee as a member of ACI Subcommittee 506-H, Shotcrete for Pools, and a member of ACI Committee 506, Shotcrete. He was recently appointed to the ASA Board of Directors while also serving as Vice Chair of the ASA Contractors Qualification Committee and a member of the ASA Pool & Recreational Shotcrete Committee.*

Inadequate Reinforcement in Swimming Pools

By Michael Reeves

Over the past 15 years, backyard swimming pools have changed immensely. Once just a place to jump in and cool off, pools have now evolved into entire backyard design masterpieces. From basic free-form pools to multiple-tier pools elevated out of the ground with negative edges and endless possibilities, pools today need to be engineered and built properly to enhance their lifecycle.

One of the key steps to building a structural swimming pool is the proper placement of the steel reinforcing bars. Reinforcing bars are the most commonly used reinforcement in swimming pools. Most pools use the wet- or dry-mix shotcrete process with single-sided forms. In shotcrete, the concrete has a very high compressive strength but the embedded reinforcing bars are needed for the concrete shell to withstand the expanding, bending, or flexing from loads on the pool. The embedded reinforcing bars not only provide structural strength to the concrete pool shell, but also help stabilize the freshly shot concrete to build up walls.

Fig. 1: Not enough reinforcing bars, and improper layout

In this article we are addressing reinforcement, but issues such as concrete compressive strength, forming, and watertightness of pool shells are also key to an overall successful project. ASA has developed a series of Position Statements establishing industry best practice for shotcreted pools. ASA Pool and Recreational Shotcrete Committee Position Statement #1, "Compressive (Strength) Values of Pool Shotcrete," details why shotcrete must have a minimum compressive strength of 4000 lb/in.^{2} (28 MPa) for serviceability and long-term durability. Often the reinforcement layout depends on proper formwork or subgrade preparation and ASA's Position Statement #6, "Forming and Substrates in Pool Shotcrete," can provide very helpful guidance.

In swimming pools, No. 4 (No. 13M) reinforcing bar is the minimum size bar that should be used. Depending on the design, we see a lot of pools with No. 5 bars (No. 16M) and No. 6 bars (No. 19M) in the reinforcing steel layout to strengthen the concrete due to higher loadings. This may happen when the pool is being supported on pilings, needs to withstand groundwater, or if there are exposed, freestanding walls.

When installing reinforcing bars in a swimming pool, it is not simply running random pieces of steel bar at nonspecific locations where the concrete is going to be placed and expect it to serve its purpose. Reinforcing steel should be placed in accordance with the pool design and generally needs to meet American Concrete Institute (ACI) standards for structural concrete.

ACI 350, "Code Requirements for Environmental Engineering Concrete Structures," provides mandatory requirements for design of concrete liquid-containing structures and is often applied to pools. Also, ACI Committee 506, Shotcreting, has established a subcommittee to develop a guide to proper use of shotcrete in the pool industry.

ACI 350 has specifications for proper cover (distance from the bar to the closest surface), minimum spacing, splices, tolerances, and so on. If you are unsure of the proper amount and spacing of reinforcing steel needed, consult with a structural engineer experienced in pool design to design a reinforcing steel layout that will ensure a quality, durable swimming pool structure. When the reinforcing steel is properly designed and placed, it works together with the concrete to create a pool shell which will resist the pressures of internal loads from the contained water, and external loads, like soil that impact the wall.

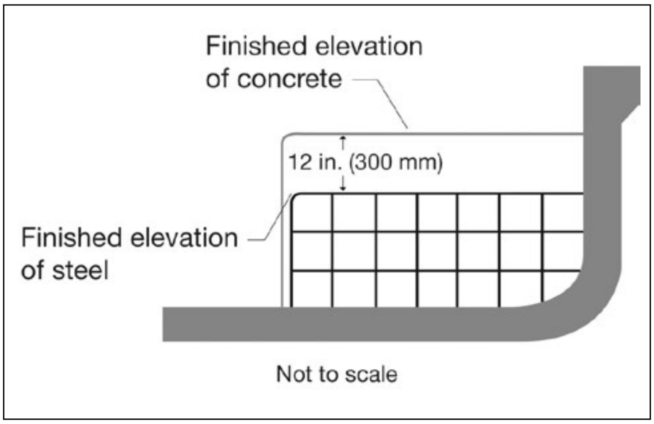


Fig. 2: Incorrect reinforcing bar layout for bench

Unfortunately, we run into problems with incorrect reinforcing bar placement more often than we would like. As you can see in Fig. 1, there is not adequate reinforcing steel in the beam of the pool. The pool beam should not be sitting on top of the soil, and the reinforcing should have extended almost to the forms. There is about 12 in. (300 mm) between the closest reinforcing and the form boards. Without reinforcing bars to provide support, this section is basically a plain concrete cantilever that will eventually crack from settlement. The same goes for installing the reinforcing steel for the pool walls and floor. Typically, pools use a minimum of reinforcing bars spaced at 12 in. on center, each way. However, there are many projects that call for 8 or 6 in. (200 or 150 mm) spacing. Another place where we often see a lack of reinforcing bars is in the bench or a sun shelf area of a pool (Fig. 2). The reinforcing steel in this sketch is set too low, which will result in 12 in. of unreinforced concrete and create a high potential for cracking. Maintaining the proper amount of steel in the concrete is critical to the structural integrity of a pool.

It is also possible to have too much reinforcing steel in one area. If the reinforcing bars are not properly spaced apart, it may be extremely difficult to properly encase the reinforcing with shotcrete. Adequate spacing between reinforcing bars is critical to allow good shotcrete placement and fully encase the reinforcing bar. Without proper encasement, voids can form in the concrete around the bars that can reduce the ability of the concrete section to carry loads, and can lead to cracks or, in extreme cases, failure of the pool shell.

The placement of plumbing in swimming pools is another critical area that can create a weak section in a wall or floor (Fig. 3). The plumbing needs to be set back far enough or even outside of the pool so that it will not impair the structural integrity of the pool shell. Again, you need to be able to have proper coverage on both sides of the reinforcing bars to make sure there are no weak points in the walls or floor.

Reinforcing bars used in structural concrete has raised deformations on it, which helps keep the reinforcing bars locked inside the concrete. Special care needs to be taken to make sure the reinforcing bars are clean of any debris (such as caked-on mud or rust) to allow them to function properly. As you can see in Fig. 4, the steel and substrate are in no way ready for shotcrete.

Fig. 3: Not enough cover over the reinforcing bars

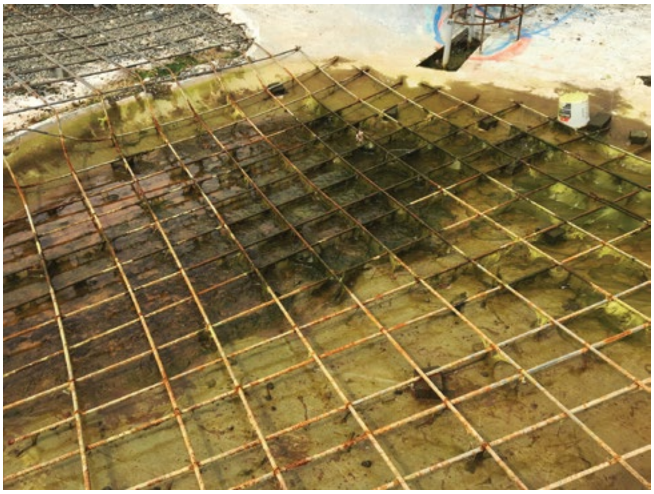


Fig. 4: The substrate and reinforcing bars are not ready for the shotcrete application

Most pools also use the in-place soil after excavation as the substrate to shoot against. As long as there is good, solid soil, this is a perfectly good substrate to shoot against. The problem arises when there is rainy weather, because unsupported soil can liquify and cave in around the reinforcing bars and, in some cases, push the entire cage of reinforcing bars into the pool. If the soil of the excavation fails, all the soil that encroached on the reinforcing needs to be cleaned out and the reinforcing resecured prior to shotcreting. If the failure of the soil significantly increases the wall thickness needed, the pool designer may need to be consulted to see whether additional reinforcing steel is required.

Fig. 5: An example of good reinforcing bar placement

The design and installation of the reinforcing bars in pools requires close attention to detail. As you can see in Fig. 5, the steel is straight, clean, and properly placed, allowing for good encapsulation. When there is a crack in the concrete pool shell, most people point to the shotcrete contractor first, and assume there is an issue with the concrete. With the issues pointed out herein, it is often not poor concrete material or placement that is the cause. When you know the proper procedures, reinforcing bar placement is not hard to do. It just takes time and attention to detail to make sure you have a strong solid cage that will do its job and hold the pool structure together, and allow for many years of use and enjoyment.

__Michael Reeves__ is the Vice President of GSI Pool Finishes and Gunite Specialists, serving the industry in Pennsylvania and surrounding states. He grew up in the profession and is a second-generation shotcrete contractor. Reeves is a member of the American Shotcrete Association, American Concrete Institute, Northeast Spa and Pool Association, and Association of Pool & Spa Professionals.

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A Jewel in the Woods

By Bill Drakeley

It happens only rarely, but occasionally you run into a client who wants to do things out of sequence. Working with a property owner who insists on an unconventional approach to a project can be a challenge. However, it definitely helps when that client is also open-minded, imaginative, and absolutely set on achieving brilliant, gemlike results.

Most often, we are asked to work on projects where there is an existing home that needs a watershape. Just as commonly, we are brought in when a home is being built at the same time as a new pool and its associated environment. In the case described in this article, however, our client owned a 20 acre (8 ha) site with little more than a modest existing farmhouse on the property. While he planned to replace that structure eventually, he told us, having teenage children meant that the fun parts needed to come *first*.

We could not argue with his logic, so we signed on to build a pool, a spa, and the surrounding decking, while the adjacent tennis court and pool house were to be handled by other contractors (Fig. 1).

A Bold Vision

Our work on the property, located in the wooded hills of Roxbury, CT, actually started several years before the pool project came into focus. Back in 2006, Drakeley Pool Co. (Bethlehem, CT) was contracted to build a meditation pool to memorialize the client's late wife. The water feature was situated in a garden area where the two had been married and included an antique olive press.

This was our introduction to both the client and the setting. His architect had sought us out based on our skills in concrete construction and our reputation for building unique water features throughout the region. It was a straightforward job, but it required a tremendous amount of sensitivity and creativity.

Our thoughtfulness on this project led the client to contact us when the discussion turned to the new pool and spa. When that time finally came, however, we were working in somewhat of a vacuum: there was a place on the plan for a house, but there were no fixed reference points when it came to scope and scale to guide us.

Fig. 1: Working with a property owner who insists on an unconventional approach to a project can be a challenge, but when working together, the final watershape can achieve brilliant, gemlike results

What we *did* have, fortunately, was the certainty of the adjacent tennis court—so we used its size and proportions to trigger our thinking. We drew up preliminary ideas for a side-by-side pool/spa composition, linking its features into the lines established on the paved surface just one level above our working space. Both pool and spa featured knife-edge-slot, perimeter-overflow designs that gave them the appearance of floating above the surrounding deck.

The watershapes and tennis court are not exact counterparts—at 25 x 80 ft (7.6 x 24 m) overall, the pool/spa footprint is not regulation tennis court size—but there is nonetheless a strong sense of visual balance. To articulate the connection, we aligned the pool's top step with the steps leading down from the court, tying the two levels together whether you are looking up from the pool deck or down from the court.

But even though the client was quite imaginative and creative, he wanted more detail than our sketches showed. So, equipped with our plans and photographs of the property, we worked with Skip Phillips and Greg Boruff at Questar Pools & Spas (Escondido, CA) to generate a computer-assisted, three-dimensional (3-D) presentation package.

The client was pleased with the 3-D renderings, commenting that what he was seeing was just what he always wanted. He then began describing the watershapes as the "jewels of the property," using a word that would take on unusual significance as the project progressed.

DEVILISH DETAILS

We started our work in earnest, excavating the site and encountering the usual run of small fieldstones as well as moisture-retaining cohesive clay soil that leads to significant freezing-and-thawing pressures. Not wanting to take any chances of the decks heaving, we installed a subdeck/subpool dewatering system that constantly drains to an outlet pipe located downslope from the pool.

We then set about forming the spa and its unusual pair of thermal ledges alongside the pool and established everything required for the two vessels' perimeter overflows (Fig. 2(a)). The pool and spa were to have entirely separate plumbing systems—separate surge tanks, separate circulation systems, separate *everything*—but what they did have in common was a narrow wall that marked the divide between them (Fig. 2(b)).

For design purposes, that wall had to be thin—no more than the width of the coping system we were using. This had consequences: We knew that if we tried to insert our customary slot-drain piping for both vessels into such a narrow wall, the shotcrete coverage of the two pipes would have violated the basic American Concrete Institute (ACI) concrete cover requirements and would have been so minimal that our annual freezing-and-thawing cycles would eventually end up shattering the wall.

Technically we would have designed the common wall between the spa and main pool as two slot-overflow systems. This means a gravity polyvinyl chloride (PVC) trunk line for each atmospheric flow off each edge (pool and spa). The main-trunk PVC gravity lines for each pool would have to have been installed adjacent to one another inside the 18 in. (450 mm) thick common wall for pool/spa connection. Inside dimensions for PVC piping are 6 in. (150 mm) and 4 in. (100 mm), respectively. Add the PVC wall thickness to this and you end up with almost 12 in. (300 mm) of plastic taking the place of concrete within the common wall. On top of that, add two layers of No. 4 (No. 13M) reinforcing bars with a 1/2 in. (13 mm) diameter and one can see that there is not enough room to get quality placement of wet-mix shotcrete around the entire diameters of both pipes, especially because there would be no spacing gaps between each pipe to get the recommended 3 in. (76 mm) of concrete coverage. With the plastic pipe taking the place of concrete and steel, winters in New England would have surely damaged the pool wall in such a way that watertightness and bond of the surface textures would have been difficult.

Instead, we set the wall up as a monolithic structural concrete wall and cut out channels on both sides before it

Fig. 2(a) and (b): The pool and spa cover a lot of ground—nearly the size of a regulation tennis court, which meant using a massive amount of reinforcing steel and pipe, and keeping track of the large number of PVC lines as they moved toward and into the equipment vault/surge tank bunker

Fig. 3: Construction included the special slot-drainage system built into the narrow wall dividing the pool and spa

fully cured (Fig. 3). On the pool side, the slot empties into several dropouts, and on the spa side, we cut the slot with a slight rise in the middle, so gravity will lead water to the sides of the spa and their drainage pipes. While it was a lot of work, it was the right engineering solution for this detail and created the very specific look we wanted.

We used toe-kick recesses to aesthetically rid the pool floor of unsightly plastic fittings. To accomplish this, we took 3 ft (0.9 m) anti-entrapment, narrow-strip drain fittings, inverted them, and placed them on the vertical side of the benches or steps (Fig. 4). A very important aspect in using this approach is to box out the forms in a 3-D format to allow for overhead or cantilevered concrete placement. This requires a qualified shotcrete crew and nozzleman to shoot around this boxed form to not trap rebound and get full encapsulation of the fitting.

The original design featured glass tile applied to the interior of the spa as well as the tops of the pool steps. As the project progressed, the client decided to further expand on his "jewel" concept by having us tile the pool from end to end. The client had previously selected a custom blue blend of 3/4 in. (19 mm) glass mosaic tile from Bisazza (Miami, FL) for the pool house. Now he wanted us to carry that look throughout *both* watershapes, creating magnificent, sparkling jewels in the middle of the property.

Because we had been operating under the assumption that the pool would have a plaster finish, we had created a radiused floor/wall connection and left the concrete in much rougher condition than we would have had we known the pool was to be tiled.

The new tile finish, chosen by the owner after concrete placement, changed the required final surface texture. By this point, we had already tested the shotcrete at 6000 psi (41 MPa) and had tank-tested the shell, filling it to verify its watertightness.

With standard plaster, a cut or rodded concrete texture creates a roughened surface that provides terrific bond and hold for that surface. Wet-mix shotcrete mixtures generally have a coarse aggregate size of 3/8 in. (10 mm) max. This rough 3-D bond plain is ideal as a securing mechanism for final submerged pool plaster. However, it is not perfectly straight in vertical and horizontal planes. A glass tile would follow these peaks and valleys in the surface and the variation would be very noticeable. So, we added a smoothing combination of pool plaster and Laticrete® products to densify the shot surface and level out the bond plane to the exacting surface requirements of the glass tile (Fig. 5).

As we continued tile installation, the stonemasons placed the granite decks—a beautiful material honed to give it a slightly rough, slip-resistant texture.

Fig. 4: Formed toe-kick recesses for the pool and spa circulation systems

Fig. 5: Smoothing the shot surface to level out the bond plane

HILLTOP BEAUTY

Although the work under our purview went smoothly, we experienced a fair share of communication issues with the general contractor who worked on the pool house. As part of our work, we had set the foundations for the walls and step systems leading up to both the tennis court and the pool house. Without consulting us, the contractor cut away certain portions of that foundation and managed to cut through some of our lines in ways that gave rise to both tension and consternation on site.

Those issues were ultimately resolved—and yet another lesson duly learned on the importance of jobsite communication across disciplines. We soon completed our work, including the rigging of a downslope building that contains two surge tanks, twinned equipment sets, an equipment-storage room, a generator bunker, and a secure space for the homeowner to use for storage.

Eventually, a grand home will take shape at the end of the pool opposite the pool house, and the view from the watershapes will shift away from the nearby trees and over to the longer, far lovelier downslope view. Sheltered from the breezes, the watershapes stand 1/4 in. (6 mm) below the deck surface, giving them the glassy, reflective, jewel-like appearance that captured the homeowner's imagination during the design process (Fig. 6).

While the client's focus was rightfully on the visual appearance of the final project, as a company we must balance that sort of aesthetic perspective with the raw practicalities of ensuring the structures are mechanically, hydraulically, and structurally sound and durable. The fact that we can do so without sacrificing aesthetics is what has earned us our reputation in our region and in the industry.

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 the ACI Certified Nozzlemen program on behalf of ASA, 2016 President of 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.*

Fig. 6: Completed pool and spa

Solemnity and Beauty

As is mentioned in the accompanying text, our first project on the property was constructing a fountain the client—a widower with two teenage boys—wanted to establish as a memorial to his beloved wife, who had passed away some years earlier (Fig. 7).

She had worked in and loved the property's garden area, which had been the setting for the couple's nuptials years earlier and was the obvious choice for placement of the memorial. The client was very clear about what he wanted: an antique stone olive press set in a basin with water flowing over a millstone core. With the certainty of his vision driving our work, the task was a simple pleasure.

More importantly, we impressed the client and his architect with the trouble-free quality of our work—a fact that led to far greater involvement with the property later on.

—Bill Drakeley

Fig. 7: Memorial fountain

Overview of ASA Position Statements on Shotcrete Pool Construction

By Charles Hanskat

Shotcrete placement has been used for decades to create high-quality, creatively shaped, durable, watertight concrete pool shells (Fig 1). Shotcrete has many inherent advantages in pool construction:

- Shotcreted pools are not limited to straight, flat surfaces. We can place concrete to create unique curving walls and radiuses (or even those flat, straight surfaces) when needed.
- Because the final surface of the freshly shotcreted concrete is readily available for finishing, we can provide any finish texture desired—from a simple, cut finish for excellent bond of later-applied plaster or tile, to a smooth trowel finish, to a surface looking exactly like an exposed rock face.
- With the readily available freshly shot concrete surfaces, very close tolerances can be met. This is important for features like infinity edges that need a uniform elevation for smooth water flow over the edge.
- Shotcrete has low form pressures during placement, so it allows light, easily placed and removed forms using less materials and labor, thus reducing overall construction duration and significantly improving sustainability of the project.
- Shotcrete using properly selected materials, appropriate equipment, and experienced shotcrete crews will create concrete sections with strength, durability, and low permeability that are equal or superior to the hardened properties of traditional form-and-pour concrete.

Fig. 1: Tight tolerances with advanced design facilitated this uniquely curved pool

Though shotcrete's use in the pool industry is widespread, unfortunately, knowledge of proper materials, equipment, and application techniques can vary widely. Our ASA members know that quality shotcrete takes a conscientious and constant effort to pay attention to ALL the details. As Technical Director for ASA, I often get inquiries from pool owners and builders about questionable shotcrete practices on their projects. Reuse of rebound, lack of curing, lack of velocity in placement, inconsistent thicknesses, and issues with excessive porosity crop up frequently. My article "Misconceptions about Shotcrete—True Stories from ASA Technical Inquiries" in the Fall 2016 issue of *Shotcrete* magazine presents many of these, if you would like to see more details.

Why do we have this large spread in quality of shotcrete placement in the pool industry? There is not necessarily a single answer. There are many smaller companies with no ACI-certified nozzlemen whose nozzlemen just learned by picking up the nozzle. They simply do not understand the basics needed to produce quality shotcrete. There are those companies who, due to the high level of competition in producing pools, feel they need to meet the same price point and quality of the lowest bidder. There are company owners who do not understand the shotcrete process and do not invest in the proper equipment or maintenance to produce quality shotcrete day in and day out.

So, what can ASA do about this lack of knowledge among the owners, designers, and contractors in the growing, and challenging business of creating pools? As Bill Drakeley, Past President of ASA, has repeatedly stated, "We need to raise the bar in the pool industry." ASA's Pool and

Recreational Shotcrete Committee, led by Bill, found there were no clear, specific reference documents that covered shotcrete pools. Though ACI 350, "Code Requirements for Environmental Engineering Concrete Structures," includes shotcrete and covers all types of liquid-containing concrete structures, it is used predominately in large water, wastewater, and industrial process projects and not in the design of pools. Local building codes also typically did not address the specific needs of shotcrete placement for pool projects.

Thus, the ASA Pool and Recreational Shotcrete Committee decided that a series of position statements, or white papers, on specific, focused issues for shotcrete placement in pool applications was the best way to share the knowledge the committee members had through their long experience with shotcrete pools.

To date, we have developed and had full Board approval on six position statements:

- Compressive (Strength) Values of Pool Shotcrete
- Definitions of Key Shotcrete Terminology
- Sustainability of Shotcrete in the Pool Industry
- Watertight Shotcrete for Swimming Pools
- Monolithic Shotcrete for Swimming Pools (No Cold Joints)
- Forming and Substrates in Pool Shotcrete

Future position statements will address issues such as curing and finishing. The full position statements are freely available at **www.shotcrete.org/resources**. The following is an overview of the content in each.

Compressive (Strength) Values of Pool Shotcrete (Position Paper #1)

This position paper deals with the specifics on ASA's recommendation that shotcrete should have a minimum 28-day compressive strength of at least 4000 psi (28 MPa). ACI 318-14, Table 19.3.2.1, for concrete in contact with water where low permeability is required (Exposure Class W1), specifies a minimum compressive strength of 4000 psi and a water-cementitious materials ratio (*w/cm*) of 0.5 or less. Shotcrete inherently has a *w/cm* of 0.45 or less, and with proper materials, equipment, and placement, can routinely achieve strengths of 4500 to 9000 psi (31 to 62 MPa). Many shotcrete applications see a 4000 psi strength at 7 days.

Definitions of Key Shotcrete Terminology (Position Paper #2)

The intent of this paper is to lay the ground work for common terminology when referring to shotcrete and serve as the shotcrete-specific terminology equivalent of ACI's extensive Concrete Terminology document. The terminology was compiled from ACI CP-60, "Craftsman Workbook for ACI Certification of Shotcrete Nozzlemen"; ACI 506R, "Guide to Shotcrete"; and "ACI Concrete Terminology." Most terms are applicable to all shotcrete. However, some are more applicable to the pool industry. For example, differentiating between "waterproof" and "watertight":

Waterproof: Completely impervious to water in either liquid or vapor state. (Because nothing can be completely "impervious" to water under infinite pressure over infinite time, this term should not be used.)

Watertight: Impermeable to water except when under hydrostatic pressure sufficient to produce structural failure.

Sustainability of Shotcrete in the Pool Industry (Position Paper #3)

Shotcrete inherently has many sustainability advantages. We use less formwork. Sometimes we do not use any formwork. When formwork is used, it is lighter and is made with less material and labor than with form-and-pour equivalents (Fig. 2). The position paper also discusses shotcrete's inherent sustainable advantages in creating complex and efficient shapes, creating better bond, speeding construction, adaptability to varying shapes and thicknesses in repair, and facilitating access to restricted or hard to reach areas (Fig. 3).

Fig. 2: Lightweight, one-sided form is all that is needed when using shotcrete

Fig. 3: Overview of a pool with extensive curves typifying shotcrete's flexibility

WATERTIGHT SHOTCRETE FOR SWIMMING POOLS (POSITION PAPER #4)

Concrete is a relatively impermeable material. I have seen cast concrete walls 35 ft (11 m) with a full water head on the inside that are completely dry on the outside. To create these functionally watertight walls, one needs to properly detail the design (movement joints, reinforcing, etc.), use a high-quality concrete mixture, and fully consolidate ALL the concrete. This can be routinely accomplished by shotcrete placement, as we use high-strength concrete (4000 psi minimum), with a low *w/cm* (0.32 to 0.45) and provide complete consolidation by high-velocity impact. Further, the quality of placement is readily visible in all areas during placement. It is not hidden at the bottom of an enclosed two-sided form. This position paper explains in greater detail why shotcrete meets and exceeds requirements from ACI 350. Further, it proves that a quality shotcrete pool shell should be functionally watertight, and subsequently applied plaster or tile **are not** what makes the pool watertight.

Fig. 4(a) and (b): Shotcrete on top of cast floor

MONOLITHIC SHOTCRETE FOR SWIMMING POOLS (NO COLD JOINTS) (POSITION PAPER #5)

This position paper focuses on the ability of shotcrete to form monolithic concrete sections even when shot in layers. This is an industry-specific adaptation of the article "Shotcrete Placed in Multiple Layers does NOT Create Cold Joints" that can be found in our website magazine archive (**www.Shotcrete.org/ArchiveSearch**). There have been specifiers who insist the entire wall of a pool be shot at one time due to fear there would be a "cold joint." But cold joints simply do not happen in shotcrete when the interfaces between layers are properly prepared, quality materials and equipment are used, and shotcrete is placed with experienced nozzlemen (Fig. 4). The paper goes into more detail about construction joints, and an explanation of how shotcrete can facilitate creating sections that act monolithically at these joints. Also, we explain why bonding agents are never recommended with shotcrete applications.

FORMING AND SUBSTRATES IN POOL SHOTCRETE (POSITION PAPER #6)

This position paper explains the wide variety of forming options available in shotcrete pools. There is discussion

Fig. 5: Lightweight curved form with steel reinforcing for radius steps

of the soil conditions in the subgrade and excavated sides of the pool, and how that may impact forming or wall thicknesses. The paper further details formwork considerations such as rigidity needed for shotcrete placement, different materials available, and the impact weather and delays may play (Fig. 5). Overall, the shotcrete contractor must verify that: the formed or natural surface being shotcreted upon is stable, rigid, and nonvibrating; the forms define and maintain the desired thickness and shape; and they fully support any attached reinforcement during shotcreting.

In Closing

When going to our Shotcrete Resources webpage, you will also see our "Board Position Paper on Shotcrete Contractor and Crew Qualifications." This paper explains why a contractor offering to place quality shotcrete must have specific knowledge, equipment, training, and hands-on experience of the entire construction team—from company management through the field crew—to truly be considered a Shotcrete Contractor. The paper details typical shotcrete crew duties and qualifications and concludes with a Shotcrete Contractor Qualification Evaluation Checklist that proves useful for owners or specifiers to qualify their shotcrete contractor on a specific project.

We expect these Pool Position Papers to be a continuing series that will bring expanded knowledge from successful and experienced members in the shotcrete pool industry to the public domain. Your comments are welcome. If you would like to share your experience with the ASA Pool and Recreation Committee in developing future papers, consider attending an upcoming meeting. All our ASA committee meetings are open to the public (**www.Shotcrete.org/Calendar**).

Charles Hanskat *is the current ASA Executive Director. He received his BS and MS in civil engineering from the University of Florida, Gainesville, FL. Hanskat is a licensed professional engineer in several states. He has been involved in the design, construction, and evaluation of environmental concrete and shotcrete structures for over 35 years. Hanskat is also a member of ACI Committees 301, Specifications for Structural Concrete; 350, Environmental Engineering Concrete Structures; 371, Elevated Tanks with Concrete Pedestals; 372, Tanks Wrapped with Wire or Strand; 376, Concrete Structures for Refrigerated Liquefied Gas Containment; 506, Shotcreting; and Joint ACI-ASCE Committee 334, Concrete Shell Design and Construction. Hanskat's service to the American Society of Civil Engineers (ASCE), the National Society of Professional Engineers (NSPE), and the Florida Engineering Society (FES) in over 50 committee and officer positions at the national, state, and local levels was highlighted when he served as State President of FES and then as National Director of NSPE. He served as a District Director of Tau Beta Pi from 1977 to 2002. He is a Fellow of ACI, ASCE, and FES and a member of ACI, NSPE, ASTM International, AREMA, ICRI, and ASCC.*

WORLD OF CONCRETE®

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american shotcrete association | asa

ACI Shotcrete Nozzlemen Certification

Certificación del ACI de Lanzador de Concreto

Tuesday, January 22, 2019
ASA Education (Wet-Mix and Dry-Mix)
Las Vegas Convention Center
—offered in BOTH English (registration code: ASATU) or Spanish (registration code: ASASTU)!

Thursday, January 24, 2019
ACI Wet-Mix Certification | Henderson, NV

The ACI Shotcrete Nozzleman Certification is an industry-wide recognition of demonstrated knowledge, via written exam, and ability to properly place shotcrete, via performance exam(s). The American Shotcrete Association is offering the (optional) opportunity for both English- and Spanish-speaking nozzlemen to attend the required classroom education (both wet- and dry-mix) and take their wet-mix performance exam(s) to fulfill requirements for ACI Shotcrete Nozzlemen Certification.

Martes, 22 de enero de 2019
ASA Educación (vía húmeda y vía seca)
Las Vegas Convention Center
—¡ofrecido tanto en inglés (código de registro: ASATU) como en español (código de registro: ASASTU)!

Jueves, 24 de enero de 2019
Certificación ACI de vía húmeda | Henderson, NV

La certificación del ACI de lanzador de concreto es un reconocimiento a nivel industrial del conocimiento demostrado, mediante examen escrito, y la capacidad de colocar el concreto lanzado adecuadamente, a través de exámenes de desempeño. La American Shotcrete Association ofrece la oportunidad opcional a los lanzadores de habla inglesa y española que asistan a la educación requerida en el salón de clase (tanto en vía húmeda como en vía seca) y tomen sus exámenes de desempeño de vía húmeda para cumplir con los requisitos para la certificación ACI de lanzador de concreto.

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GENESIS

(ASA Corporate Member)

Water is the essential element of a great backyard. Whether a homeowner chooses a swimming pool for family fun and fitness, a spa for relaxation, or simply wants to bring exceptional beauty to outdoor space, water is a medium of endless potential.

With so many options available, homeowners need true professionals to create backyard environments that will provide years of carefree recreation and pleasure. Fortunately, GENESIS®, the leading educator in the field of residential watershapes, brings expertise to its growing network of students including builders, contractors, and landscape architects on whom homeowners can depend for quality construction and design.

HISTORY

GENESIS was established in 1998 and joined by leaders looking to lift our industry's ability to design, engineer, construct, and service watershapes that resonate with people's minds and spirits. Since its humble, yet passionate beginnings, thousands of professionals have trusted GENESIS faculty and courses. GENESIS has long been reaching second-generation pool builders; and, now in its 20th year, the educator is training second-generation GENESIS students. Since the 2016 merger with the National Swimming Pool Foundation® (NSPF), also an International Association for Continuing Education and Training (IACET)-approved provider, GENESIS is even better prepared "to help people live healthier lives through aquatics" by carrying out its goals to educate, certify, and connect the very best companies and individuals in the pool and spa industry.

GENESIS UNIVERSITY

Genesis University® educates, certifies, and connects watershape professionals through coursework, projects,

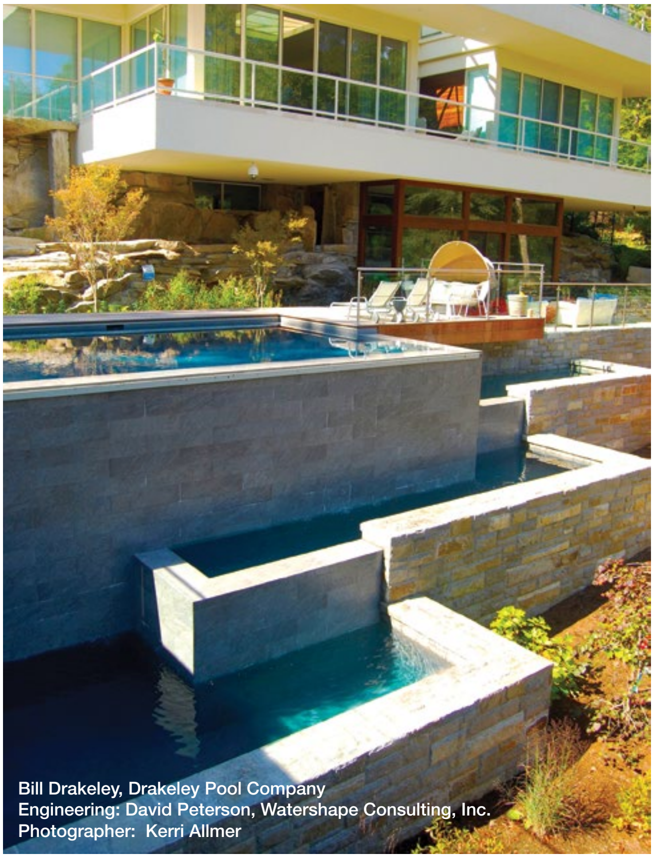
Michael Nantz, Elite Concepts Inc.

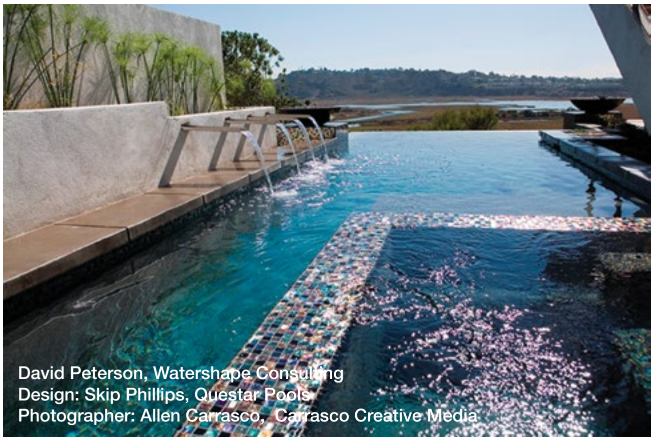
examination, and continuing education. GENESIS' expansive curriculum is developed using strict guidelines maintained by IACET. NSPF trains 35,000 individuals annually both nationally and internationally through its Certified Pool Operator® (CPO) certification. A CPO Certification provides individuals with the basic knowledge, techniques, and skills of pool and spa operations. The combined organization is at the forefront of the industry as the leading educator in both public pools and residential construction.

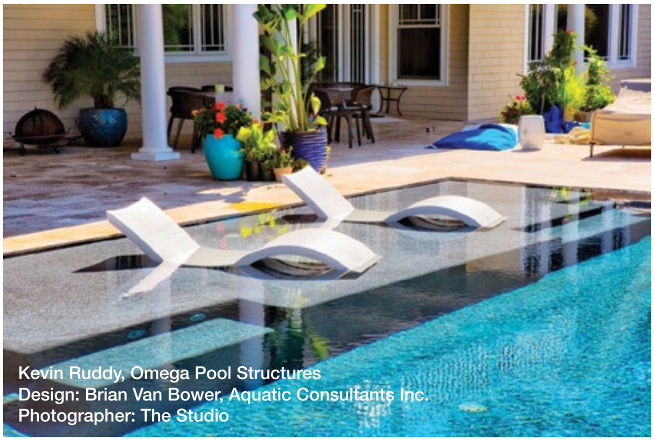
SOCIETY OF WATERSHAPE DESIGNERS

The Society of Watershape Designers certification is the only accredited educational program specifically developed for those individuals in the swimming pool, watershapes, or water architectural fields seeking excellence. Society of Watershape Designers throughout the world are credited with the design and construction of the most conceptually creative, technically advanced, and structurally sound watershape structures in existence. These impressive structures collectively push the boundaries of creative expression using water as their media.

Those who achieve Society of Watershape Designers Registered and Master certified status have completed at least 150 hours of GENESIS education; see p. 37. The curriculum leads to skills and knowledge encompassing color theory, the principles of design, multi-dimensional visual communication, the vocabulary of architectural design and


Bill Drakeley, Drakeley Pool Company
Engineering: David Peterson, Watershape Consulting, Inc.
Photographer: Kerri Allmer


David Peterson, Watershape Consulting
Design: Skip Phillips, Questar Pools
Photographer: Allen Carrasco, Carrasco Creative Media


Kevin Ruddy, Omega Pool Structures
Design: Brian Van Bower, Aquatic Consultants Inc.
Photographer: The Studio


Grant Smith, Aqua-Link Pools & Spas
Engineering: David Peterson, Watershape Consulting, Inc.
Mechanics: David Penton, Fluid Dynamics Pool and Spa


Ryan Oakes, Clearwater Construction Group
Photographer: Exum Photograph

Andy Kaner, Aquatic Consultants, Inc.

history, and the principles of proper pool and watershape construction.

Within the Society of Watershape Designers is an elite group of 17 individuals who have achieved GENESIS' highest level of professionalism, SWD Master status. For the full list of its Masters, visit **www.genesis3.com/swd-master-pool-designers.html**.

NEXT 20 YEARS AND BEYOND

GENESIS has been providing the pool, spa, and watershaping industry an unparalleled level of education for the past 20 years. As our industry continues to evolve and change, GENESIS will continue to be at the educational forefront providing the time-honored education students require.

SOME OF GENESIS' KEY ACHIEVEMENTS IN THE LAST YEAR:

CERTIFY

- Separated the Genesis University brand from the Society of Watershape Designers (Society);
- Credentialed nine new SWD Registered—those having completed 150 hours of coursework; and
- Launched NSPF's Advanced Service Technician™ Training Courses, leading to AST^CM Certification.

EDUCATE

- Celebrated another year, offering 100+ course hours at the International Pool | Spa | Patio Expo;
- Reached over 1500 students, who entrusted GENESIS with their training;
- Launched CONSTRUCTION 281: Major Renovations, to address the renovation segment;
- Expanded its curriculum to include a "Service" track to make employee training more effective; and
- Expanded reach to the Northeast Spa & Pool Association, World Aquatic Health Conference, Western Pool & Spa Show, and Canadian Pool & Spa Show Conference & Expo.

CONNECT

- Connected with architects (at AIA & ASLA) to position SWD Masters as premier design and construction resources;
- Expanded social events within all schools to strengthen the GENESIS family;
- Expanded exposure of SWD members to affluent consumers by launching the "Outdoor Living Showcase" in partnership with RMS Media Group;
- Advertised in Luxury Pools, Ocean Homes, and social media outlets featuring SWD Masters and Sponsors;
- Reveled together at the Annual Winemaker Dinner at the International Pool | Spa | Patio Expo; and
- Partnered with ASA to educate pool builders/watershape designers on the proper and beneficial placement of shotcrete in pool design.

GENESIS®

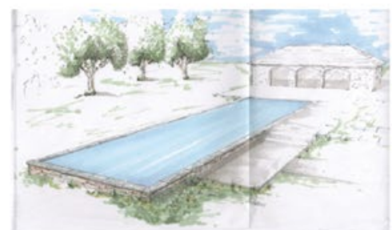
SOCIETY OF WATERSHAPE DESIGNERS®

How can I become a member of the Society of Watershape Designers®? Upon completing the seven core classes and accruing 150 hours of total GENESIS® education, an individual may apply for SWD® Registered status.

Where do I start? We suggest starting with CONSTRUCTION 201: Basic Pool Construction and DESIGN 101: Introduction to Perspective Drawing. the latter of which is a prerequisite for DESIGN 211. Otherwise, students can choose the core course order depending on timing and preference. Contact Lisa Ryckeley, Director of Operations (lisa@genesis3.com or 615-907-1274) for help on your GENESIS journey!

CONSTRUCTION 201: BASIC POOL CONSTRUCTION

See and understand the complete construction of basic pools through a 3-day building journey from layout to chemical balancing. This is the pool industry's flagship construction program. **24.0 hours**

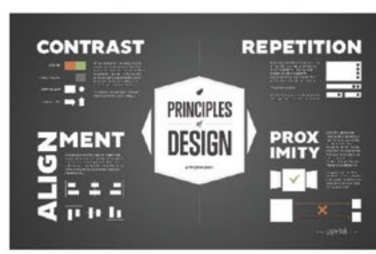


DESIGN 101: INTRODUCTION TO PERSPECTIVE DRAWING

Communication is vital to the success of any professional, and basic drawing skills are one of the most important tools for design-professionals to master. This 8-hour program explains how simple perspective drawings can communicate complex design and construction details. **8.0 hours**

ENGINEERING 211: BASIC FLUID ENGINEERING

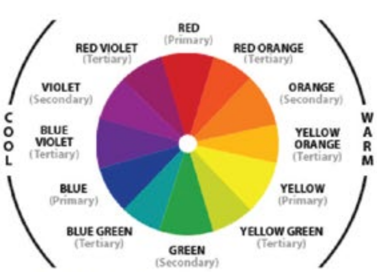
A beautiful and structurally sound watershape is still a failure if the mechanical systems are not designed and built properly. Incorrect equipment and plumbing sizes are dangerous, inefficient, and may result in non-functional systems. **16.0 hours**



DESIGN 211: ELEMENTS OF DESIGN

There is a science to good design including both elements (line, shape, space, size, texture, hue, value) and principles of design (balance, movement, repetition, contrast, variety, emphasis, unity).

(D101 is a Pre-Requisite) **16.0 hours**

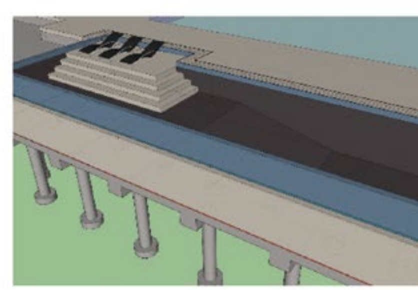


DESIGN 231: COLOR THEORY AND ITS APPLICATION

Color principles influence our emotions, so material selections could be the difference between project success and failure. See how landscape designers use this science to create beautiful projects. **16.0 hours**

DESIGN 271: 20TH CENTURY ARCHITECTURAL STYLES

The pool design should complement the architecture and landscape architecture of its environment. To do this successfully, the designer should comprehend the style and context of the project. **16.0 hours**



DESIGN 202: SKETCHUP
DESIGN 203: AUTOCAD
DESIGN 204: POOL STUDIO

Computer modeling is the preferred tool for creating and sharing construction documents with other team members. Students choose 1 of 3 course options. **16.0 hours**

The SWD® Core Courses comprise 112 of the 150 credit hours required to be eligible for SWD® Registered status. The remaining 38 credit hours are electives and can usually be obtained free of charge by attending the International Pool | Spa | Patio Expo and other trade events where Genesis University® courses are offered.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Shotcrete Truck Safety

By Mason Guarino

SEATBELTS, SEATBELTS, SEATBELTS! There, now that this is out of the way we can start. The key to making safety work is education, practice, and repetition. None of this is ever too much when it comes to ensuring everyone goes home safely every day. Truck safety is often overlooked, as the majority of the shotcrete crew does not have to interact with trucks on site. There are some general truck rules that can be followed to keep drivers and crews safe and there are some truck-specific safety items as well. The shotcrete crews typically interact with three types of trucks, including concrete, mobile volumetric mixer, and crew trucks. Most truck safety should be common sense; however, some things can be overlooked by even the most experienced crew members.

General Truck Safety

General truck safety is the easiest; some of it also applies to small personal vehicles that most workers are familiar with already. One of the easiest things to do is spend some time driving without any radio or music and learn what noises are normal and which ones are a cause for alarm. Some drivers do this religiously and never listen to the radio. All drivers should make it a regular practice to listen to your truck periodically.

Driver awareness and alertness is one of the most important safety factors. Driver fatigue can easily cause accidents on and off the jobsite. Not having enough rest to be alert as needed for safe operation of a vehicle can be disastrous, especially with the larger trucks that handle poorly and stop slowly when loaded. All drivers need to ensure they have enough rest to be safe.

Fig. 1: A news helicopter picture of the incident where a car came in contact with the passenger front corner of our truck and was turned in front of the truck and pushed a mile down a main highway

Drivers need to know their trucks and perform daily vehicle inspection reports. If something prohibits safe operation of the vehicle, immediately take the vehicle out of service until it can be repaired. On-road driver safety and responsibility should be a normal practice; follow the rules of the road, keep your truck maintained, and keep good records of maintenance or of any problems.

Camera Systems

With the price of technology decreasing, it is becoming much easier to install a truck camera system to help protect the company and the driver from injury and lawsuits. Backup cameras can be helpful, but having a camera on the driver, the front, back, and each side of the vehicle can easily alleviate a potential lawsuit from a mischievous individual or show the police that the truck driver did everything right when a car got too close. We had an incident a few years ago where, according to the driver, people were suddenly beeping and pointing at him and he pulled over to find a small car turned sideways in front of his 77,000 lb (35,000 kg) truck that he had pushed for a mile (1.6 km) down the highway at highway speeds (Fig. 1). Luckily no one was hurt, and no lawsuits were brought; however, a camera system that recorded all the movements would have shown who was at fault. GPS systems in the truck that monitor speed are recognized by the DOT and can help prove drivers are obeying the laws as well.

Jobsite Safety

The jobsite is where more experience is needed. Many drivers are only experienced with on-road driving and do not encounter off-road driving. A lot of driving for shotcrete work requires off-road driving. Some off-highway driving is easier than others, such as mines and large-scale construction sites where roads are built within the sites to keep everyone safe. Many project sites such as retaining walls, soil-nail walls, and especially residential swimming pool work have less-than-desirable off-road driving conditions. These sites can be sloped in many ways, requiring the driver confirm they can even take their truck where it needs to go safely. Typically, the concrete truck—whether ready mixed or mobile volumetric mixer—is the heaviest vehicle with the highest center of gravity of any vehicles on site. Just because a dump truck made it through upright does not mean it is safe for the concrete truck. These trucks can and do tip over. Drivers should evaluate where they are going whether on- or off-road before driving down to the discharge location. This is true whether it is the crew truck, the dump truck, or the concrete truck. Check for stable ground conditions and ensure nobody is ever beside a truck when driving into a jobsite. A truck that commonly weighs close to 80,000 lb (36,000 kg) can easily run over a soft spot with one wheel, which could cause the truck to tip (Fig. 2). Check for problematic areas, such as septic tanks, leach fields, weakened manholes, recently backfilled soils, or other potential soft spots. Truck drivers should ALWAYS have someone helping them back up into tight sites with slopes and drop-offs on the side of the road. In tight situations, some drivers may need help even when driving forward.

Fig. 2: An example of why vehicle inspections and knowing your truck are so important. This body broke loose from the frame of the truck and tipped over

DRIVER TRAINING

Driver training is crucial to achieving many years of safety. Just because a driver has a commercial driver's license (CDL) that allows them to drive a large vehicle does not mean they have the correct experience to get into a truck and be a successful driver of that vehicle. Their experience could be limited to straight trucks over the road with no off-road experience. Or maybe they just graduated from CDL driving school, and while driving schools teach how to drive the school's lightly loaded trucks they will not have the experience necessary to safely drive a top-heavy truck weighing 70,000 to 80,000 lb (32,000 to 36,000 kg). These "new" drivers need to spend time riding with an experienced driver who can speak their language fluently and can demonstrate the correct skill set to drive that vehicle. Teaching a new driver how to be safe is more than just telling them to go slow on sharp corners, obey laws, and be careful. New drivers need to be educated on the weight their truck carries, how it carries it, and how that affects the acceleration and more importantly the stopping of the loaded truck. They need to be shown and taught why they need to drive a certain way and understand that it is very easy to roll over a large, heavy truck.

Once a truck arrives on site, there is a different aspect of safety. Because the majority of readers here do not drive or operate concrete trucks, this article will not go in too much detail about them. Concrete trucks are operationally much simpler than volumetric mixer trucks. While there are lots of potential safety hazards with concrete trucks, the driver should be well-trained by the concrete batch plant company and understand their specific truck, so the shotcrete crews do not need to get involved in operating it safely on site. For the members of the shotcrete crew, the best thing to do around a concrete truck is to keep your distance and allow the operator to do their job.

VOLUMETRIC MIXER TRUCK SAFETY

Many shotcrete companies own and run volumetric mixer trucks. These are more common with the dry-mix shotcrete process; however, wet-mix batching trucks are becoming more popular. The volumetric mixer trucks have a slew of moving parts, including augers, conveyors, chains, gears, hydraulic booms, pumps, and hoppers. Drivers need to be thoroughly trained on how to load their trucks properly.

If you own volumetric mixers, testing should be conducted and pictures should be taken of what a full load entails. In Massachusetts, where South Shore Gunite Pools & Spas is based, our trucks are allowed to have a gross vehicle weight (GVW) of 77,000 lb. When the truck was purchased, it had mounts for side boards to protect the body from loading accidents, so we installed 2 x 12 in. (50 x 300 mm) lumber like we had on the dump trucks for years. Many drivers assume that we could fill the truck to the level of the boards and no sand would fall out on the highway… so that must be a full load. After initial testing we realized that if we loaded the truck to that level, it would still be safe to travel without anything spilling, but the truck could easily weigh up to 90,000 lb (41,000 kg) or more if the sand was wet. While the truck engine, axles, and suspension may all individually be able to handle this weight, it adds significant liability, such as breaking laws (that can incur fines), and simply is just a bad idea. The cement bins are also a fixed size, so if your truck is carrying around 90,000 lb that means there is probably 12,000 lb (5400 kg) too much sand in the truck. If your volumetric mixer is poorly calibrated, the concrete mixture will have far too much aggregate, and if calibrated properly your truck will be heading back to reload with an extra 12,000 lb on it. This would certainly use more fuel than necessary and is simply never cost-justified. With volumetric mixer trucks, there are a lot of moving parts in a dirty environment, and small and large breakdowns happen regularly. Experienced shotcrete contractors with a fleet of these trucks know that if you want to have three trucks ready to go you will need to own four, as something is always wrong with at least one of them.

AUGER SAFETY

Normal operation of volumetric mixer trucks is typically very safe because the manufacturers include safety equipment, such as guards, covers, shrouds, and latches to prevent injuries. It is when something goes wrong or breaks that things can become dangerous. With all these moving parts small problems are common and can usually be repaired in the field with basic crew truck tools. Common problem areas are in the augers, where materials such as rocks, hardened cement powder chunks, street cones, balls, and tree limbs can end up in the sand from many different sources. Experienced volumetric mixer crews can tell of many more strange objects that made their way into the aggregate bin and jammed up the mixer.

When things like this happen, DO NOT stick your hand in and free it. Steps need to be taken to ensure any work directly around augers is safe. Initially reversing the auger should be attempted to try to use the auger to free itself from what was causing a jam. If reverse does not work, the operator should do their best to relieve auger pressure by moving it into forward and reverse very lightly to find the middle of that optimal spot where the auger is not jammed under compression and could jump when the object is freed. Once it is certain that the auger is free, the truck should be shut down. This prevents any oil pressure from getting to something if a lever is bumped or a remote control falls. While it is possible to turn some valves and maybe isolate what is being worked on, why not just kill the power to everything to ensure nothing bad can happen? Once it is certain that all or as much pressure as possible is relieved from the auger and the truck is shut down, the operator should still not stick their hand into the auger to remove the jammed object. A lot of these augers will turn freely with a large tool when the truck is off, allowing the operator to slowly and carefully advance and auger with lots of control to work something out and then test if it is clear when it seems to be. Use an appropriate tool—preferably one with a longer handle that allows two hands to be on it for more control. Typically at this point the jam can be cleared relatively easily.

CONVEYOR BELT SAFETY

Conveyor belts pose a different and more complex jamming issue. The belts are typically attached to a chain that is difficult to see along its full length. These belts need to be extremely well maintained and always have the chains properly lubricated. These chains are frequently exposed to sand and dusty conditions—the opposite environment a chain wants to live in. With proper maintenance, cleaning, and lubrication, conveyor belts can last a long time. However, if the chains are not well maintained, the links will wear excessively and can start to come apart. When that happens, they always seem to jam themselves up in areas that are very difficult to repair. As any experienced volumetric truck operator knows, these material-conveying parts will never fail with only a little concrete material left—they will instead fail when the truck is full, thus making it even more difficult to diagnose and fix a problem. Again, when trying to repair these items, shut the truck off.

Most of these trucks have some type of chain drive. These chain drives are extremely easy to maintain as long as they are lubricated and checked regularly. If they are not checked, the chains can start to stretch a little or chain tensioners can come loose. When this happens, the chain starts to break teeth on the sprockets and once some teeth are missing they will try to jam up. When these jams occur, approach them in a similar way as the auger; try to relieve pressure by moving the mechanism in forward and reverse and then shutting the truck off. These chains are also heavy and even with the truck off and no tension, the chains can move a little, and a finger caught between a chain and a gear does not feel good.

ON-SITE REPAIRS

When these problems occur on-site, it is not uncommon for half of the crew to turn into professional mechanics who want to join in on fixing the problem. This is where the crew leader needs to step in and assign the correct people

Fig. 3(a) and 3(b): A driver mentally unfit to operate a truck took a turn too quickly and rolled our fully loaded mobile mixer. The body was able to be repaired but the truck was totaled

to complete the repair. Those people are usually the truck operator and ONE other person to assist. Keeping the repair process to two people allows clear information to be passed between the two and no one will hand-advance something when the other person is not ready. If for some reason there is no line of sight or it is noisy, a third person to ONLY convey information between the two can be added. Be clear, concise, and take a deep breath. These problems can be extremely frustrating, especially if you are sitting on a prevailing wage job with eight or more shotcrete crew members waiting to do their job. Stay calm, think clearly, and fix the problem safely. If there is a hot head on the crew, keep them away. If there is a hot head running the repair, let them take care of it. Would you risk your finger, hand, limb, or life over someone else's frustration?

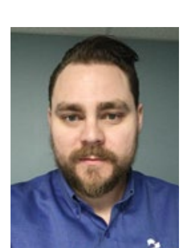
Mental Fitness

Truck drivers need to be mentally fit to be able to handle an 80,000 lb vehicle safely. Unfortunately, we found out about the mental unfitness of one of our drivers when they were driving a mobile volumetric mixer to a jobsite. The driver was familiar with the jobsite and knew where the turn was, but personal issues created a distraction for him. As a result, the driver was not paying attention and saw the left-hand turn he was supposed to make when he should have already been slowing down. He still tried to make the left-hand turn, although his speed was obviously too fast, and ended up rolling the truck over off a 6 ft (1.8 m) embankment (Fig. 3(a) and (b)). The driver suffered a broken arm and the truck was totaled. The driver did not return to work, as he could not focus on what he needed to focus on to safely do his job.

Conclusions

For those of you who do not have experience with volumetric mixer trucks, a little guidance: Yes, they break down; Yes, they break with full loads of sand and cement with broken augers and conveyor belts; and Yes, everyone that uses volumetric mixer trucks has been in the back of them hand-shoveling 30,000 to 40,000 lb (14,000 to 18,000 kg) of sand out of the truck to begin the repair, or even worse hand-shoveling over 8000 lb (3600 kg) of cement powder out of the cement bin. But here is a special message to those company owners and managers out there who think all that expensive sand around their sand barns needs to be cleaned up and used: if the sand barn has a dirt floor, that sand is a buffer from those auger busters—just let it be.

In summary, truck safety is all about education, practice, and repetition for all those associated with operating the vehicles. Drivers should get to know their vehicles and not assume every vehicle will act the same on or off the road. There are many aspects of truck safety that all need to be taught, monitored, and maintained to keep everyone returning home safely every day. Stay focused—not distracted—and ultimately make the commitment to stay safe.



Mason Guarino *started in the pool industry when he was 14, learning how to install reinforcing bars. 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.*

The Restoration of Lincoln Park Fountain

By Armando Ramos

Lincoln Park is a 270 acre (109 ha) park that borders the Hackensack River on the western edge of Jersey City, NJ. The entrance to the 180 acre (73 ha) eastern section of the park leads to a fountain that opened in 1911. It was billed as the largest fountain in the nation at the time of its construction. The fountain consists of a 53 ft (16 m) tall center sculpture with a 155 ft (47 m) diameter basin around it. Over the years, the structure deteriorated significantly, and the Hudson County, NJ, administration, decided to restore the structure. The restoration of the Lincoln Park Fountain required complete demolition and removal of the original water-containing basin and replacement with a shotcreted concrete basin.

Fig. 1: Setting pencil rod for grade control

Superior Gunite reconstructed the basin in two phases. The first phase included the slab, and the second phase was placement of the walls. Both phases employed the wet-mix shotcrete process. The basin's slab was 17,500 ft^2 (1600 m^2) in plan area with a minimum thickness of 10 in. (254 mm) of concrete. The outer perimeter wall of the basin was 2 ft 1 in. (0.64 m) thick with the height stepping from 2 ft 4 in. to 3 ft 7 in. to 4 ft 7 in. (0.71 to 1.1 to 1.4 m). In addition, there were 24 square pilasters spaced uniformly around the wall that increased the wall thickness to 2 ft 6 in. (0.76 m). The slab work included shooting 12 pedestals for the frog-shaped sculptures housing the fountain nozzles, plus 11 pedestals for light fixtures. Superior Gunite also shotcreted the inner wall of the basin, which was a 17 in. (0.43 m) tall, 1 ft (0.3 m) thick circular wall with a diameter of 29 ft (9 m) centered on the fountain's main sculpture.

The extremely detailed design of the blockouts for the precast architectural concrete on the inner face of the perimeter wall presented a major challenge for Superior Gunite. There were several stages of stepping in and out on the face of the wall, and the design changed for each of the three heights of wall. There were rectangular indentations on the face of all the columns centered on light fixtures. There was a slight slope on the top of the wall to direct rainwater towards the outside of

Fig. 2: Overview before concrete placement

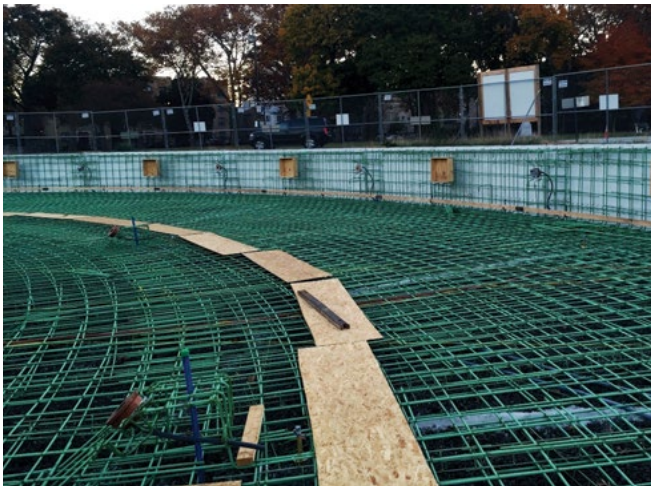


Fig. 3: East quadrant reinforcing showing box outs in wall

Fig. 4: Shotcrete placement in outer basin wall

PROJECT DETAILS

Project Location
Jersey City, NJ

Shotcrete Contractor
Superior Gunite

General Contractor
Nicholson & Galloway

Architect and Engineer
Helena Ruman Architects

Material Suppliers/Manufacturers
Ferrara West/Eastern Concrete Materials

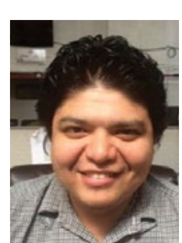
Owner
Hudson County, NJ

Fig. 5: East quadrant completed

the fountain. All this required extensive and painstaking prep work to set the ground wires for the face of shotcrete.

The shotcrete team used 690 yd^3 (535 m^3) to shoot the slab including overbreak volume on the subgrade, and 190 yd^3 (145 m^3) to shoot the walls and pedestals. Superior Gunite used a 4000 psi (28 MPa) macro-synthetic fiber concrete mixture supplied by Ferrara West/Eastern Concrete Materials. The structural fibers used were manufactured by Euclid. The shotcrete project ran from October to December 2015. Another major challenge the general and shotcrete contractors faced was completing the construction of the basin before freezing winter weather arrived in the Tri-State area. Superior Gunite met this challenge by accelerating production of the walls on days with acceptable temperatures in early December. The walls were completed just in time before the consistently below freezing temperatures of the season settled in.

Fig. 6: Completed fountain in operation



***Armando Ramos** is a Project Engineer and Estimator for Superior Gunite. Ramos has been with the company since 2012. He received his BS in civil engineering from Rensselaer Polytechnic Institute, Troy, NY. He has been working for the New York branch for 5 years, while also spending 1 year in Superior's San Leandro office.*

Shaft Lining with Dry-Mix Shotcrete

By Lihe (John) Zhang, D.R. (Rusty) Morgan, Ted Walter, Brian McInnes, Andrew Rule, and Allen Mitchell

The Greater Vancouver Water District (GVWD), located in the lower mainland region of British Columbia, Canada, constructed a new water supply main in a tunnel under the Fraser River, just downstream of the Port Mann Bridge. This new water main will help ensure the continued, reliable delivery of clean, safe drinking water to municipalities south of the Fraser River. The steel water main was constructed within a 1 km (0.62 mile) long by 2.8 m (9.2 ft) inside diameter tunnel driven through soil, underneath the riverbed, connected by two 50 to 60 m (160 to 200 ft) deep shafts at the north and south ends of the tunnel. The shaft on the north side of the Fraser River was constructed with interlocking slurry wall panels to create a circular shaft approximately 8.16 m (27 ft) in diameter and 60 m deep. The final design required a 1.5 m (4.9 ft) thick circular reinforced cast-in-place (CIP) concrete wall to be placed within the slurry wall. The design of the shaft required a bond breaker acting as a slip liner between the slurry wall and CIP wall, so in the event of an earthquake, the circular reinforced CIP concrete wall can move freely relative to the slurry wall. An 8 m (26 ft) diameter shotcrete wall was to be applied to the slurry wall and a bond breaker installed against the finished shotcrete wall. Dry-mix shotcrete was selected to be applied to the slurry wall. Screed rails, which were to be installed every 1.5 m (5 ft), had a specified verticality tolerance of 10 mm (0.4 in.) between rails. The specified vertical tolerance of the final shotcrete wall was +5/–3 mm (+0.2/–0.1 in.) between screed rails.

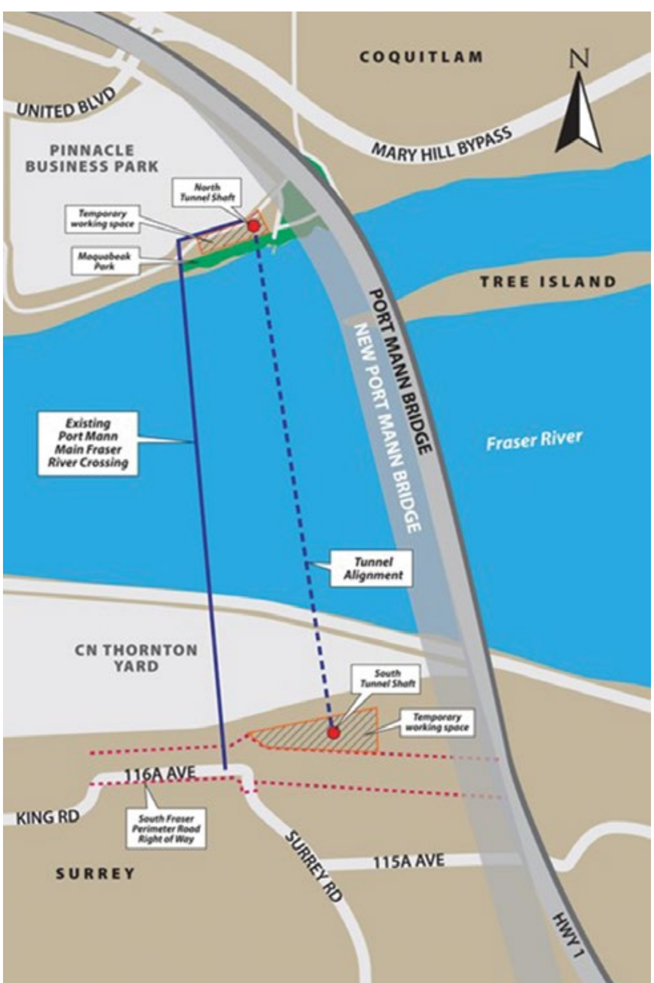


Fig. 1: Project overview and location

BACKGROUND

The Port Mann Main Water Supply Tunnel consists of a 1 km long tunnel under the Fraser River from Surrey to Coquitlam, BC, Canada (Fig. 1). The tunnel contributes to the water supply from the Coquitlam Reservoir and is part of the expansion and seismic upgrade of the GVWD water transmission system. The tunnel boring machine (TBM) used to bore the tunnel created a 3.5 m (11.5 ft) diameter cut that enabled the installation of the segmental lining that measured 3.3 m (10.8 ft) outside diameter and 2.8 m inside diameter.

Shafts were sunk at both the south and north ends of the tunnel. At the north shaft, the seismic design required the installation of a slip liner between the outer slurry wall

Fig. 2: Completed shotcrete wall with plastic slip liner installed

and the final reinforced CIP liner to eliminate the possibility of composite action between them in the event of seismic-induced deformations.

Shotcrete Lining Construction Method

A two-part system was developed that included shotcreting a smooth, circular wall against the slurry wall and then fastening a plastic liner to the wall. The CIP wall would then be placed against the plastic liner, which would act as the bond breaker required during a seismic event (Fig. 2).

The Contractor, working with the Engineer of Record, developed the following shotcrete construction method. A total of 12 steel columns were evenly spaced around the shaft collar (Fig. 3). A steel hollow structural section (HSS) was welded to the top of each column, as shown in Fig. 4. An FG-LL31 self-leveling Zenith Laser Plummet was screwed into the HSS with bolts, so that the laser line shot straight down with an accuracy of ±5 mm/100 m (±0.2 in./330 ft). The laser line was offset 50 mm (2 in.) from the theoretical perimeter of the 8 m diameter finished wall.

Screed rails were made from 13 mm (0.5 in.) round bar that was bent to match the radius of the shaft's final diameter. The screed rails were fixed in place by drilling and grouting several steel dowels circumferentially around the shaft wall every 1.5 m. For each screed rail, three lasers were used to position a curved aluminum template, which was clamped to the drilled dowels. The screed rails rested on the dowels and were clamped to the aluminum template (Fig. 5 and 6). Once in the correct position, the screed rails were welded to the dowels and the template was moved to the next screed rail position. Rails were installed to a tolerance of ±10 mm (0.4 in.), becoming the guide for shotcrete application.

Performing this work in a 60 m deep shaft required a mobile platform. The platform was used in two ways during construction. First, a crane-supported platform was used to install screed rails (Fig. 7). Once complete, the platform was transformed into a floating platform by attaching hollow

Fig. 3: North shaft slurry wall—Coquitlam, BC, Canada

Fig. 4: North shaft slurry wall with steel columns and laser setup

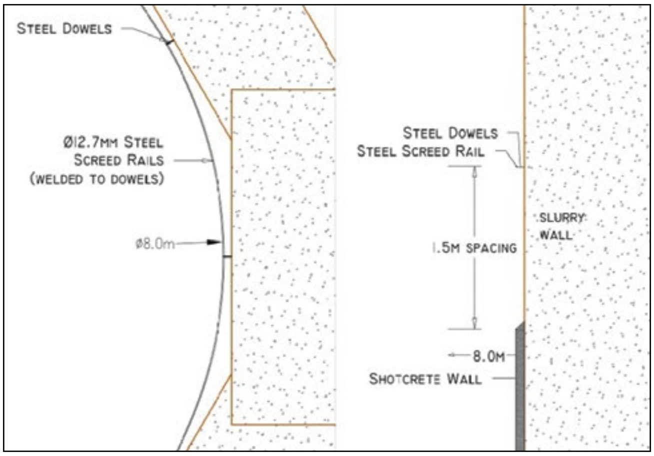


Fig. 5: Screed rail setup

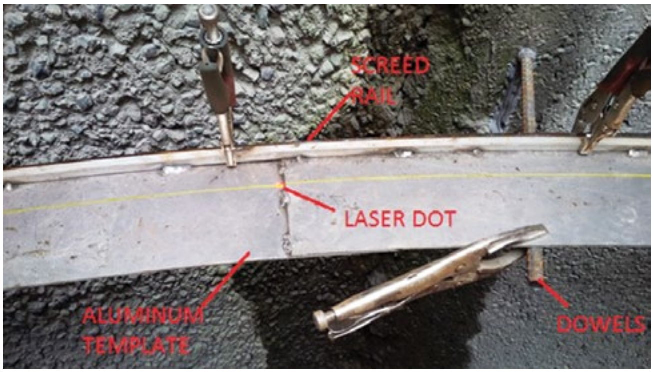


Fig. 6: Screed rail installation (looking down)

Fig. 7: Crane-lifted platform during rail installation

plastic floats below the deck (Fig. 8). Shotcrete was applied from this floating deck. The floating deck had many advantages during shotcrete application. It could carry the crew and equipment, and also catch the shotcrete overspray and rebound. There were no support cables in the way, and thus harnesses and lifelines were not required during shooting.

Once screed rails were installed throughout the shaft, the shaft was filled with water ready to accept the floating deck. Starting at the bottom of the shaft, the shotcrete liner procedure was as follows:

- Apply base course shotcrete to a height of 1.5 m, screed rail to screed rail. Approximately 25 mm (1 in.) of thickness was left for the finishing course.
- Shaft is filled with additional water until floating platform is raised to next lift.

Fig. 8: Floating platform during shotcrete application

- Shoot the next lift, add water, raise platform, and then repeat the process.
- Finishing from the bottom of the base course to the top of the shaft required approximately 36 lifts.
- Finishing course is applied to each lift from the top down by dewatering shaft until platform is lowered to next lift, apply finish course, and repeat.

SHOTCRETE MIXTURE DESIGN

The water table surrounding the north shaft was controlled by both tidal and river levels and was often near the ground surface. As a result, the slurry wall was under constant water pressure and there were leaks throughout the shaft causing water infiltration. A dry-mix shotcrete with maximum accelerator dosages was selected to help mitigate the water ingress.

The project specification required a 28-day compressive strength of 40 MPa (5800 psi). The main purpose of the shotcrete was to act as a filler to bring the slurry wall to a circular shape. Table 1 shows the concrete mixture designs used on the project.

Mixture B1 was applied for the base course shotcrete liner. Whenever water was observed coming out of the slurry wall, Mixture B2 was used to obtain faster set. Initially for dry areas, Mixture B3 was used to apply the finishing coat. During construction in October and November, the finish course shotcrete set more slowly because of cooler ambient temperatures and Mixtures B4, B5, and B6 were used as needed to reduce the setting time and speed up the finishing process. The accelerator dosage was designed

Table 1: Prebagged dry-mixed shotcrete mixture proportions per 1.0 m³

Material	Base course mixture (SSD) mass		Finish course (SSD) mass			
	B1, nonaccelerated (kg)	B2, accelerated (kg)	B3, nonaccelerated (kg)	B4, 1.5% accelerated (kg)	B5, 2.0% accelerated (kg)	B6, 3.0% accelerated (kg)
Cement (Type 10)	400	400	400	400	400	400
Fly ash (Type F)	0	0	0	0	0	0
Silica fume	40	40	20	20	20	20
Coarse aggregate, 12.5 mm (SSD)	420	420	0	0	0	0
Sand (SSD)	1320	1320	1760	1760	1760	1760
Estimated water (L)	180	180	180	180	180	180
Combined aggregate gradation	ACI 506R-16 Gradation No. 2[2]		ACI 506R-16 Gradation No. 1[2]			
Estimated as-shot air content (±1%)	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
Dry powdered accelerator, % by mass of cement	0	12	0	6	8	12
Totals:	2360	2372	2360	2366	2368	2372

*Note: 1 kg/m³ = 1.6856 lb/yd³

such that the finishers had enough time to screed and trowel the final shotcrete surface to the tolerance requirements. Heaters and hot water pressure washing were also used to increase the ambient and substrate temperature of the base course in the shaft.

Preconstruction Trial Shooting and Nozzlemen Qualification

Preconstruction trial shooting was essential for such an unusual dry-mix shotcrete project. The preconstruction trials were planned and conducted to:

a. Qualify the shotcrete mixture—testing to verify the shotcrete mixture met the project specification requirements (Fig. 9(a) and 9(b)).
b. Qualify the shotcrete nozzlemen for the project—the shotcrete nozzlemen used on the project were ACI-certified for dry-mix shotcrete in a vertical orientation. They shot qualification panels and mockup panels to demonstrate that they could place shotcrete meeting the project specification requirements.

A mockup test panel with the same curvature and thickness required for the project was set up at ground level on site for the preconstruction trial panels (Fig. 10(a) and 10(b)). Screed rails were installed to control the wall thickness. Each nozzleman was required to shoot one mockup panel and one material test panel for each mixture. Base course shotcrete Mixtures B1 and B2 were applied followed by application of the finish course shotcrete Mixture B3. The final surface finish was applied and tolerance was measured.

Cores were extracted from the mockup panels for visual evaluation of consolidation. Cores were extracted from the material test panels for determination of compressive strength test at 7 and 28 days, as well as boiled water absorption and volume of permeable voids at 7 days.

Quality Control Inspection and Testing

Compressive strength of cores extracted from material test panels served as the primary quality control testing. However, some compressive tests for the base course shotcrete were lower than expected. Therefore, in-place cores were taken and tested for the base course shotcrete with 3% accelerator. Cores for the finish course shotcrete were all extracted from test panels.

Fig. 9: Nozzlemen qualification: (a) shooting test panels; and (b) setting time and early strength tested for each mixture

Fig. 10: Preconstruction mockup panel: (a) shooting mockup panel; and (b) closer view of mockup panel

Figure 11 shows the compressive strengths for all the cores extracted from test panels for the finish course dry-mix shotcrete were over 25 MPa (3600 psi) at 7 days, and nearly all were higher than 40 MPa at 28 days except for one test with 38 MPa (5500 psi) shot on December 6, 2013. This shows that with a single exception, the shotcrete met the specified compressive strength of 40 MPa at 28 days.

Figure 12 shows the compressive strength of cores extracted from test panels and in-place base course shotcrete (the dry-mix shotcrete with 3% accelerator). A set of three cores was extracted from test panels for every day of shotcrete application. Some cores did not reach the required compressive strength of 40 MPa at 28 days. Prior to applying the finish course, in-place cores were taken of suspect lifts. All lifts exceeded 35 MPa (5100 psi) compressive strength and almost all lifts exceeded 40 MPa compressive strength, which was considered acceptable by the Engineer.

DRY-MIX SHOTCRETE SETUP

The dry-mix shotcrete process facilitated easy access, allowed frequent movement of equipment, and helped with dust control. The dry-mix shotcrete process results in higher rebound compared to the wet-mix shotcrete process. When using dry prebagged materials, dry-mix shotcrete application requires the use of a predampener with a hopper that can load 1 yd^3 (0.8 m^3) of prebagged materials into a rotary gun. A delivery hose, air compressor providing air flow at 24 m^3/min (850 ft^3/min) at a pressure of 0.83 MPa (120 psi), and dry-mix nozzle connected to a water supply hose were used. The predampener is essential for the dry-mix shotcrete process when using prebagged materials. It dampens the dry-mix concrete materials to a moisture condition of about 4 to 6% (Fig. 13(a) and 13(b)), reducing dust, facilitating transport of the material through the hose, and reducing the risk of shock from static electricity.

The dry-mix machine and predampener were set up at the surface, and hoses 35 to 60 m (100 to 200 ft) long were used to convey the materials to the nozzleman on the floating deck.

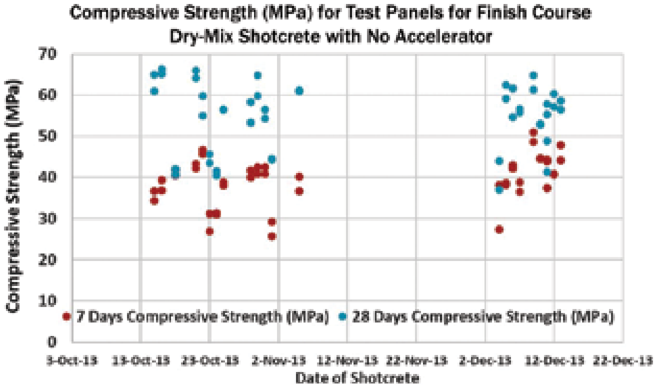


Fig. 11: Compressive strength for cores extracted from test panels for finish course dry-mix shotcrete without accelerator (Note: 1 MPa = 145 psi)

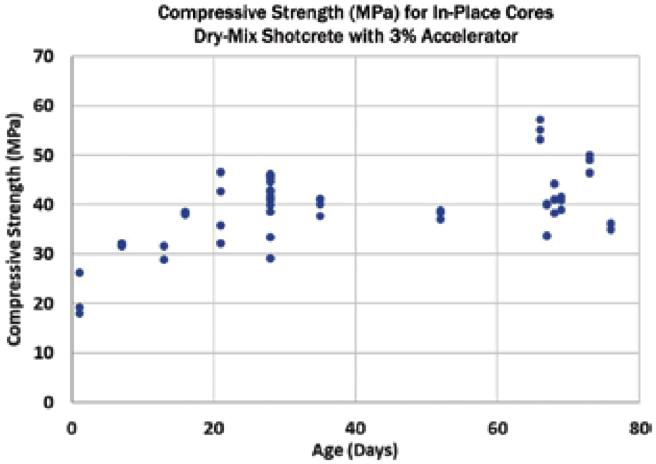


Fig. 12: Compressive strength from in-place cores, base course shotcrete (Note: 1 MPa = 145 psi)

Fig. 13(a) and (b): Dry-mix shotcrete machine with predampener

Fig. 14: Finished base course shotcrete

Figure 14 shows the base course shotcrete of up to 180 mm (7 in.) thick, with ACI 506R-16 (Table 1.1.1) Gradation No. 2 shotcrete (containing coarse aggregate) with 3% accelerator used to fill the gap between the slurry wall and steel screed rails and creating a smooth circular surface. Approximately 25 mm was left for final finish shotcrete application.

The following procedure was used for the finishing course:

1. Blow off excessive water on the surface of the base course layer of shotcrete;
2. Apply shotcrete (Fig. 15 and 16); and
3. Finish shotcrete.

Construction sequence and timing are critical. The substrate surface moisture condition was kept SSD (saturated surface-dry) during Step 1. The finishing took place right after Step 2. It was critical to finish the final shotcrete surface before the dry-mix shotcrete (with accelerator) reached initial set. This was usually about 5 to 10 minutes after shotcrete application.

CONSTRUCTION CHALLENGES

Cold Weather Shotcrete

As the project progressed into November and December, the ambient temperature on site dropped to 5°C (40°F) or

Fig. 15: Application of finish coat dry-mix shotcrete from floating deck

Fig. 16: Birds-eye view of dry-mix shotcrete application from the floating deck. Note the low dust and simple setup of the shotcrete operation. Horizontal screed rails to control the base course thickness were spaced at 1.5 m

lower. This delayed setting of the shotcrete and affected finishing practices for the shotcrete finish course. Several heaters were installed in the shaft, and the base course surface was cleaned with high-pressure hot water and steam, with temperatures of 90 to 100°C (194 to 212°F). The shotcrete material temperature was kept at 12°C (54°F) or higher to allow the cement to hydrate with proper setting and early-age strength development. Additionally, the shaft was covered and heated overnight. Dry-mix material bags were also kept above 20°C (68°F) using tarps and heaters.

Finishing

The base course shotcrete was left with an as-shot finish. The finish course was given a steel trowel finish (Fig. 17(a) and 17(b)). A total of a three mixture designs were applied to the walls. In areas with little to no groundwater present, Mixture B3 with no accelerator was used. In areas with light to moderate flows of groundwater, Mixture B4 with 1.5% accelerator was used. In areas with heavy groundwater flows, Mixture B6 with 3% accelerator was used. In the areas using the B3 or B4 mixtures, it was often required to install drainage pipes to allow a path for water to escape during application and setting. Mixture B6 took approximately 5 to 10 minutes to set in cooler weather, allowing the finishers ample time to finish the surface, while setting fast enough to stop water inflows. The drainage pipes were later removed and the remaining holes were dry packed with grout.

Water Leakage from the Slurry Wall

This shaft is alongside the bank of the Fraser River and is subject to high groundwater levels. Water ingress is quite common in a slurry wall shaft through the cold joints between overlapping panels. The high hydrostatic pressure from the leakage made it nearly impossible to stop water inflows. Sodium silicate grout was injected behind the shaft slurry wall to help reduce water leakage through the slurry wall. Additionally, the base course substrate was dried using an air lance (blow pipe) and the dry-mix shotcrete nozzle used with water and air only (no concrete materials) to bring the surface to an SSD condition immediately prior to shooting the finish course. This was found to be effective for base course shotcrete application and final finishing most of the time. However, there were some occasions where a buildup of water pressure on the base course shotcrete behind the finish course caused bulges in the finish course shotcrete, as shown in Fig. 18(a) and 18(b). These areas were cut out

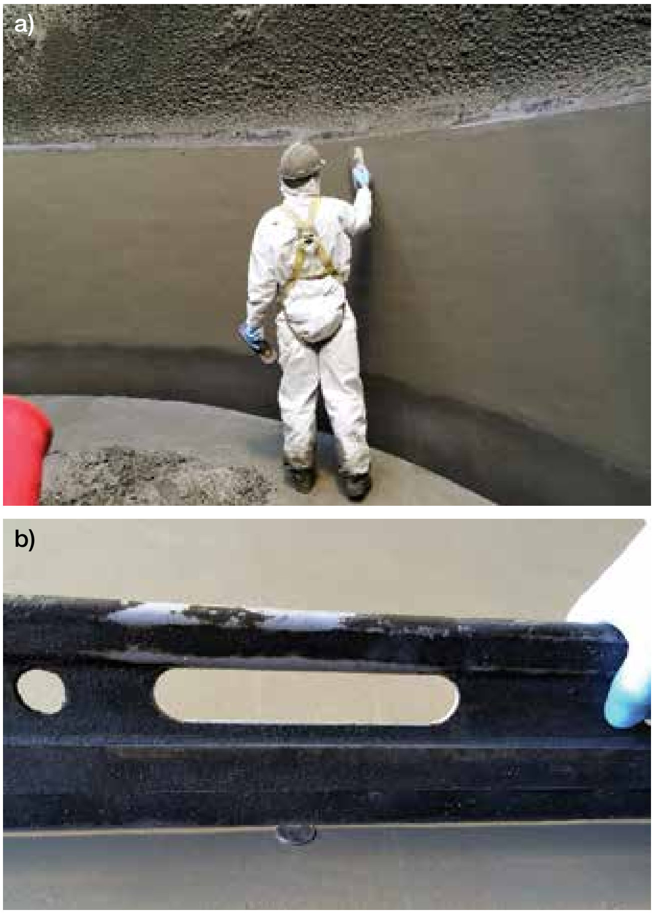


Fig. 17: (a) Steel trowel finishing; and (b) checked finish tolerance with a Canadian quarter, which is less than 2 mm thick

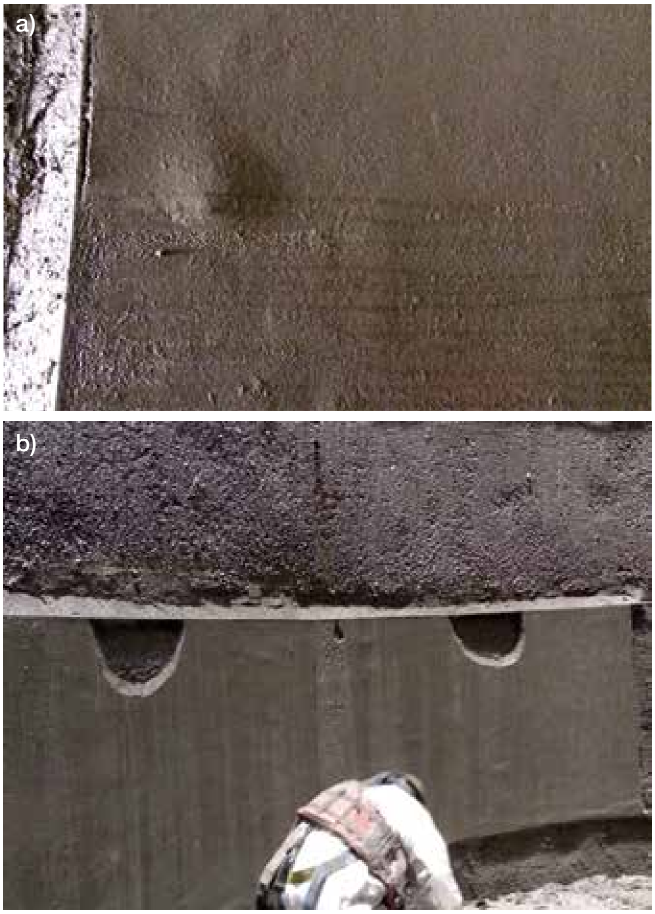


Fig. 18: (a) Water pressure buildup at the back of the finish course shotcrete; and (b) the shotcrete popouts were cut off and repaired with shotcrete when the shaft was dry

and repaired with highly accelerated shotcrete and a drainage pipe.

SUMMARY OF DRY-MIX SHOTCRETE WORK

- Hanging/floating deck: The suspended, then floating deck was a very innovative way to move between lifts during screed rail installation and the shotcrete application. It was cost effective and reduced the construction schedule. In addition, water in the shaft for floating the deck provided water curing for the shotcrete lining. All these proved a distinct benefit compared to other decking options, such as scaffolding the entire shaft.
- Dry-mix shotcrete application: Dry-mix shotcrete was selected due to its inherent application flexibility, fast setting time, and ability to deal with groundwater leakage into the shaft. The predampened dry-mix shotcrete was placed with good control of rebound and overspray. It should be noted that overspray or waste was far less than expected, resulting in approximately 10 to 20% of the total volume. The dry-mix shotcrete prebagged material worked well in providing final liner construction with varying thickness. Rigorous quality control inspection and testing confirmed the high quality of the shotcrete placement.
- Cold weather shotcrete: During cold weather, when ambient temperatures fell below 5°C, additional precautions and protective measures were implemented. Pressure washing with hot water properly prepared the base course shotcrete substrate, raising the surface to the temperature needed for receiving the final finish course shotcrete appropriate for the specific accelerator dosages used. Keeping the area warm with heaters, as well as keeping dry mixed bags warm prior to placement, was also effective. The finish course shotcrete was designed to set up quickly, while still allowing sufficient time for steel trowel finishing to the specified tolerances.

CONCLUSIONS

- Dry-mix shotcrete, when properly applied, can provide a high-quality shotcrete lining, especially for liners with irregular shapes requiring varying thickness.
- The floating deck construction method is an innovative construction method for shaft lining construction. It

improved the quality of shotcrete construction; reduced rebound and overspray; reduced the construction schedule, labor, and materials costs; and thus reduced the overall cost of the project.

- Special measures need to be adopted to deal with the buildup of water pressure behind a layer of freshly applied shotcrete. The procedures described in this report were effective in dealing with this problem.

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2. ACI Committee 506, "Guide to Shotcrete (ACI 506R-16)," American Concrete Institute, Farmington Hills, MI, 2016, 52 pp.

Lihe (John) Zhang *is an Engineer and Owner of LZhang Consulting & Testing Ltd. He received his PhD in civil engineering from the University of British Columbia, Vancouver, BC, Canada, where he conducted research on fiber-reinforced concrete. He has over 15 years of experience in concrete and shotcrete technology and the evaluation and rehabilitation of infrastructure. Zhang is a member of the American Concrete Institute. He is Chair of ACI Subcommittee 506-F, Shotcreting-Underground, and a member of ACI Committees 130, Sustainability of Concrete; 506, Shotcreting; and 544, Fiber-Reinforced Concrete. He is an ASA/ACI C660-approved Shotcrete Nozzleman Examiner. Zhang is a member of ASTM Committee C09, Concrete and Concrete Aggregates. With ASA he serves as the 2018 ASA President, member of the Board of Direction, and Chair of the Technical Committee.*

D.R. (Rusty) Morgan*, FACI, is a Civil Engineer with over 50 years of experience in the concrete and shotcrete industries. He served as a member and Secretary of ACI Committee 506, Shotcreting, for over 25 years. He is a past member of ACI Committees 365, Service Life Prediction, and 544, Fiber-Reinforced Concrete. Morgan is a founding member and Past President of ASA. He is an ASA/ACI C660-approved Shotcrete Nozzleman. Morgan is a past member of the Canadian Standards Association Concrete Steering Committee and was a Canadian Representative on the International Tunnelling and Underground Space Association Committee, Shotcrete Use. He has worked on over 1000 concrete and shotcrete projects around the world during his consulting career and has edited five books and published over 150 papers on various aspects of concrete and shotcrete technology. In 2001, Morgan was elected as a Fellow of the Canadian Academy of Engineering.*

Brian McInnes *is a Project Engineer for McNally Construction Inc. with over 8 years of experience in both tunneling and marine industries. He has held several roles such as Civil Coordinator, Project Engineer, and Project Manager on various projects, including the Dixie Road Tunnel, Port Mann Main Water Supply Tunnel, and the Five Finger Marine Outfall. McInnes was responsible for developing the construction execution plan for the shotcrete work on Port Mann as well as managing the execution of the work.*

Allen Mitchell *is a Senior Project Engineer at Metro Vancouver and was the owner's Project Manager for the Port Mann Water Supply Tunnel project.*

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Ted Walter *is President and Owner of Can-Tech Shotcrete Inc. of Burnaby, BC, Canada. Since incorporation in 1988, Can-Tech Shotcrete Inc. has specialized in the application of wet-mix and dry-mix shotcrete in tunnels, in the repair of marine structures, and seismic upgrade of buildings and dams. Over the past 30 years, Walter has completed many unique and challenging shotcrete projects, such as the North Shaft shotcrete liner.*

Cellular Sprayed Concrete

An innovative method for remixing and making high-performance shotcrete

By Kyong-Ku Yun

Cellular sprayed concrete is an innovative method of remixing ordinary portland cement (OPC) concrete into a high-performance concrete (HPC) by adding cellular material and silica fume or other powdered admixtures at a jobsite. This method enables the distribution of very-fine silica fume or other powdered admixtures in stiff ready mixed concrete.

Creating cellular sprayed concrete is a simple and economical way to produce HPC that can be shotcreted or conventionally placed at a jobsite. It can be applied to many jobs, including new construction, major rehabilitation work, underground applications, and architectural projects.

This article discusses the concept of cellular concrete, its fresh properties, hardened properties, durability, validation of silica fume dispersion, and also provides examples of field applications.

INTRODUCTION

HPC is produced by incorporating silica fume or other powdered admixtures (mineral or organic) in the concrete mixture. The powdered materials are usually preblended in a factory. Because of their fineness, it is very difficult to add and disperse them in a batch plant when the concrete is mixed. One can use preblended cement to produce HPC, but it may need extra attention for all batching and delivery procedures, including blending, packing, transportation, stocking, and mixing. This extra work can result in very expensive concrete.

Silica fume is a by-product of ferrosilicon or silicon metal; it has nanoparticles. It also has a micro filling effect and pozzolanic reaction that helps to fill the voids between the hardened cement particles, resulting in reduced permeability, increased watertightness, higher strength, and ultimately more durability.[1] Silica fume is a popular material for shotcrete work because of its improved adhesion, increased layer thickness, as well as higher strength and durability. With silica fume's high fineness, it is commonly preblended with cement, and this can lead to a higher cost.

Fig. 1: (a) Cellular material; and (b) spraying cellular sprayed concrete

THE CONCEPT AND INNOVATION OF CELLULAR SPRAYED CONCRETE

Fresh concrete is generally a flowable material but with low fluidity. When silica fume is added to fresh concrete, it will not be well dispersed due to its high fineness and large effective surface area. Cellular material embeds air content (Fig. 1(a)), which has a ball bearing effect and enlarges concrete's volume when added to concrete. If a large amount of cellular material—for example, 30% by volume—is added to fresh concrete, it will increase the concrete's fluidity. If silica fume is added to the modified cellular concrete with high fluidity, it can be easily dispersed in the much more liquid concrete.[2] Concrete with the cellular material traps a lot of air inside, which reduces the compressive strength of concrete. However, this much higher air content can be substantially reduced by spraying the concrete with the high velocity inherent in the shotcrete process (Fig. 1(b)).

Production cost and construction time can be reduced because the high-performance cellular sprayed concrete is produced at the jobsite with only the cost of adding silica fume and cellular material. Mixing the cellular concrete on the jobsite eliminates the need for production, transportation, and storage costs when using special blended cement.[3]

The cellular sprayed concrete process includes:

1. Transportation of ordinary low-slump ready mixed concrete to a jobsite in a truck;
2. Then, 20 to 30% by volume of preformed cellular material is discharged into the truck, transforming the stiff concrete, into a slurry with very high slump;
3. Silica fume is added and the concrete is remixed to disperse the silica fume; however, the concrete still contains lots of air; and
4. The cellular concrete with the high volume of air is discharged into the concrete pump and sprayed from the nozzle at the end of the delivery line with high velocity. The impact force of the sprayed concrete process reduces the air content, creating low-slump HPC in place.

Table 1: Mixture Design

	w/cm	*s/a* (%)	Unit weight (kg/m³)					
			w	c	FA (S)	CA (G)	SF	Air entrainment
OPC	0.4	75	184	460	1111	376	—	1.8
SF6	0.4	75	184	432	1065	361	28	2.3
SF8	0.4	75	184	423	1050	355	37	2.3
SF10	0.4	75	184	414	1035	350	46	2.3

Note: *s* is fine aggregate (sand); *a* is total aggregate (sand and gravel)

Slump and Air Content of Cellular Sprayed Concrete

Slump was checked using ASTM C143/C143M at various stages: as delivered to the site, after adding cellular material, after adding silica fume, and after spraying. Air content at each stage was measured based on ASTM C231/C231M for air content up to 10% of air content, and using the unit weight method for air content above 10%. The OPC concrete was very stiff, with 10 mm (0.4 in.) slump, but became fluid by adding 27% cellular and then became stiff concrete with 50 mm (2 in.) slump after spraying. The air content in the ready mix concrete was 3.5%, then increased to 27% after adding cellular, 24% after adding silica fume, and returned back to 4.5% after spraying. The spraying broke down the big air bubbles by impact.

Dispersion Theory of Silica Fume in Cellular Sprayed Concrete

The ultra-fine particles of silica fume cannot be dispersed in fresh, relatively stiff concrete; however, it can be mixed in a fluidized concrete (slurry). Silica fume is dispersed in cellular sprayed concrete in three ways: mixing more easily in the more fluid slurry; increasing the concrete volume for a larger contact area;[4] and additional mixing provided by the impact and resulting agitation from high velocity spraying.

Black carbon is 10 times finer than silica fume and was used in the trials of cellular sprayed concrete to analyze the dispersion effect. The dispersion of silica fume was verified by energy dispersive X-ray spectroscopy (EDS) analysis, where the distribution of the components of cellular sprayed concrete was analyzed with the standard deviation and coefficient of variation of the silicon (Si) content at each point.[5]

EXPERIMENTAL PROGRAM AND TEST RESULTS

Mixture Design and Tests

The basic concrete mixture design was set to have 460 kg/m³ (775 lb/ft³) of cement content, a water-cementitious materials ratio (*w/cm*) of 0.4, and 75% of fine aggregate ratio (*s/a*). An air-entraining agent was used to achieve the targeted slump of 80 ± 20 mm (3 ± 0.8 in). The main experimental variable was the amount of cellular material used by volume. Cellular amounts of 15, 20, 30, and 35% were used. The effect on concrete properties was investigated by measuring slump, air content, compressive strength, and an air void image analysis.

The OPC used in this test has a fineness of 3300 cm²/g and specific gravity of 3.15. The maximum size of coarse aggregate was 10 mm (3/8 in.), which has a specific gravity of 2.67. The silica fume has a specific surface area of 200,000 cm²/g. The foaming agent has surface-active molecules and is composed of hydrophilic groups and hydrophobic groups that changed the characteristics of the surface tension of a diluted aqueous solution in the foaming agent, and thus the viscosity.

Air Content and Slump Test Results

The change in air content and slump was measured, compared, and analyzed in accordance with the cellular amount variations of 15%, 20%, 30%, and 35%. Very high air content was measured before spraying, but it was reduced to 4 to 6% after spraying regardless of initial air content. This is an indication of dispersing big air bubbles, leaving only small ones inside the cement paste. The increased air content before spraying resulted from the incorporated foam, and was dissipated after spraying to ultimately keep a relatively constant amount of air in the in-place concrete.

Figure 2 illustrates the test results of slump variations before and after spraying. Due to the ball bearing effect, higher slump was measured as the amount of cellular incorporated increased. However, slump measured after spraying was reduced to less than 50 mm. It had very low slump after spraying, which is good for stability of the placed concrete.

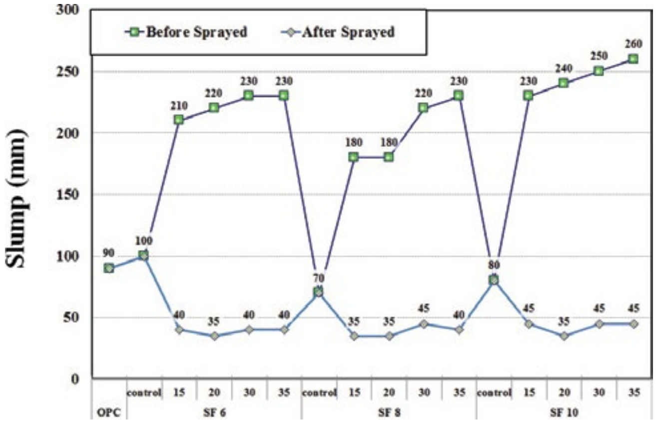

Fig. 2: Slump measured before and after spraying

Compressive Strength Test Results

To investigate the variations in compressive strength according to the amount of cellular incorporated, compressive strength was measured at 28 and 56 days. Compressive strength at 28 days showed a tendency to generally decrease as the amount of cellular increased, as shown in Fig. 3. Increased water content was at fault, due to effectiveness in focusing only on the cellular content's dispersing of the silica fume and neglecting the amount of water included in the cellular material.[6]

Spacing Factor and Specific Surface Area Test Results

Figure 4 shows the results of air void image analysis for the test specimen after spraying. There is a tendency for spacing factors to decrease as the cellular amount increases, and vice versa for a specific surface area. These are good indications that the freezing-and-thawing resistance of cellular sprayed concrete is acceptable for harsh cold weather environments.

EXAMPLES OF FIELD APPLICATIONS

Regionally Symbolic Tunnel Portal

Tunnel portals were built using the sprayed concrete (shotcrete) process that allowed carving for texture and acid staining for coloring, thereby creating an appearance of rock. These tunnel portals were designed with the input of the local community to portray their regional character. The local communities were very satisfied to have their own beautiful and symbolic tunnel portals. This was made possible with the inherent benefits of shotcrete technology such as adaption to curved and irregular surfaces, different surface finishes, excellent hardened physical properties, reduced construction time, and cost effectiveness.[7]

The construction period was shortened by adopting cellular sprayed concrete because it provided a massive quantity of concrete using conventional ready-mix concrete and wet-mix shotcrete equipment. The additional equipment required for making cellular concrete included a foam generator and a nozzle. This maximized the cost savings for HPC by minimizing the special equipment required. Figure 5 shows an example of a tunnel portal built with cellular sprayed concrete.

Artificial Rock Slope Stabilization

Spraying, carving, and coloring natural rock patterns is an eco-friendly technology that harmonizes with the surrounding landscape. This method was adopted for stabilizing adjacent slopes. It was designed with the input of the local government officials who were pleased with the beautiful, eco-friendly slope. Spraying, carving, and coloring were done according to the given specifications.[8]

A high placement rate of HPC was possible in the first lift by shooting with the optimized cellular technique. After shooting the second lift, the exposed surface of fresh concrete was carved into natural rock patterns with added coloring. This technique helped to match the natural rock shapes and colors, as shown in Fig. 6.

Two-Lift Concrete Pavement (2LCP)

Two-lift concrete paving involves placing two layers of concrete *wet-on-wet* instead of the traditional method of using a single homogeneous layer of concrete. The thick bottom layer provides the opportunity to optimize the use of local aggregates and recycled materials to produce an economical, durable mixture, and then places the top high-quality pavement system with the most desirable surface characteristics, such as improved skid resistance and reduced noise. The time gap between placing the layers is often no more than 30 minutes. The challenge involved in the construction of two-lift concrete systems might be the additional cost and logistics required for two concrete batch plants to produce different concrete mixtures and two slip-form pavers for paving both the bottom and top layer at the same time.[9]

In this application for cellular sprayed concrete, it attains its high performance with the addition of silica fume and polymer powder. The cellular material makes it suitable for spraying while maximizing the dispersibility of the fine powders. The spraying process regulates the consistency

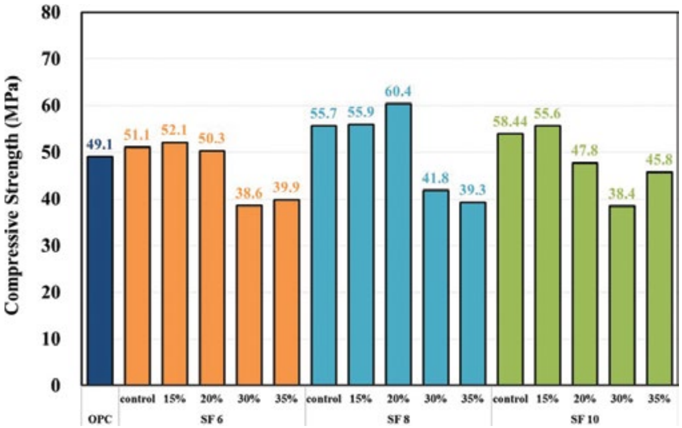

Fig. 3: Compressive strength after spraying at 28 days

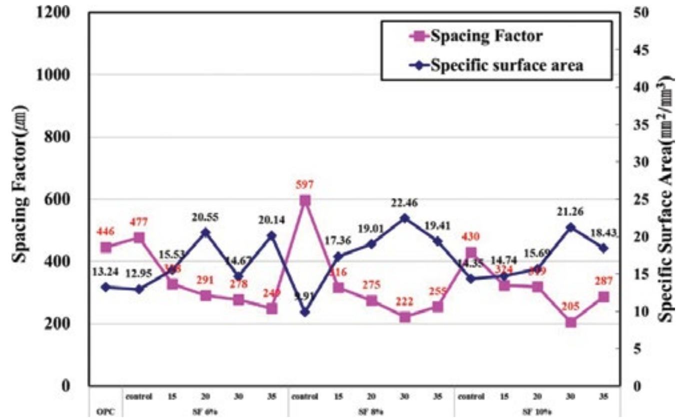

Fig. 4: Image analysis of air void spacing

Fig. 5: Regionally symbolic tunnel portal built with cellular sprayed concrete

Fig. 6: Artificial rock slope stabilization with cellular sprayed concrete

of the mixture by dissipating the increased air content due to the addition of cellular material.[10]

Cellular sprayed concrete can be adopted in the construction of two-lift concrete pavement by supplying conventional concrete to a site where it will be remixed on site to achieve HPC. There are future plans to conduct trials to develop a simple and economical field application of 2LCP with only conventional concrete supply.

Conclusions

Cellular sprayed concrete is a new concept. It is produced by incorporating cellular material and mineral admixtures into conventional concrete at a jobsite. This method allows for a reduction in production costs and construction time as high-performance cellular sprayed shotcrete is produced with ready mix concrete on a jobsite without the production, transportation, and storage required when a special blended cement is used.

Cellular sprayed concrete is very simple, economical, unique, and versatile. This innovative method of transforming cellular sprayed concrete was successfully adopted at tunnel portal slope stabilization and 2LCP.

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How It's Made: Wet-Mix Shotcrete Equipment

By Andy Kultgen

In the shotcrete industry, we occasionally inform or remind people that shotcrete is a method of placing concrete. This is very evident in wet-mix shotcrete, where everything about the process, from the concrete truck to the end of the hose, is common with "small-line" concrete pumping. It is only in the nozzle where the wet concrete is accelerated to a high velocity that the process becomes wet-mix shotcrete. Steel pipeline, reducers and bends, heavy-duty rubber hose, and the appropriate couplings make up this concrete delivery system. Each of these components have evolved through the decades as the concrete pumping industry has developed more capable and powerful equipment, more demanding concrete mixture designs, and greater performance requirements set forth by specifiers. Manufacturing methodology has progressed to keep pace with the advancing designs and customer demands.

Past articles have covered wet-mix concrete pumps and air compressors. This article will cover manufacturing methods for all the components and accessories of the wet-mix shotcrete system. The next issue of *Shotcrete* magazine will include an article with a deeper discussion on heat treating of steels, including processes such as "quench and temper" and "case hardening" that you may hear used to describe equipment.

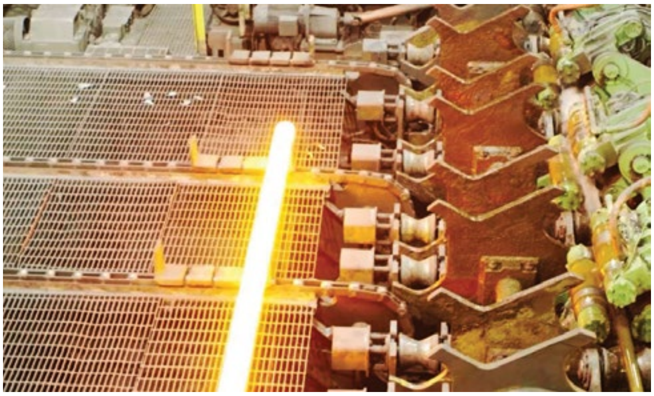

Fig. 1: A newly formed seamless steel tube rolls out of the seamless mill. The stabilizing rollers and piercing bar can be seen on the right. The solid billet, heated to 2250°F (1230°C), is forced in at the top right while being pressed and rotated. The tubing rotates, being pressed and stressed by the piercing rollers, while the piercing bar opens the inside diameter (Photo courtesy of ArcelorMittal Shelby)

A NOTE ON TERMINOLOGY

Within the concrete pumping industry, slickline is often referred to as "pipe." Technically, "pipe" refers to a specific set of sizes and wall thicknesses, defined by ASME B36.10M-2015, Welded and Seamless Wrought Steel Pipe, and manufacturing methods defined by ASTM A53/A53M, or other specifications for increasingly demanding applications. Other materials are referred to as "tubing." For the purpose of this article, the words "pipe" or "pipeline" may denote materials that are either pipe or tubing. Note that "3-inch pipe" may refer to pipeline built from 3 in. (75 mm) Nominal Pipe Size (NPS) schedule 40 pipe, 3 in. NPS schedule 80 pipe, or 3 in. inner-diameter tubing. All three of these options have different inner diameters. Mixing these pipes would create small steps from pipe to pipe, potentially creating pumping difficulties.

STEEL PIPELINE

Most pipeline used for concrete pumping consists of steel pipe and raised flange end connectors. The ends are typically welded to the pipe, either in a factory setting or in the field at a local shop or jobsite. The pipe can be made in two basic ways: seamless and welded. Whether it is made seamless or welded, all pipe begins as large blocks of cast steel in the specified chemistry, or recipe, from a steel supplier. To manufacture seamless pipe (Fig. 1), the block is heated and formed into cylindrical blanks. At "yellow-hot" temperatures above 2000°F (1100°C), the cylinder is rolled and put under enough pressure to create a tear in the center. That tear is driven over a mandrel and the blank is shaped to create a hollow pipe of the required outside diameter. For welded pipe, the block of steel is rolled into sheet corresponding to the required wall thickness of the pipe (Fig. 2(a)). At the pipe mill, the sheet is rolled into a tube with a seam on one side or wound into a tube shape with a seam that spirals around the pipe (Fig. 2(b)). Next, continuous welding machines weld the seam together. Both kinds of pipe can then be further processed to refine the dimensions, finish, or material structure (Fig. 3). Seamless and welded pipe both have advantages and disadvantages compared to one another.

The pipe that is typically available in the smaller diameters used in shotcrete is single-walled, mild carbon steel chemistry, and delivered in a relatively soft but tough state.

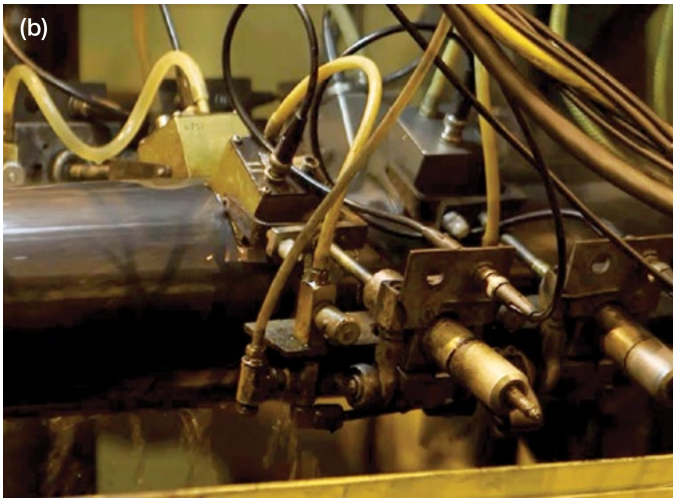

Fig. 2(a) and 2(b): A continuous ribbon of steel, up to 11/16 in. (17 mm) thick at this mill, is unrolled and fed into the tube welding mill. Rollers progressively curl the sheet into a tube. Induction coils heat the edges of the ribbon and rollers press the edges together to the final tubing diameter, creating a weld seam. Sensors monitor weld seam quality immediately after the tubing is welded
(Photos courtesy of ArcelorMittal Shelby)

In larger-diameter pipe intended for use in large projects or on truck-mounted boom, there are a wide variety of single- and dual-walled pipes of varying chemistries and heat-treatment states available.

MANUFACTURING PIPELINE

Grooved ends were once used in all diameters of concrete pumping pipe because they were widely available for commercial building mechanical purposes (for example, water and fire suppression). However, increasing pumping pressures rendered those types of pipe connections obsolete in larger pipe. Grooved ends are still occasionally used in small line pumping and shotcrete. Manufacturing pipe with grooved ends involves cutting the pipe to length and cutting or rolling the groove into the ends of the pipe, either one end at a time, or in cases of larger volume production, both ends at the same time.

Pipeline with raised ends are typically made by welding specially machined flanges onto the pipe. The raised ends are machined separately. At larger manufacturers, commonly used high-volume designs are produced on powerful, high-speed, computer-controlled machine tools that can create a raised end in less than a minute. Piping is first cut to the required length. The common lengths found in the industry are 10 ft (3.05 m) and 3 m (9.84 ft). The raised ends are welded onto the ends of the pipe (Fig. 4). Larger pipe and higher-rated pressures generally require more specialized and tightly controlled welding procedures. Hardened pipe is adversely affected by the heat of welding. Making hardened pipe requires additional processes to protect the hardened crystal structure from the heat of welding, while still maintaining the required weld strength. The same process applies to bends and reducers. After being welded, components are typically inspected, painted, and labeled with a tag including the manufacturer, part number, working pressure, and weight as specified by ASME B30.27, Material Placement Systems.

Fig. 3: Tubing is pulled over a mandrel and through a die set. At this mill, powerful electric motors can pull the tubing with up to 1,000,000 lb (450,000 kg) of force. The drawing process thins the tubing wall and reduces the diameter, allowing for precise control of inside and outside diameters. This tubing is known as drawn over mandrel (DOM) or cold drawn tubing
(Photo courtesy of ArcelorMittal Shelby)

HIGH-STRENGTH HOSE

Concrete pumping hose requires specialized construction techniques. A pumping hose will typically have many layers but can be broken up into the following groups: the inner liner, the reinforcement, and the outer jacket. Hose is produced by wrapping the hose materials onto a long mandrel, sometimes several hundred feet long, from the inside out. First, a heavy layer of rubber is wrapped onto the mandrel to create the inner liner. This part of the hose is in contact with the concrete and the rubber is formulated to resist the constant wear of the abrasive concrete and the often-sharp edges of the large aggregate. Next, the reinforcing layers are wrapped onto the inner liner. Many materials can be used for hose reinforcement, including solid steel wire, wire rope, and a variety of textiles ranging from nylon to Kevlar, in the form of ropes or even woven fabrics. The next layer is the outer jacket. This layer is designed to protect the hose

Fig. 4: The raised flange end is welded onto cut-to-length tubing. This machine is semi-automated and welds both ends of the pipe simultaneously. Depending on the size and shape of the parts, some are welded by more automated robotic welders and some parts are welded by hand. Many different combinations of weld type (for example, TIG, MIG), weld wire, technique, and machine settings are used on different types of products
(Photo courtesy of Construction Forms, Inc.)

from jobsite hazards and during transportation. The jacket will also include identification, pressure rating, and weight information, similar to the steel pipe. The hoses, still on the mandrels, are put into an autoclave or oven to bond the layers together and cure the rubber compounds. The formulation of the rubber compounds, wrapping technique, and curing process are often closely guarded trade secrets, as they can drastically change the wear properties, flexibility, and life expectancy of the hose.

Fig. 5: A powerful crimping press inserts the hose barb into the hose, then compresses the ferrule onto the hose, securing the hose barb in place. This press is hydraulically powered and has eight dies that close simultaneously around the ferrule
(Photo courtesy of Construction Forms, Inc.)

PUMPING HOSE MANUFACTURING

After the hose is cured and removed from the mandrel, it can be used for manufacturing pumping hose. To connect the hoses to other pumping system components, they need raised ends. Usually this is achieved by inserting a machined hose barb, which includes the raised end into the end of the hose, along with placing a ferrule (sleeve) on the outside of the hose. Then the ferrule can be crimped down to secure the hose barb in the end of the hose (Fig. 5). For some hoses, this process is reversed, and the hose barb is expanded into the ferrule rather than the ferrule being crimped down onto the hose barb.

PIPE COUPLINGS

The pipe couplings that are generally available in the concrete pumping market are all similar in design, having two main halves that hold the raised ends (or grooves) on

Fig. 6: A foundry employee pours molten iron into sand molds on this semi-automated production line. This machine will typically produce a mold every 1 to 2 minutes. Each mold may have several cavities, producing several pieces of a part with each pour. A large weight is set on the top of each mold to keep the top half of the mold from floating up on the molten metal
(Photo courtesy of Alliant Castings)

the pipes together, and some means of keeping the two coupling halves together. In the simplest, but also the highest-strength cases, that means two to four bolts and nuts to hold the halves together. It is common, though, to find a wide variety of "snap couplings" that use a lever and connecting links to connect the coupling halves. The coupling halves are typically either castings or forgings in a variety of materials, including iron and steel alloys and aluminum alloys. A small number of specialty couplings are machined from blocks of steel or aluminum, called billets, but these are generally more expensive due to more extensive machining requirements.

Castings are the most basic form of metal production; all metal manufacturing begins with a casting. To make coupling halves, molten metal is poured into a negative mold made of either sand or ceramic (Fig. 6). The foundry must analyze the chemical makeup of the molten metal, as small changes in the contents of some elements can result in large changes in the performance of the finished product. The metal cools and solidifies, and the mold is removed. Excess metal is trimmed away. In some cases, the casting is heat-treated to gain the desired crystal structure in the metal. This changes the mechanical properties, such as strength and toughness of the metal.

Forging is the process of hammering metal into the desired shape. Forged coupling half production will begin with a block, bar, or rod of the desired material. The forging can happen at higher temperatures, known as hot forging, where the steel structure behaves more pliably, and the crystal structure can change (Fig. 7). The critical temperature where the crystal structure can change is different for each alloy, but in lower carbon-steel it is around 1330°F (725°C). If the forging is performed at lower temperatures, generally room temperature, it is referred to as cold forging. The metal blank is shaped by powerful forging machines. These machines use either hydraulic presses or large weights dropping under gravity to form the metal. The presses have dies in the negative shape of the coupling halve. These dies progressively shape the blank into the coupling half shape. Sometimes a punching die is used to create holes, trim off any excess material, and free the coupling half from any remaining metal blank. The coupling halves can then be heat-treated to gain the desired crystal structure, but as with castings this is not always necessary. Forging can create residual stresses in the metal, which can be advantageous in certain situations where the residual stress works in opposition to the stress being placed on the forging during regular use.

Fig. 7: A forge employee positions a hot steel blank to be formed into shape on a forging press capable of pressing with 2500 tons (3.3 million kg) of force. The press is several stories tall, reaching above and below ground. There are three progressive shapes in this die set; the blank will be moved from one impression to the next each time the press closes
(Photo courtesy of Cornell Forge Company)

The coupling halves, either castings or forgings, are then machined or have holes drilled if necessary. The couplings are assembled, inspected, and painted. The couplings should have the manufacturer, part number, pressure rating, and weight information, as do the other elements of the concrete pumping system.

SHOTCRETE NOZZLES

There are a wide variety of wet-mix shotcrete nozzles available in the marketplace. Many have evolved to meet the specific needs of certain segments of the shotcrete market, such as large-aggregate structural shotcrete, or refractory lining, and some have grown from similar industries, such as fireproofing. All these nozzles have the common goal of injecting air into the flow of concrete and accelerating the concrete in a controlled stream at high velocity to the receiving surface. Nozzles are composed of several pieces that can be disassembled for cleaning or replacement. The nozzle bodies and raised coupling ends are made from various steels.

Nozzle tips may be made from a wide variety of rubbers or plastics, or in some cases, steel. The air rings, or plenums, used in wet-mix nozzles can be made from a much wider variety of materials, as they generally do not come in contact with the abrasive concrete. The wide variety of types of nozzles and materials used mean there are a correspondingly large number of manufacturing methods used to produce them.

Generally speaking, the steel components are castings or tubing components that have been further machined (Fig. 8),

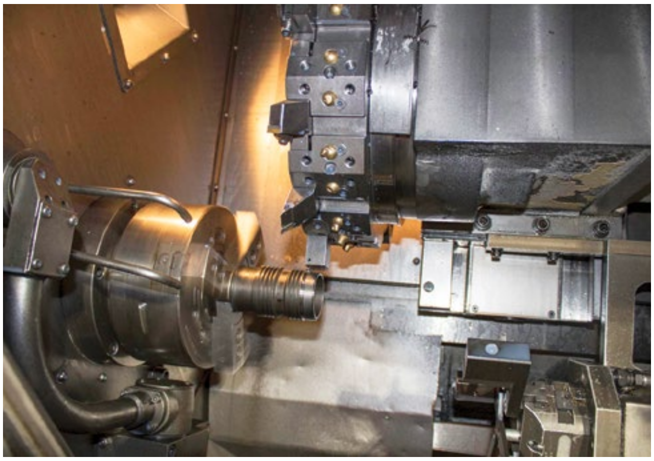

Fig. 8: A CNC-controlled lathe machines a shotcrete nozzle body. This lathe has eight tools in its magazine and can load steel blanks and unload finished parts automatically. Normally, the part would be covered in a stream coolant during machining. This nozzle body begins as a piece of steel tubing and has all its features machined into it. Additionally, these nozzle bodies are case-hardened after machining
(Photo courtesy of Construction Forms, Inc.)

and the nozzle tips are cast or injection molded into dies (Fig. 9). One design of nozzle may excel in certain situations and fall short of another design in other situations. The nozzle is very much up to the preference of the nozzleman, their application style, and type of work.

The concrete pumping system is a major contributor to whether your wet-mix shotcrete job will go smoothly or create difficulties along the way. The large variety of project types undertaken by concrete pumpers and shotcrete contractors produces a demand for a wide variety of equipment and accessory options. A basic understanding of these different components can help you best match your shotcrete system to your job requirements. Please check back in the next issue of *Shotcrete* magazine for an overview of metallic crystal structures and how different heat treatments can drastically change the performance of a material.

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Fig. 9: Rubber nozzle tips are produced by compressing a rubber block or injecting rubber into a mold. The rubber is heated and cured while in the mold, setting the final shape and properties
(Photo courtesy of Molded Dimensions Inc.)

THREE EUCLID CHEMICAL EMPLOYEES RECOGNIZED AT ACI CONVENTION

Three employees of The Euclid Chemical Company were recognized at The ACI Concrete Convention and Exposition on March 25, 2018, in Salt Lake City, UT. The American Concrete Institute (ACI) Convention brings together concrete industry leaders to discover the latest in the design, construction, maintenance, and repair of concrete projects. The ACI Opening Session and Reception recognizes individuals who make great contributions to the concrete industry.

Michael Mahoney, Director of Marketing and Technology for Fiber Reinforced Concrete, Euclid Chemical, was appointed to the prestigious ACI Fellowship title. "It is a wonderful honor to be made a Fellow of the American Concrete Institute, as it is one of the most significant titles in our industry and I am very appreciative to be recognized for the hard work and my dedication to ACI," Mahoney said. "Working on ACI committees and industry-specific technical organizations that improve the standards and practice of fiber-reinforced concrete has been a significant part of the greater responsibilities of my role for a long time now, and I look forward to continuing this work into the future." ACI's citation for Mahoney's Fellowship stated that he has had a "major positive influence on both standards and practice in fiber-reinforced concrete" and that "he has been instrumental in the transfer of new ideas, innovation, and technology to the construction industry."

Amir Bonakdar, Western Region Manager for Business Development, Euclid Chemical, was presented with the ACI Young Member Award for Professional Achievement. This award recognizes the contributions of younger members of the Institute. ACI recognized Bonakdar for his "major positive influence on the design and practice of fiber-reinforced concrete through ACI committee work and industry-specific technical organizations."

William J. Lyons III, National Business Development Manager for the Northeast, Euclid Chemical, was bestowed the Chapter Activities Award. Lyons, already an ACI Fellow, achieved this for his commitment to furthering the goals of the CIB of NYC – ACI Chapter through many activities.

From left to right: Amir Bonakdar, Michael Mahoney, William Lyons

These achievements highlight the critical role that Euclid Chemical's employees play within the concrete industry and the importance that these industry leaders have on shaping, influencing, and informing the sector.

ATKINSON CONSTRUCTION'S CORDELL HULL CAPITAL CONNECTOR WINS PROJECT AWARD

The Tennessee Concrete Association (TCA) awarded the Best Specialty Concrete Project Award to the Cordell Hull Capital Utility Connector Project. Atkinson performed an $11 million subcontract to complete the excavation of a 430 ft (131 m), arch-shaped tunnel under the center of the Tennessee State Capital that will provide indoor and ADA access from the Capital to the Cordell Hull State Office Building, as well as a utility corridor to connect communication lines between the two buildings. Atkinson's scope of work included deepening two elevator shafts; excavating stairwell and mechanical shafts; ground support, including spiling, lattice girders, rock bolts, and steel fiber-reinforced shotcrete; and upon excavation completion, Atkinson placed structural invert concrete throughout the tunnel. This TCA Concrete Excellence Award for Best Specialty Concrete Project was presented to the project team at TCA's 2018 Annual Convention on February 8, 2018.

Cordell Hull Capital Connector Tunnel

SOCIETY OF WATERSHAPES DESIGNERS ANNOUNCES NEWEST SWD MASTER

Oakes

The Society of Watershapes Designers[CM] announced its newest SWD Master, Ryan Oakes. Oakes is a Managing Partner in Clearwater Construction Group and Revolution Gunite. He is a licensed pool contractor in North Carolina and Virginia and has been designing and building watershapes in the United States and abroad, from swimming pools to art pieces and even aquaculture systems, for the past 20 years.

In 2017, Oakes became a voting member of ACI Subcommittee 506-H, Shotcreting-Pools, and an Associate member of ACI Committee 506, Shotcreting. He was recently appointed to the American Shotcrete Association (ASA) Board of Directors while also serving as Vice Chair of the ASA Contractors Qualification Committee and a voting member of the ASA Pool & Recreational Shotcrete Committee.

A NEW BEGINNING

Amec Foster Wheeler officially changed its name to Wood on April 16, 2018. With over 55,000 people in 60 countries, Wood is a new global provider in the delivery of project, engineering, and technical services to energy and industrial markets. The combination of Wood Group and Amec Foster Wheeler brings a broader market spread, wider footprint, and a more comprehensive range of services to support customers.

ACI ANNOUNCES ITS 2018-2019 OFFICERS

The American Concrete Institute (ACI) introduced its 2018-2019 President, Vice President, and four Board members during The Concrete Convention and Exposition in Salt Lake City, UT, in March 2018.

David A. Lange was elected to serve as President of the Institute for 2018-2019; Jeffrey W. Coleman was elected Vice President for a 2-year term; and Randall W. Poston, whose term began in Spring 2017, is the Institute's other Vice President. Heather J. Brown, Mark A. Cheek, Michael J. Paul, and Michelle L. Wilson were elected to serve as members of the ACI Board of Direction for a 3-year term.

ACI President Awad (left) hands the gavel to incoming ACI President Lange

President

Lange

David A. Lange, FACI, is Professor of civil and environmental engineering at the University of Illinois at Urbana-Champaign, Urbana, IL. He joined the faculty of the Department of Civil and Environmental Engineering in 1992. He is Director of the Center of Excellence for Airport Technology, a research center working in partnership with the Chicago Department of Aviation and the O'Hare International Airport. A long-time ACI member, Lange has served on the ACI Board of Direction and is a past Chair of the ACI Technical Activities Committee, the Publications Committee, and the Board Outlook 2030 Task Group. He currently is a member of the ACI Foundation Board of Trustees, Financial Advisory Committee, and Faculty Network, and ACI Committees 236, Material Science of Concrete; 237, Self-Consolidating Concrete; 241, Nanotechnology of Concrete; 544, Fiber-Reinforced Concrete; and S802, Teaching Methods and Educational Materials. Lange received the 2003 and 2018 ACI Wason Medal for Most Meritorious Paper.

Lange is a Fellow of the American Ceramic Society (ACS) and he received a J. William Fulbright Scholar Award in 2013. He served as Associate Department Head for Civil and Environmental Engineering at the University of Illinois at Urbana-Champaign from 2004-2010.

Lange received his BS in civil engineering from Valparaiso University, Valparaiso, IN; his MBA from Wichita State University, Wichita, KS; and his PhD in civil engineering from Northwestern University, Evanston, IL.

Vice President

Coleman

Jeffrey W. Coleman, FACI, is a licensed professional engineer and Attorney at Law and Principal Partner of The Coleman Law Firm, LLC, Minneapolis, MN. He has been an ACI member for over 37 years. Coleman is the author of the book *Legal Issues in Concrete Construction*, published by ACI in 2004 (second edition published in 2014), and previously authored the "Concrete Legal Notes" section of *Concrete International*.

Coleman is a past Chair and current member of ACI Committee 132, Responsibility in Concrete Construction. He is a past Chair and current Trustee of the ACI Foundation, and a member of the ACI Financial Advisory Committee, TAC Construction Standards Committee, and ACI Committee 563, Specifications for Repair of Structural Concrete in Buildings. He has also served on the ACI Board of Direction and has been a member of the ACI Construction Liaison Committee, TAC Specifications Committee, Convention Committee, and ACI Committees 215, Fatigue of Concrete, and 301, Specifications for Structural Concrete. He received the 2016 ACI Delmar L. Bloem Distinguished Service Award.

Coleman received his BS in civil engineering in 1976 and his MS in structural engineering in 1977 from Iowa State University, Ames, IA. He is a licensed engineer in Iowa, Minnesota, and Wisconsin, and a lawyer in Minnesota, Wisconsin, North Dakota, and Iowa. He practices regularly in other states through admission "pro hac vice."

After completing his law degree in 1984, Coleman served as General Counsel for Ellerbe Associates, Inc. (later Ellerbe Becket, Inc., and now part of AECOM). He started his own firm in 1991, which was quickly merged and renamed Coleman, Hull & van Vliet, PLLP. In 2013, he founded The Coleman Law Firm, LLC—committed to continuing his representation of engineers, architects, and the concrete construction industry.

Coleman represents engineers, architects, concrete contractors and suppliers, and building owners in all aspects of construction. He is a Past President of the Minnesota Concrete Council (MCC) and a former Board member. He is also a Sustaining Member of the American Society of Concrete Contractors (ASCC). Coleman served five terms on the Board of Directors of the American Council of Engineering Companies, Minnesota, and has recently been appointed to a sixth term. He is one of the only two nonpracticing engineers to receive the Tom Roach Award for Outstanding Service and Motivation to the Consulting Engineering Professional Community. Coleman is a past member of the Minnesota Board of Architecture, Engineering, Land Surveying, Landscape Architecture, Geoscience, and Interior Design (the Minnesota Licensing Board), and the University of Minnesota Concrete Conference Planning Committee. He is a frequent lecturer on topics involving construction law but is also a regular practitioner involved with construction disputes involving concrete.

Directors

Brown

Heather J. Brown, FACI, joined the Concrete Industry Management (CIM) Program in August 2001 and is currently Director and Professor of the newly formed School of Concrete and Construction Management at Middle Tennessee State University (MTSU), Murfreesboro, TN. She is a member of the ACI Foundation Scholarship Council, and ACI Committees 522, Pervious Concrete, and C655, Foundation Constructor Certification. She has also served on ACI Committee 544, Fiber-Reinforced Concrete, and as a Student Chapter Advisor. Named a Fellow of ACI in 2015, Brown also received the 2008 ACI Walter P. Moore, Jr. Faculty Achievement Award.

Brown has authored and coauthored more than 30 papers and has been published in *Concrete International*, ASTM *Journal of Testing and Evaluation*, *Transportation Research Record*, *International Center for Aggregate Research Journal*, *American Chemical Society Journal*, and *Tennessee Concrete*. She has been a presenter and guest lecturer on topics such as factors affecting concrete strength, pervious pavements, fiber-reinforced concrete, whitetopping pavements, high-performance concrete, flowable fill, skid-resistant aggregates, and concrete construction tolerances.

Brown has been honored as a recipient of the MTSU Outstanding Grantsmanship, MTSU Overall Excellence, and MTSU Faculty Who Make a Difference Awards. She was named as one of the Influential Women in Business in Rutherford County in 2015 and one of the Most Influential People in *Concrete Construction* in 2017.

She received her BS, MS, and PhD in civil engineering, all from Tennessee Technological University, Cookeville, TN. Her technical experience also includes 5 years of material research for the Tennessee Department of Transportation as a graduate student.

Cheek

Mark A. Cheek, FACI, is Vice President of The Beta Group, Engineering and Construction Services in Gretna, LA, where he has served for 19 years. Cheek has over 29 years of experience in the construction industry, including construction materials testing and inspection and geotechnical and civil engineering.

He has been an active ACI member since 1991 and was named a Fellow of ACI in 2006. Cheek is the Chair of ACI Committee C620, Laboratory Technician Certification, and a member of ACI Committees 214, Evaluation of Results of Tests Used to Determine the Strength of Concrete; 228, Nondestructive Testing of Concrete; C610, Field Technician Certification; E905, Training Programs; and ACI Subcommittee C610-FQR, Field Testing Technician Grade I Quality Reviewer. He previously served on the ACI Certification Programs Committee; Chapter Activities Committee; Convention Committee; Honors and Awards Committee; International Project Awards Committee; Membership Committee; Student and Young Professional Activities Committee (of which he is a past Chair); and E702, Designing Concrete Structures.

Cheek received the 2011 ACI Chapter Activities Award. He has been a member of the Louisiana Chapter – ACI since 1989, serving on the Board and as President in 2001. He has also been on the chapter's certification committee since 1989 and currently serves as the committee's Chief Examiner. He received the 2005 Louisiana Chapter's Chapter Activities Award and the 2012 Distinguished Chapter Member Award. Also, Cheek was Co-Chair of the 2005 and 2009 ACI Conventions in New Orleans, LA.

He is a member of ASTM International Committee C09, Concrete and Concrete Aggregates; American Society of Civil Engineers (ASCE); and Concrete and Aggregate Association of Louisiana (CAAL). Cheek is the Chair of CAAL's Technical Committee. He is also an Examiner for the National Ready Mixed Concrete Association (NRMCA) Pervious Concrete Contractor Certification program and an approved NRMCA Plant Inspecting Engineer. He conducts training programs for both ACI and NRMCA throughout Louisiana and Mississippi.

Cheek received his BS in civil engineering from the University of New Orleans, New Orleans, LA, and is a licensed professional engineer in Louisiana and Mississippi.

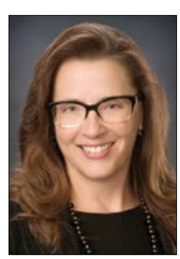
Michael J. Paul, FACI, is Principal Structural Engineer in the Philadelphia, PA, office of Larsen & Landis, where he provides engineering for building projects. With more than 40 years of construction and engineering experience, Paul's work includes troubleshooting, repair, restoration, and rehabilitation of concrete, in addition to the design of new structures of all types. Brandywine Shoal Lighthouse and the Caesar Rodney Monument are two of his repair and restoration projects that have been featured in *Concrete International*.

Paul

Paul is the Chair of the ACI Membership Committee and past Chair of the International Project Awards Committee and ACI Committee 124, Concrete Aesthetics, for which he continues to edit the "Notable Concrete" series produced for ACI conventions and excerpted in *Concrete International*. He served on the editorial review panel for both Sustainable Concrete Guides of the U.S. Green Concrete Council. He is a member of several other ACI committees, including 120, History of Concrete, as well as ASTM International committees.

Concluding 20 years of undergraduate teaching, Paul recently stepped down as Coordinator for the Senior Design capstone course in the Department of Civil and Environmental Engineering at the University of Delaware, Newark, DE. The course received the National Council of Examiners for Engineering and Surveying (NCEES) Engineering Award Grand Prize in 2010. He was named Engineer of the Year in 2008 by the American Society of Civil Engineers (ASCE) Delaware Section and has received numerous service awards from professional, technical, and community organizations.

Paul received his BA from Dartmouth College, Hanover, NH, and his MSCE and MArch from the Massachusetts Institute of Technology, Cambridge, MA. He is a licensed professional engineer, a licensed architect (American Institute of Architects), and is LEED-AP accredited.



Wilson

Michelle L. Wilson, FACI, is Director of Concrete Technology at the Portland Cement Association (PCA), Skokie, IL. She has over 20 years of experience relating to concrete materials, specifications, performance, troubleshooting, and repair.

She is responsible for the development, content, and delivery of PCA's educational programs and products covering the entire spectrum of concrete technology, and she is co-author of PCA's Design and Control of Concrete Mixtures. She has given numerous workshops and presentations around North America, including World of Concrete, International Builder's Show, and CONAGG/CON-EXPO.

Wilson is Chair of ACI Committee 301, Specifications for Structural Concrete, and a member of the TAC Construction Standards Committee and ACI Committees 201, Durability of Concrete; 329, Performance Criteria for Ready Mixed Concrete; and E707, Specification Education; and serves as a consulting member on ACI Committee 311, Inspection of Concrete, and Joint ACI-ASCC Committee 117, Tolerances. She received the 2008 ACI Young Member Award for Professional Achievement and became a Fellow of the Institute in 2011. Wilson is a member of ASTM International Committee C09, Concrete and Concrete Aggregates, and serves on the C09 Executive Committee.

Prior to joining PCA in 1999, she worked for Construction Technology Laboratories (now CTLGroup), PCA's sole subsidiary, specializing in concrete evaluation and troubleshooting on various projects throughout the United States. Wilson has also worked as a field inspector performing quality control for STS Consultants, Ltd., in Milwaukee, WI.

Wilson received her BS in architectural engineering from Milwaukee School of Engineering, Milwaukee, WI, with an emphasis in structural engineering and concrete materials.

For additional information, visit **www.concrete.org**.

THREE ASA CORPORATE MEMBERS LISTED ON *PSN* TOP 50 BUILDERS

ASA Corporate Members South Shore Gunite Pools & Spas, Inc.; National Pools of Roanoke Inc.; and J. Tortorella Custom Gunite Pools were listed on the *Pool and Spa News* (*PSN*) 2018 Top 50 Builders List. *PSN* recognizes the builders who shine the most in revenue and four other criteria, including staff management, industry involvement, web presence, and community involvement. For more information, visit **www.poolspanews.com/companies/top-50-builders/see-who-made-this-years-pool-spa-news-top-50-builders-list_o**.

ASA EDUCATION TAB NOW ON THE ASA WEBSITE

ASA updated its Education/Certification tab on the ASA website (**www.shotcrete.org**). Users can now easily access information and register online for programs, including the Contractor Qualification, Shotcrete Inspector Education, On-Site Seminars, and the ASA/Université Laval Scholarship.

ASA FALL COMMITTEE MEETINGS

ASA Fall Committee Meetings will be held Saturday, October 13, 2018, in Las Vegas, NV, prior to The ACI Concrete Convention and Exposition, October 14-18. The meeting schedule is now available and registration is not required to attend the ASA meetings. All are invited to attend ASA meetings to help advance the use of shotcrete in the industry. The ASA meetings at the ACI Convention will be at the Rio All-Suites Hotel & Casino. ACI's theme for the convention is "Dream Big, Build Bigger."

CONTRACTOR QUALIFICATION SEMINAR AVAILABLE AT INTERNATIONAL POOL | SPA | PATIO EXPO

INTERNATIONAL POOL | SPA | PATIO EXPO
SPONSORED BY APSP
american shotcrete association asa

The Contractor Qualification Seminar Program was introduced at the ASA Convention last March in Napa, CA. Due to the successful launch, ASA is excited to offer the next Contractor Qualification Seminar at the International Pool | Spa | Patio Expo, in Las Vegas, NV, on November 1, 2018, from 9:00 a.m. to 4:00 p.m.

One of the mandatory requirements in the new ASA Contractor Qualification Program (CQP) is the attendance of a company representative at a full-day Contractor Qualification Seminar presented by ASA. The seminar focuses on the many aspects of successful shotcrete contracting and how shotcrete construction compares to more traditional form-and-pour concrete construction. The seminar is geared toward education of contractors, but may be valuable to owners, engineers, architects, and suppliers who want to learn more about the details required to consistently construct high-quality, durable concrete structures with shotcrete placement.

This seminar provides a thorough knowledge of shotcrete, including logistics (site and project), environmental requirements, safety, crew requirements, shotcreting equipment, concrete mixture design, QA/QC, surface preparation, formwork, reinforcements, embedments, placement, finishing, testing, curing, and protection. The seminar presenter(s) have decades of experience in shotcrete construction and can provide insight into the multitude of details required for successful field shotcrete placement. The presentation is highly interactive with the attendees, and questions from the attendees are welcome and encouraged.

Attendees seeking Shotcrete Contractor Qualification for their company (one representative per company) will be required to take a written examination at the conclusion of the seminar.

A compilation of seven shotcrete-related ASTMs, ACI 506R-16, "Guide to Shotcrete," ACI 506.2-13, "Specification for Shotcrete," ASA's Safety Guidelines for Shotcrete, and the 90-minute written exam are included with the registration fee.

To register for the seminar, visit **www.poolspapatio.com/en/register.html**. More information on the Contractor Qualification Program can be found at **www.shotcrete.org/education**.

NOZZLEMEN CERTIFICATION EDUCATION FOR ACI WET-MIX CERTIFICATION AVAILABLE AT WORLD OF CONCRETE 2019

ASA is offering the full Nozzlemen Certification Education course and testing in English or Spanish for those interested in wet-mix certification on January 22, 2019, in concurrence with World of Concrete in Las Vegas, NV. This is a great opportunity to take advantage of while attending WOC. For more information and to register, visit **www.shotcrete.org/WOC**.

ASA OFFERS FULL-DAY SHOTCRETE INSPECTOR EDUCATION SEMINAR

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

This program covers over 40 critical elements of shotcrete applications that on-site inspectors must know to properly evaluate and sign off on acceptance documents for shotcrete. These include an overview on material selections, equipment, placement techniques, finishing, curing, protection, testing, and safety as it relates to the building official or inspector. Upon completion of the course, the Inspectors should have:

- A fundamental understanding of the wet- and dry-mix shotcrete processes;
- Current knowledge of ACI reference material and other Industry standards pertaining to acceptable shotcrete placement;

- Industry-specific knowledge to determine if materials and methods, as well as testing used by the crew, meet shotcrete project specifications; and
- Sufficient insight to recognize satisfactory application techniques, and actions that may reduce quality of the final product.

Profile of individuals to attend this course:

- Concrete Construction Inspectors or Transportation Construction Inspectors.
- ACI Concrete Field Testing Technicians—Grade I.
- Engineers or Specifiers who desire or are required to possess additional education to properly inspect shotcrete operations on projects.
- Building officials who desire further knowledge of acceptable shotcrete placement methods.
- Concrete producers and material suppliers who supply to the shotcrete projects.

ASA Inspector Education—Recommended References available for purchase from ASA, ACI, and ASTM International:

- ACI 506.2-13, Specification for Shotcrete
- ACI 506R-16, Guide to Shotcrete
- ACI 506.6T, Visual Shotcrete Core Quality Evaluation TechNote
- ASTM C1140/C1140M-11, Standard Practice for Preparing and Testing Specimens from Shotcrete Test Panels
- ASTM C1604/C1604M-05(2012) Standard Test Method for Obtaining and Testing Drilled Cores of Shotcrete
- ASTM C42/C42M-16, Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
- ASTM C1141/C1141M-15, Standard Specification for Admixtures for Shotcrete
- ASTM C1385/C1385M-10, Standard Practice for Sampling Materials for Shotcrete
- ASTM C1436-13, Standard Specification for Materials for Shotcrete
- ASTM C1480/C1480M-07(2012), Standard Specification for Packaged, Pre-Blended, Dry, Combined Materials for Use in Wet or Dry Shotcrete Application

All attendees for the full session will receive a certificate of completion from ASA. Additionally, engineers and architects can receive 7 hours of AIA-approved credit for the seminar. For more information or to request a seminar, visit **www.shotcrete.org/pages/education-certification/shotcrete-inspector-program.htm**.

ASA WELCOMES NEW STAFF— LACEY STACHEL AND KAREN SMITH

You may have seen e-mails or heard a new voice from ASA recently. Our part-time staff member, Beth Hinman, retired in June, and we have added two new staff members to help handle the workload from our significantly increased programs and activities.

Lacey Stachel is the Editorial and Marketing Manager with primary responsibilities for ASA's marketing activities such as social media, the monthly eNewsletter "What's in the Mix," and *Shotcrete* magazine. Stachel's industry experience includes serving as an Editor for ACI's *Concrete International* and a Staff Liaison for the Concrete and Masonry Related Associations (CAMRA). She received her BAA in integrative public relations from Central Michigan University, Mount Pleasant, MI.


Stachel

Karen Smith is our Customer Service Representative with responsibilities including maintaining our member database, processing memberships (new and renewals), convention registrations, bookstore orders, and general administrative tasks. Smith started with ACI in March of 2011 and she has served in a variety of roles for both ACI and AOE clients, including seminar and meeting registrar, copyright registration, member services coordinator, membership payment processing, maintaining ACI chapter information, and bookstore orders.


Smith

With the growing number of programs and activities at ASA, we heartily welcome Lacey and Karen to the Association!

ASA'S ON FACEBOOK AND TWITTER

With Lacey Stachel on board, ASA is increasing our social media presence on Facebook and Twitter. You can find us on Facebook @AmericanShotcreteAssociation, and on Twitter @ShotcreteASA. We would love to have pictures or videos of your projects, or announcements of interest to the shotcrete industry, to consider for inclusion in our posts. Please send content to lacey.stachel@shotcrete.org.

SHOTCRETE CALENDAR

OCTOBER 13, 2018	**ASA Fall 2018 Committee Meetings** Rio All-Suites Hotel & Casino | Las Vegas, NV **www.shotcrete.org/committees**
OCTOBER 14-18, 2018	**The ACI Concrete Convention and Exposition** Theme: "Dream Big, Build Bigger" Rio All-Suites Hotel & Casino | Las Vegas, NV **www.concrete.org**
OCTOBER 31-NOVEMBER 2, 2018	**International Pool | Spa | Patio Expo** Conference: October 28-November 2, 2018 Mandalay Bay | Las Vegas, NV **www.poolspapatio.com**
NOVEMBER 1, 2018	**ASA Contractor Qualification Seminar** at International Pool | Spa | Patio Expo Mandalay Bay | Las Vegas, NV **www.poolspapatio.com**
NOVEMBER 7-9, 2018	**ICRI Fall Convention 2018** Theme: "Resiliency Above and Beyond Concrete Restoration" Omaha Marriott Downtown at the Capitol District | Omaha, NE **www.icri.org**
DECEMBER 2-5, 2018	**ASTM International Committee C09, Concrete and Concrete Aggregates** Washington Hilton | Washington, DC **www.astm.org**
DECEMBER 3-7, 2018	**AEMA's 2018 Annual Meeting, Exposition & Short Courses** Washington Hilton | Washington, DC **www.miningamerica.org**
JANUARY 22, 2019	**ASA Shotcrete Nozzleman Education** at WOC English OR Spanish class | ACI Wet-Mix Certification available Las Vegas Convention Center | Las Vegas, NV **www.shotcrete.org/WOC**
JANUARY 22, 2019	**ASA General Membership Meeting and (New) Shotcrete Reception** at WOC Las Vegas Convention Center | Las Vegas, NV **www.shotcrete.org/WOC**
JANUARY 22-25, 2019	**World of Concrete** Las Vegas Convention Center | Las Vegas, NV **www.worldofconcrete.com**
JANUARY 23, 2019	**ASA Contractor Qualification Seminar** at WOC Las Vegas Convention Center | Las Vegas, NV **www.shotcrete.org/WOC**
JANUARY 24, 2019	**Advanced Shotcrete: Innovative Techniques for Architectural & Structural Projects** Las Vegas Convention Center | Las Vegas, NV **www.worldofconcrete.com**
JANUARY 24, 2019	**ACI Wet-Mix Nozzleman Certification** Hydro Arch | Henderson, NV **www.shotcrete.org/WOC**

FEBRUARY 25-26, 2019	**ASA 2019 Shotcrete Convention and Technology Conference** Omni Amelia Island Plantation Resort | Fernandina Beach, FL **www.shotcrete.org/convention**
FEBRUARY 26, 2019	**ASA Outstanding Shotcrete Projects Awards Banquet at Shotcrete Convention** Walker's Landing | Fernandina Beach, FL **www.shotcrete.org**
MARCH 23, 2019	**ASA Spring 2019 Committee Meetings** Québec City Convention Centre and Hilton Quebec Québec City, QC, Canada **www.shotcrete.org/committees**
MARCH 24-28, 2019	**The ACI Concrete Convention and Exposition** Theme: "Nordique Concrete" Québec City Convention Centre and Hilton Quebec Québec City, QC, Canada **www.concrete.org**
MORE INFORMATION	**To see a full list with active links to each event, visit shotcrete.org/calendar.**

REED NOW OFFERS PAN MIXERS

REED's new Pan Mixer can mix a 2200 lb (1000 kg) batch of materials in 3 minutes. The mixer then quickly discharges the material into the pump hopper to be either sprayed or pumped.

The M2200 features variable-speed mixer blade rotation (hydraulic motor drive, 59 RPM maximum, torque 13762 Nm [10,150 ft-lb]); manual retractable legs, four each; forklift tubes and lifting eye kit for easy lifting and transport; work platform with control box and safety railing; quarter-panel safety grate cover with cutoff switch; stainless steel water tank for precise water measurement; bolt-on style paddles for easy change-out; bag splitter; NEMA four fully enclosed weatherproof control box mounted on operator platform; and power on-off, mixer stop-start, e-stop, horn-reset, mixer RPM control, primary discharge open-close, cleanout discharge open-close, cleanout tilt up-down, hydraulic pressure gage, and amp meter.

The 6600 lb (3000 kg) mixer is 8.0 x 7.1 ft (2.4 x 2.2 m). The minimum is 8.5 ft (2.6 m) for transport and the maximum is 12.8 ft (3.9 m) for operation at maximum height. The minimum clearance under the discharge door is 3.9 ft (1.2 m) and the maximum clearance is 6.4 ft (2.0 m).

The M2200 Pan Mixer can also be powered by a small hydraulic power pack (sold separately). The power pack includes electric power, 50 HP, 440 V, 3 Phase, 60 Hz (50 Hz is also available); diesel power (optional); variable displacement hydraulic piston pump; and quick disconnects (hydraulic, electrical) for ease of set up and clean up. The power pack will store under the M2200 mixer during transportation.

The M2200 Pan Mixer was designed for easy transportation. The four legs of the mixer quickly shorten to reduce the shipping height, the water tank folds downward for transport, and the hydraulic power pack slides underneath the mixer. A forklift driver can quickly unload the M2200 from a flatbed truck using the forklift tubes on the mixer and the power pack.

REED's M2200 Pan Mixer and optional power pack collapsed for transport

For more information, contact Mike Newcomb at mike.newcomb@reedmfg.com or visit **www.reedpumps.com**.

KRYTON UNVEILS HARD-CEM

Kryton International introduced its integral concrete dampproofing admixtures into the construction mainstream decades ago and is continuing its innovative mandate. It recently acquired Cementec Industries, a manufacturer of concrete additive solutions for the construction, oil, and gas industries.

Kryton unveiled its latest product, Hard-Cem®, an integral concrete hardening admixture. This solution is added directly to the concrete mixture and is engineered to provide concrete with extraordinary resistance to abrasion and erosion, and increased mechanical-wear durability. This technology allows Hard-Cem-treated concrete to last up to six times longer than untreated concrete. Kryton launched Hard-Cem at the 2018 World of Concrete in Las Vegas, NV.

"Vancouver has been our headquarters for the past 45 years and we are proud to be bringing this Canadian innovation to the global market," said Kari Yuers, Kryton President and CEO. "We have fun in discovering new technology and sharing advancements with our building partners all over the world, so that they too can effectively build structures that last," she highlighted.

"We are happy to be growing globally and creating more jobs locally as demand for our concrete waterproofing and durability solutions grows," added Kevin Yuers, Kryton Vice-President of Product Development.

For more information, call +1.800.267.8280 or visit **www.kryton.com**.

BLASTCRETE'S CONCRETE PUMP ATTACHMENT

Blastcrete Equipment LLC's RD6536 Skid Steer Pump attachment is compatible with any skid steer and provides a fast, efficient solution for pumping grout materials, 3/8 in. (10 mm) shotcrete, and 3/4 in. (19 mm) structural concrete mixtures in a variety of concrete and shotcrete applications. The attachment features Blastcrete's 3 in. (76 mm) hydraulic squeeze pump, making it ideal for ICF, block fill, form and pour, driveways, basements, and shotcrete applications.

The RD6536 provides variable speeds of 0 to 25 yd^3/h (19 m^3/h). Contractors can pump materials 250 ft (76 m) horizontally and up to 50 ft (15 m) vertically with the use of a rubber delivery line.

The receiving hopper includes a hydraulic agitator that keeps the mix well-blended, ensuring aggregate and sand stay evenly suspended throughout the mixture. Not only does this result in high-strength concrete, it keeps the aggregate and sand from settling to the bottom of the hopper and clogging near the suction area.

Operators can run the RD6536 in both forward and reverse to relieve pressure from build-up clogs and eliminate potential damage to the pump. The pump also features hydraulically powered controls that operate both agitator and pump speed. The unit's oil requirement is 18 gal./min (68 L/min) at 3000 psi (21 MPa).

The skid-steer pump weighs 2700 lb (1200 kg) and features a 48 in. (1.2 m) wide frame (55 in. [1.4 m] with the receiving hopper), narrow enough to fit between the wheel wells of most standard work trucks. The RD6536's forklift pockets allow quick and easy loading and unloading from the transport vehicle.

Blastcrete designed the RD6536 for a long service life and fast and simple maintenance by using steel construction that prevents concrete from coming in contact with the pump's moving parts. Using just water and a sponge ball, the pump can be cleaned in about 5 minutes. The primary wear part, the rubber pumping tube, can be easily replaced on the jobsite in about 20 minutes.

For more information, call +1.800.235.4867 or visit **www.blastcrete.com**.

MOONFLO PAPR SHOTCRETE HELMET

Gunite Supply & Equipment and Airplaco are now offering Moonflo Powered Air Purifying Respirator (PAPR) Shotcrete Helmet. The Moonflo PAPR Shotcrete Helmet was designed by shotcreters for the shotcrete industry. It has been tested by third party engineering firms and meets required health and safety standards. The Moonflo PAPR Shotcrete Helmet can have other industrial uses. The basic helmet can be configured as a dust helmet, a welding helmet, or a sandblast helmet.

For more information, call +1.888.349.2950 or visit **www.airplaco.com**.

Dees Hennessey, Inc.

GENERAL ENGINEERING CONTRACTORS

Dees-Hennessey, Inc.

Founded over 30 years ago, Dees Hennessey, Inc. (DHI), has specialized in shotcrete almost from the beginning. Del Dees established the company in 1985 as an excavation support company. He quickly saw the versatility and importance of shotcrete with its application to benefit excavation support. DHI quickly branched into structural wet-mix shotcrete and the company has seen tremendous growth with this expansion of the company. Today, DHI does over 75% of its business in structural wet-mix shotcrete. Del Dees retired in 2007, leaving the company to the present ownership group whose members were already involved with the company. Under the leadership of Dan Evans and Ron Coleman, DHI has continued its strong growth in structural wet-mix shotcrete.

DHI specializes in working with the client or General Contractor in finding ways that shotcrete can be used to benefit a project. This goes beyond just looking at a project to determine the most economical solution, but working with schedule constraints, reinforcing bar configurations, placement locations, and strength requirements to help the General Contractor minimize the cost of the project and schedule requirements.

An example of this is a project that is currently being completed in San Francisco, CA, where DHI installed over 1500 yd^3 (1150 m^3) of wet-mix shotcrete in multiple levels of grade beams along a steep slope, so the tiebacks extending through the grade beams could be locked off and the next lift started in a 5-day cycle. Meeting with the General Contractor before the project started, DHI developed a working plan for all parties with an acceptable budget, required strength requirements, and modeled a mobile work platform that could facilitate reinforcement placement as well as shotcreting. By using wet-mix shotcrete and advanced planning, DHI was able to take the General Contractor's 5-day cycle and reduce it to 3 days when construction started.

DHI is known for completing some of the most remote projects with difficult to impossible access to install shotcrete. In one case, DHI had a dam resurfacing project where wet-mix shotcrete material had to have set suspended for

Preparing for shotcrete placement on a building seismic retrofit

Shooting a dam face

4 hours to allow delivery to a remote location in the middle of the Sierra Nevada Mountains at 9500 ft (2900 m) elevation, with the additional challenge of on-site pumping distances over 200 ft (60 m). Another example is using a helicopter to transport wet-mix shotcrete to the opposite side of a canyon so that the wet-mix shotcrete material could be pumped for 750 ft (230 m) to line the crown of a tunnel that was in danger of collapse. DHI has also worked with QUIKRETE® and MAPEI® to develop special structurally reinforced bags with premixed shotcrete materials that can be flown by helicopter to an isolated location and dropped off next to a AirPlaco® ProCreter shotcrete mixer/pump at the remote project location.

DHI has been a member of ASA since 2002 and has been involved at the committee level over the past decade. DHI would like to thank the leadership and vision that such members as Chris Zynda and Larry Totten have provided on the West Coast in the promotion and acceptance of shotcrete throughout the region. Because of their leadership and the promotion provided by ASA, shotcrete is an accepted method throughout the West Coast and DHI is looking forward to continuing the tradition established by these gentlemen.

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Shooting colored shotcrete for a skate park

CANUSA EQUIPMENT LTD

Canusa Equipment Ltd. has been supporting the concrete industry in Canada and the United States since 1998. As a REED dealer, Canusa Equipment provides customers with concrete pumps, parts, technical support, and training. The company handles all phases of equipment service, repair, modification, and construction that is related to the concrete industry.

Kim Fabbro, the Founder, began his career in 1979 as a concrete pump operator and at the same time took courses and training in the field of fabrication and repair of equipment. Since then, he has been dedicated to the service and repair of pumps and related equipment. Seeing the potential for applying his skills beyond the pumping industry, he has expanded operations to include service and support for most industrial equipment, and numerous fabrication projects such as building electrical control panels, truck mounting pumps, equipment modification, drilling equipment, and barge unloading facilities.

Canusa Equipment sells and installs radio remote equipment for all types of applications. Canusa Equipment, in the past, started off with concrete pump remote installations. Over time, the company helped manufacturers of the radio remote systems with testing and development of their products. Working with manufacturers led Canusa Equipment to expand from concrete pumps to other areas such as wood chippers, movie special effects props, and barge winch systems, just to name a few.

Canusa Equipment credits the design and manufacturing of the Canusa PDM-1 Predampener and Mixer to its customers. Their complaints about the equipment they used included:

1. Too much dust at the machine and a significant loss of material out the bottom of the skirts.
2. The mixing process was not continual, constantly producing too many wet clumps and dry patches.
3. The operator had to repeatedly adjust the water sprayers

Inventory of REED pumps

Canusa PDM-1 Predampener and Mixer

to compensate for the inconsistent mixing along with auger speeds.

4. The variable dampness would confuse the nozzleman adding and subtracting water as well to compensate for the changes.

Thus, there was no coordination between the gunman and nozzleman keeping the mixture predampened properly. Customers said hydro-mix nozzles do work with lower volume applications, but as they increased material flow, the extra water introduced into the mixture would ball up the material into clumps and plug the nozzle on exit. They referred to this problem as a “snot ball” effect. Initially there would be a good flow of material but then there would be a slow buildup in the hose and nozzle that would eventually break loose and blow out in the form of a big snot ball. This process would always repeat itself during the shoot.

Canusa Equipment’s customers wanted something that would do a better and more efficient job than the existing equipment. The company developed a machine to address their concerns that has exceeded their expectations. Predampening dry material properly controls the dust around the machine, improves visibility for the nozzleman, reduces equipment wear, and reduces static electricity. A major benefit in productivity is reducing the amount of rebound with better hydration of the dry materials. Not only will the PDM-1 predampener do all this with dry-mix materials, but it can also be adjusted for wet-mix applications. When a jobsite engineer requests certain parts of the project to be done with the dry process, and a different section to be shot wet, the PDM-1 predampener can do both continuously and correctly. Performance, consistency, and mobility, perfect for underground, remote, or confined spaces.

For 20 years Canusa Equipment has ensured that its customers are satisfied with the equipment they have purchased, new and used. Canusa Equipment works with all its manufacturers to help improve the equipment they produce to get better results for everyone involved. Whether you are starting up, expanding, or have a custom project in mind, Canusa Equipment can help.

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INTERESTED IN BECOMING A MEMBER OF ASA?

Read about the benefits of being a member of ASA and find a Membership Application at **shotcrete.org/membership**.

SHOTCRETE FAQs

As a service to our readers, each issue of *Shotcrete* magazine 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 at **http://shotcrete.org/pages/products-services/technical-questions.htm**.

Question: *The company installing our pool ran short of wet mix by about 4 yd^3 (3 m^3). The pressure truck left, leaving one finisher behind. It was about an hour before the last of the material arrived and what had already been placed had pretty much set. He added about 20 gal. (76 L) of water so he could get it in place. The fully exposed areas, I feel, would be OK. However, the long tapered overlays concern me for strength; it seems like more of a patch. Since it was not shot in place to compress and integrate it, will it bond and strengthen properly?*

Answer: Proper shotcrete placement of concrete depends on high-velocity impact of the concrete materials for full consolidation. Though not clear from your inquiry, it sounds like the additional concrete was just dumped in place without high-velocity impact. Thus, you simply have normal cast concrete that would require some type of external vibration to densify and properly consolidate the concrete. The bond of cast concrete would be inferior to the bond from shotcrete since you do not have the high-velocity impact driving the cement paste into the previously shot material. Also, adding 20 gal. of water at the site would substantially weaken the concrete from the original design strength of the concrete mixture. Further, feathering edging in a joint is not recommended since you end up with a very thin overlay at some point that may tend to spall or delaminate much more easily at the thinner section. A better approach when running short of concrete is to stop and prepare a joint for later shotcreting. For best bond, joints should be cut at a 45-degree angle, roughened, and then cleaned and wetted immediately before shooting.

Thus, answering your final question, in summary the bond will be reduced, and with the higher water content, the concrete will be weaker than properly shotcreted concrete.

Question: *Are there cases of shotcrete being sprayed on the underside of metal floor decking for the purpose of sound transfer reduction and dampening between levels? If so, are there special application methods and formulations?*

Answer: We could not identify any specific cases of shotcreting onto metal decking for sound dampening. However, shotcrete is used in a wide variety of overhead applications, and as long as we can get good bond to the underside of the metal decking, should perform well. Depending on the surface profile of the metal decking, you may want to consider attaching studs to the decking to enhance the overall bond of the concrete. You may also want to consider using lightweight shotcrete since the concrete sounds like it is more for acoustic purposes, than for structural.

Question: *Per contract I have to reinforce first-floor walls with 5 in. (125 mm), 4000 psi (28 MPa) concrete. Due to poor condition of the backup wall, conventional form-and-pour is not an option. I have proposed the use of shotcrete to the architect. What type of shotcrete will meet design criteria for this type of work?*

Answer: Shotcrete is a placement method for concrete. It is routinely used to strengthen existing masonry or concrete walls. The 5 in. thickness can be easily achieved with either dry-mix or wet-mix shotcrete. If using dry-mix, you may want to review available prepackaged bagged dry concrete materials. A comprehensive listing of our ASA member companies supplying bagged dry concrete materials can be found in our Buyers Guide at **www.shotcrete.org/BuyersGuide**. If using wet-mix, the local concrete supplier should be able to provide concrete mixture designs that will achieve the 4000 psi compressive strength requirement. Dry-mix and wet-mix processes use different equipment and skills of nozzlemen are somewhat different. We encourage requiring use of an ACI-certified shotcrete nozzlemen in the process to be used on the project. If looking to select a qualified shotcrete contractor, you may want to review our ASA position paper on Shotcrete Contractor and Crew Qualifications at **www.shotcrete.org/media/pdf/ASAPositionPaper_Board_1.pdf**.

Question: *I recently had a project that requires a velocity of ±400 psi (2.8 MPa) to be applied to prepared areas of deteriorated concrete. My questions is: What is the velocity of the material being applied if I am using 50 ft x 1 1/2 in. (15 m x 38 mm) shooting hose with 60 psi (0.4 MPa) supplied pressure? I would also like to know how that is calculated.*

Answer: Shotcrete placement requires high velocity for full consolidation and compaction of the concrete. Standard shotcrete equipment with a properly sized air compressor will produce a velocity of 60 to 80 mph (95 to 130 km/h). The 400 psi you stated is not a velocity, but a pressure. Sixty psi is a very low air pressure and may not create the velocity needed for proper shotcrete placement. Shotcrete generally uses compressors that create 100 to 125 psi of air pressure. Also, depending on the shotcrete process used (wet-mix or dry-mix), ACI 506R-16, "Guide to Shotcrete," states you need an air compressor that can produce a flow rate of at least 200 ft^3/min (5.7 m^3/min) for wet-mix to 600 ft^3/min (17 m^3/min) for dry-mix for your 1-1/2 in. diameter hose.

Question: *What is the maximum lift for an 8 in. (200 mm) wall against wood lagging temporary shoring?*

Answer: There is not a fixed value that one can use for maximum lift height. The maximum lift height when bench shooting is controlled by the concrete mixture (admixtures, aggregate, slump), concrete temperature, size and layout of reinforcement, substrate being shot against, and ambient temperatures. These factors must be evaluated by the nozzleman during the placement. The maximum height is constrained by the ability of the fresh concrete in the lower portion of the lift to carry the weight of concrete in higher portions without creating sagging or sloughing. Hot weather conditions will allow higher lift heights than cold weather in non-accelerated concrete mixtures.

Question: *I have some hairline cracks visible in the outer 3 in. (75 mm) thick shotcrete outer shell of a monolithic dome home. How concerned should I be about them? The outer coat was applied 10 months ago and they seem to be spreading. The shotcrete was applied over chain-link fencing. These cracks are several feet long and most are from doorway or window openings. What is the best/easiest way to repair these?*

Answer: The design of any concrete structure must consider loadings and environmental conditions. This includes drying shrinkage of the concrete, and daily and seasonal thermal changes that introduce stresses within the concrete sections. Domes are thin-shell concrete structures and stress concentrations are expected around any openings through the shell. Typically, the design engineer will provide additional reinforcing bars around openings and especially at corners of openings to accommodate the buildup of stresses in these locations. Also, chain-link fence is not considered as acceptable concrete reinforcement, as it cannot accept tension in a straight orientation within the concrete. Proper concrete reinforcement is either deformed reinforcing bars or steel mesh with smooth wires laid out in an orthogonal pattern.

You should have a professional engineer with experience in concrete shell design and construction evaluate your dome home for structural integrity. If the cracking is determined to not affect the structural integrity, epoxy or poly-urethane grout injection is routinely used to seal cracks in concrete.

Question: *I live in NW Florida, Fort Walton Beach. In 1987 a previous owner gutted and substantially rebuilt my house. The exterior brick walls were covered with wire mesh and over 1 in. (25 mm) of coquina shell shotcrete. I bought the house in 1993. I am forever trying to reduce my bills. I would like to find any information I can use to reduce my home insurance. Do you have any links to anyone that has data about my siding being more fire resistant or wind resistant than ordinary masonry/brick veneers? Any guidance you can provide will be greatly appreciated.*

Answer: "Coquina shell shotcrete" is not a well-defined concrete material. Though it may have been promoted to you as shotcrete, it may well have been a stucco-like application accomplished with low-velocity plastering equipment, and thus not high-velocity shotcrete placement. Without physical characteristics of the in-place material (strength, density, type, and amount of reinforcement), it is hard to delineate the structural enhancement the coating may provide. You could have an evaluation by an engineer or testing lab to ascertain the characteristics of the in-place material. Then refer to ACI 216.1-14, "Code Requirements for Determining Fire Resistance of Concrete and Masonry Construction Assemblies," to see whether your composite system has enhanced fire resistance as compared to brick alone. Regarding wind resistance, you would need to have a structural engineer evaluate the composite system for any potential increase in strength against wind loadings.

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