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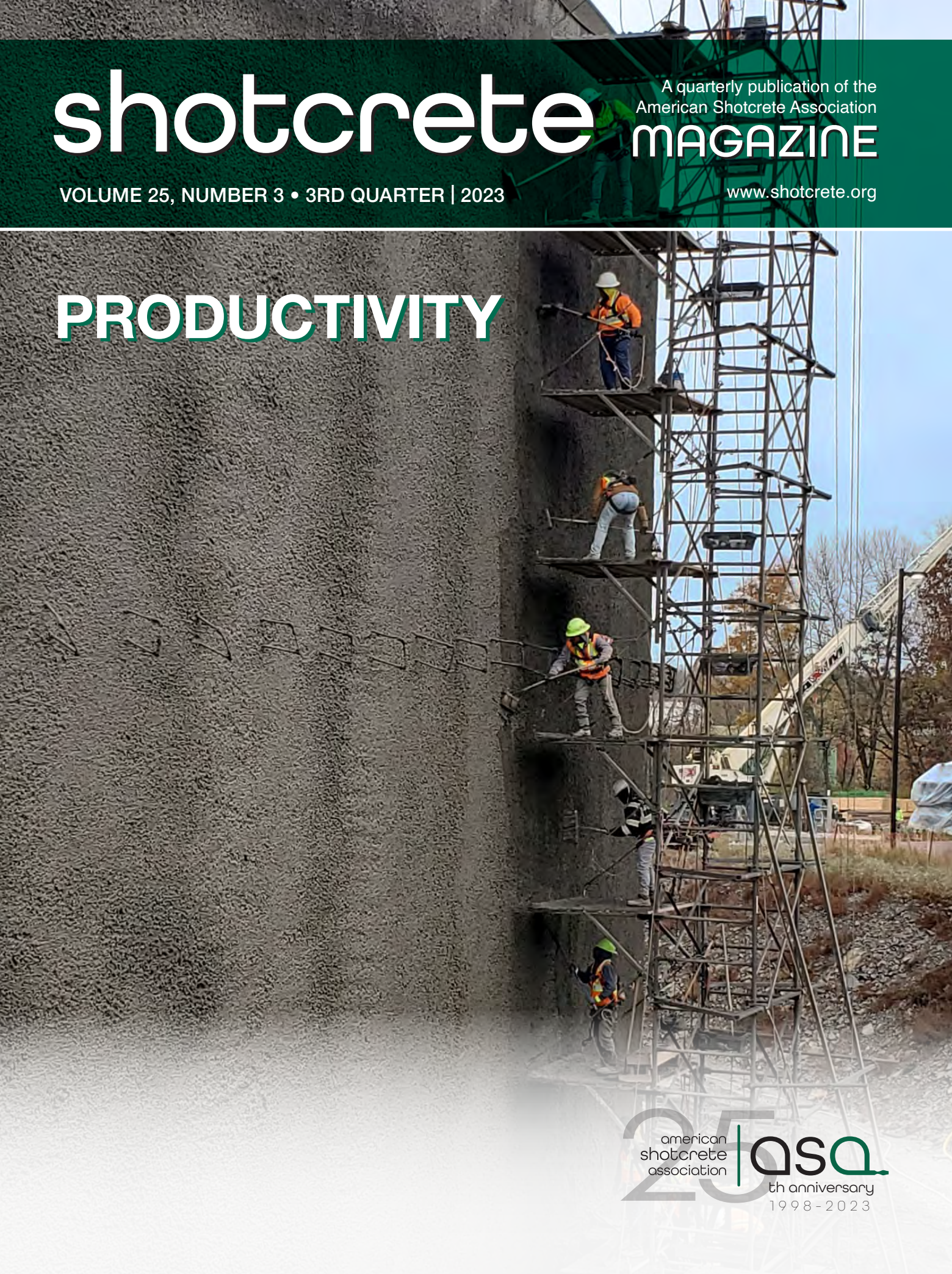
PRODUCTIVITY



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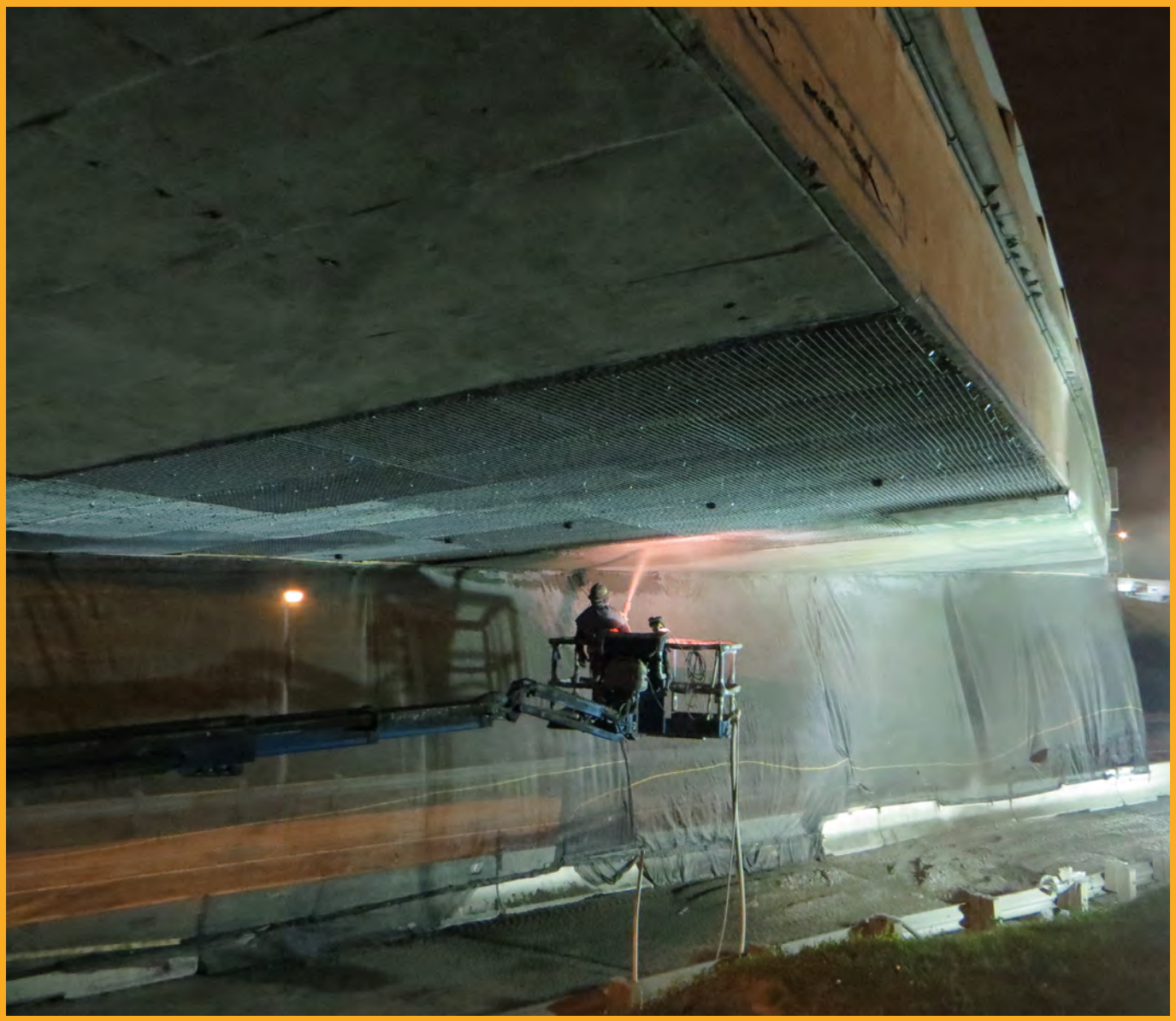

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FEATURES

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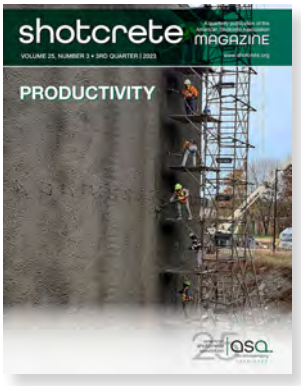
Editor's Note: Shotcrete is a placement method for concrete. However, for the sake of readability, the word "shotcrete" is often used either to identify the shotcrete process (method of placement) or the shotcrete mixture (product materials).

DEPARTMENTS



High-Production, Quality Shotcrete: CROM project in Nicholasville, KY
Read about this project on page 10.

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Make Us Bigger and Make Us Stronger

By Frank Townsend

School is back in session, which means extra stress on parents and students, and more traffic. But to me, it means time to get back into the classroom and educate our successors on what shotcrete is and how it can be used on their future projects. It is time to educate future engineers, project managers, and contractors so they can bring up the good idea to use the shotcrete process on a project to save an owner time and money. By making connections with college-age students now, we will strengthen the connection between their education and the world they live in. Through ASA, we provide valuable tools for students to connect what they learn in the classroom to real-world applications on job sites.

This is the time to publicize what we do to a target audience of university students and students in trade schools. We need to plant the seeds of the benefits of the shotcrete process, how common and appropriate it is, and how often it is being used in their area. Educating them on these things is very important to create momentum in the younger generation. Reaching a wider audience gives ASA, and shotcrete, more credibility and impact.

As these students advance in their careers, they will learn the basics, they will learn the theories, they will practice state-of-the-art research, and they will grow taller, and taller, and taller. But while they are in this stage of learning, we have the ability to turn a "curiosity" moment into an opportunity for acquiring some real-world knowledge. Maybe along the way, we can even get them to feel that astonishment at the wonders of the world. Educating the younger generation on the versatility of shotcrete will open more doors for them to connect professionally with peers, specialized faculty, and industry experts with unique stories and points of view on the world of shotcrete. This is an investment towards STEM (science, technology, engineering, and mathematics) growth, supplying mentors and collaboration opportunities for future work. Showing them that shotcrete opportunities are all around us, and that learning matters, is putting coins into a piggy bank that will eventually support or fund future generations of graduate students and professionals who will specialize in shotcrete placement.

ASA is reaching out to over 100 colleges and universities across the country offering to come into their classrooms and to provide a free class on shotcrete. This is often a great help for concrete and materials professors, providing the only real engagement their students would have with the shotcrete application process.

Trade schools should also not be neglected. They support the backbone/labor force required for the industry. Without the nozzle person, the finishers, and the operators… well, none of us would be here. With the growing demand for the use of this process, we need to train the workforce in correct application practices.

If you know of any interested parties that would like a class, please reach out to us at ASA to make contact. This is a "WE" initiative so it's all hands on deck, guys and gals.

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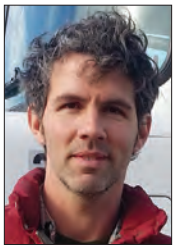
Contractor Qualification and Pool & Recreational Committees

By Ryan Oakes and Marcus von der Hoffen



The ASA Contractor Qualification program (CQP) has evolved since its inception over five years ago. We've implemented many modifications based on input from shotcrete contractors pursuing the qualification, committee members and staff. However, the program was originally designed and currently geared towards general structural shotcrete placement. Consider the Level I and Level II designations:

Level I

- Sections 10 in. (250 mm) or less in thickness
- One curtain of reinforcing with #6 or smaller bars and non-contact lap splices with 2.5 in. (64 mm) separation or more
- Vertical heights up to 11 ft (3.4 m)
- Stable soils, and no ground water or contractual environmental requirements
- No overhead work
- Volume of shotcrete 30 yd3 (23 m3) or less per project

Level II

- Sections greater than 10 in. (250 mm) in thickness
- Projects with reinforcing bars of #8 (#25M) bars or larger in a complex geometry or congested layout
- Vertical heights over 11 ft (3.4 m) requiring a 3-pass wall
- Difficult access, dewatering, or environmental requirements
- Projects with overhead shooting
- Structures that require pre-construction mock-up panels per the applicable Building Code Sections that require water stops, large embeds, pipes or movement joints
- Projects that require scaffolding, man-lifts, confined space, or use of safety harnesses
- Sections that require two curtains of reinforcing or contact lap splices
- Pumping distance greater than 200 ft (61 m) horizontally or 25 ft (7.6 m) vertically
- Scheduling or trade coordination challenges
- Complex formwork, tight tolerances, and/or shapes

Pools have widely varying levels of difficulty. One may see integral spas, rock features, slides, challenging sites, infinity edges, acrylic embedded windows and more. All those items add complexity to a "standard" pool. Looking at the Level I and II designations above you can see that some aspects of pool shotcrete placement may fit into either category, but many items are simply not applicable in pool construction. Most pool shotcrete companies specialize in pools and do not shotcrete infrastructure, underground or other structural applications. Pools are a well-defined product and have a more limited number of specific components or aspects that require quality shotcrete placement.

Thus, the Pool & Recreational Committee (P&R) and the Contractor Qualification (CQ) committees have worked together to develop a new CQP specifically for the pool

industry. P&R committee members edited the existing CQP making modifications to more sharply focus the new program on what pool shotcrete contractors need to do to produce strong, durable concrete pool shells.

For this initial launch, the draft policy details a single "Pool" designation. This provides a third option to the ASA Qualified Contractor program, allowing for "Pool" to follow either process, as their qualification, i.e. for the Qualified Shotcrete Contractor – Wet-Mix-Pool .

Both the CQ and P&R committees are meeting together virtually before our Fall Committee Day (October 28, 2023 in Wakefield, MA) to develop the final draft. We hope to have a proposed Pool CQP to recommend to the Board this Fall 2023. If approved by the Board, we hope to start publicizing the program at pool education sessions and pool-oriented trade shows, such as the International Pool Spa Patio show in November. Look for an article in a future issue of *Shotcrete* that will provide more details on the new program.

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Corporate Reorganization – ASA Style

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

ASA, from a staff perspective, is a continual challenge to get all the programs, certifications, committees, member services, education, and convention handled in an efficient way. And we've made remarkable progress in expanding what ASA means and provides in the concrete construction world.

Accomplishing what we need to do on a daily basis has taken the front seat to what we'd like to do to further advance what ASA does for members and the concrete industry. From the early days of ASA, we've had two staff members. Starting with a part-time Executive Director and a full-time Program Coordinator in the early days, we evolved over our first two decades to a full-time Executive Director (Charles Hanskat) and Assistant Director (Alice McComas). Routine association functions (accounting, IT, customer service, warehouse, etc.) were handled by an association management firm retained by ASA (CAM, then AOE, and now Virtual), though completely monitored by our full-time staff.

But over our first 20+ years, ASA has experienced growth – lots of growth. We have added more programs (like contractor qualification and shotcrete inspector), increased membership, instituted an annual awards program, gotten our committees more active, experienced massive growth in nozzlemen certification, improved *Shotcrete* magazine, started an annual convention, and significantly increased our outreach efforts.

To effectively manage our workload, the Board recognized we needed more "horsepower" to move ASA ahead. In 2020, we brought Tosha Holden, as Managing Editor and Marketing Manager, onboard to handle our quarterly magazine production. She was also charged with increasing our social media outreach and administering the annual ASA Outstanding Shotcrete Project Awards program.

Even with a third full-time staff member, we still found ourselves struggling to fit everything we needed to do in the time available. Enhancements to membership retention, improving our programs, and further increasing outreach to students and potential members are just some of the areas that could benefit ASA and our service to members and the industry. But we needed more resources to accomplish those goals.

When the Board reviewed and approved our revised strategic plan at the ASA 2023 Convention, the decision was made to approve hiring a fourth full-time staff member. We looked at what qualities, experience, and strengths a new person should have to best support our growth alongside our existing staff.

We decided to reorganize. *Shotcrete* magazine demands an extensive editorial effort. One of the strengths of our magazine is the fact that our articles, by and large, come from members - members who are active in the shotcrete world daily. That often means our articles are not always in print-ready condition.

Thus, we looked for someone who could bring editorial experience and good organizational skills on board. Cindy Spires joined our ASA team in August 2023 as Managing Editor. Look at our Association News later in this issue for more information and a picture of Cindy. Cindy jumped into the role with both feet and has already accelerated our ability to get new issues out. She has already brought some great ideas for things we can do to improve the magazine and more easily aid authors in accomplising more timely submission deadlines. Cindy will also be backing up Alice with the nozzleman certification work.

With the magazine production now in Cindy's capable hands, Tosha has transitioned to become Member Engagement and Marketing Manager. She remains responsible for social media, the Awards program, and overall marketing for ASA. However, she will now more actively assist in the work of ASA Committees to develop, support, and enhance membership initiatives for new, existing, and potential members including students. We are excited to see the work of ASA expand.

Through this reorganization, we strive to use the talents of our entire team where they can produce the best results. We're still a small team, and honestly, there are many parts of what we do at ASA, like convention, where we all work together to get everything done. We appreciate our members' support and look forward to making ASA membership more valuable to all.

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High-Production, Quality Shotcrete

By Bruce Russell

High-production shotcrete projects are amazing to observe; when operating at optimum level, it appears to be very simple. Those of us in the shotcrete industry know better; there are many well-trained people and detail-based processes required to make it all happen. The following is a brief layout of what it takes to operate as a high-production shotcrete contractor while producing the highest quality product.

Fig. 2: Shop - Gainesville, FL

SUPPORT STAFF

Office

Our office staff is responsible for all the behind-the-scenes tasks that keep the company running smoothly. These tasks include, but are not limited to, the following:

- Business Development
- Project Management
- Quality Control
- Accounting
- Team Services
- Engineering
- Bidding
- Risk Management
- Estimating
- Internal Support
- Drafting
- Safety
- Software Development
- Marketing

Fig. 2: Shop - Gainesville, FL

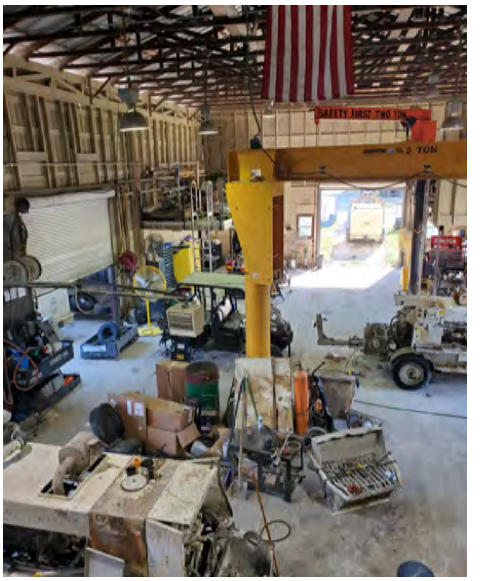


Fig. 3: Shop - Gainesville, FL

The 120 individuals that are part of the office staff mentioned above are responsible for finding the opportunities, designing, bidding, managing, billing, paying bills, and ensuring everyone gets a paycheck every week. Without each and every one of the team members mentioned above performing at a high level, our company couldn't execute the field projects successfully.

Shop

Without all the 75 hard-working individuals at our shop who are developing and maintaining our equipment, our field crews would not be able to produce the high-quality work that we are known for.

Here are some of the primary responsibilities of our shop team:

- The Shipping and Receiving team
- The Mechanics team consists of 7 full-time mechanics responsible for keeping our field equipment maintained and ready to be deployed.
- The Yard crew loads and unloads materials and equipment.
- The Lumber yard crew precuts all our project-specific formwork.
- The Expediting team arranges for our equipment to be shipped to and from our projects.

Field

Our field teams are led by 29 superintendents, 16 of which work in our Coatings and Restorations division. The remaining 13 superintendents build cylindrical, wrapped prestressed concrete tanks. All of these tanks have cast concrete floors with shotcreted walls. Many of our tank building superintendents are ACI-certified nozzlemen. They have worked in the shotcrete industry for over 20 years and have trained numerous nozzlemen over the years.

To give some perspective on the need for an efficient and well-trained field team, last fall we began one of our larger tank projects located in Nicholasville, KY. The project was scheduled for construction extending through the winter months, so we accelerated the project to get as much of the shotcrete applied as possible before the cold winter temperatures in northern Kentucky could set in. We had over 43,000 ft^2 (4000 m^2) of shotcreted vertical wall with an average thickness of 15.5 in. (400 mm). With this large area, and the amount of shotcrete required — over 2,500 yd^3 [1900 m^3]— our management team decided to explore the use of two separate shotcrete crews applying material simultaneously. To do this, there was a lot of pre-planning and coordination required. We assembled two fully outfitted shotcrete teams, each with a pump, air compressor, mobile platforms, certified nozzlemen, and finishing team members. The request was made to the concrete plant to furnish our project with 200 to 250 yd^3 (150 to 190 m^3) per day with 10-yd^3 (7.6 m^3) trucks spaced approximately 20 minutes apart to ensure fresh materials for application. Constant communication with the batch plant was required to adjust the batching and subsequent delivery times as needed.

This project was larger than most of our standard projects, but with the vision to see the project through to completion as a result of our abilities as a “High Quality, High Production” construction company, we were able to substantially shorten our time onsite. The project still lasted through the winter months, but by accelerating the shotcrete process, we were able to complete the bulk of the shotcrete quicker and move on to forming and casting the dome roof before the bitter cold set in. This gave us more options to stay productive while working inside the tank. This is only one example of the way we approach every project by asking the question: what can we do to improve our quality and production?

Fig. 4: Nicholasville, KY

Fig. 5: Nicholasville, KY

Equipment

The standard shotcrete operating equipment we use on our projects consists of the following:

- Minimum 600 CFM (17 m^3/min) air compressor
- Schwing SP 750-15 pump
- 300 – 400 heavy duty concrete pipe and hose (3 in., 2-1/2 in. & 2 in. [75 mm, 63 mm, 50 mm]) with 2 in. HD nozzle body
- Kawasaki KX 60 front end loader
- Mobile arial platform

Fig. 6: Equipment - Nicholasville, KY

Routinely, daily equipment maintenance in the field is performed by our field crews. When projects end, we try to rotate our equipment through our shop in Gainesville where our staff of seven full-time mechanics reside; they maintain, service, and prepare our equipment for next project. Without quality maintenance of the equipment, breakdowns will put a costly halt to production.

Nozzlemen

We currently have 28 ACI-certified shotcrete nozzlemen, and all are certified for wet-mix in a vertical orientation. We have two that are also certified for dry-mix vertical, one that is also dry-mix overhead certified. All our project documents include the following phrase: “all shotcrete applied by or under the direct supervision of an ACI-certified Nozzleman.” This is an important detail in our industry. Over the 70 years that we have been in business, we have spent a great deal

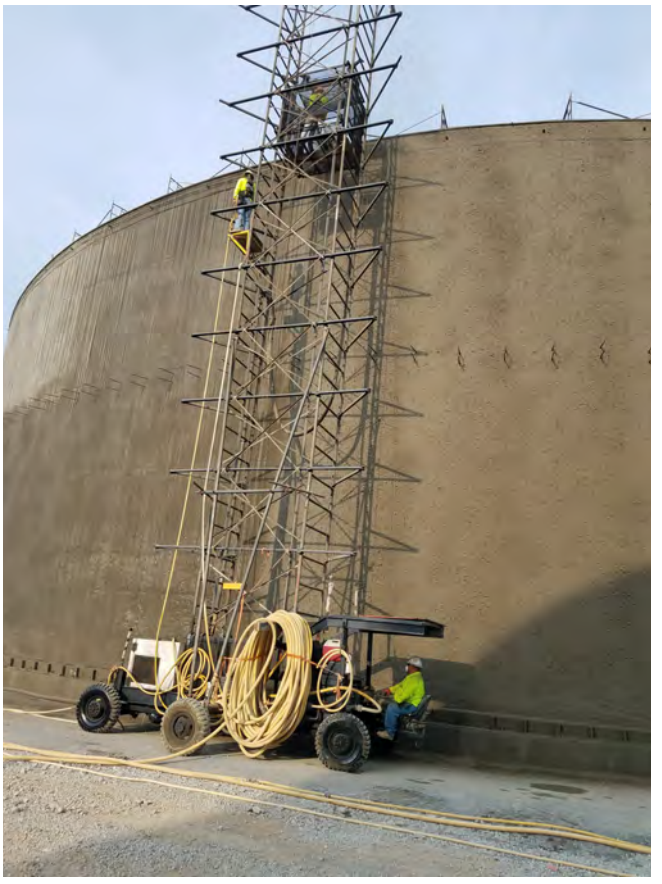


Fig. 7: Equipment - Nicholasville, KY

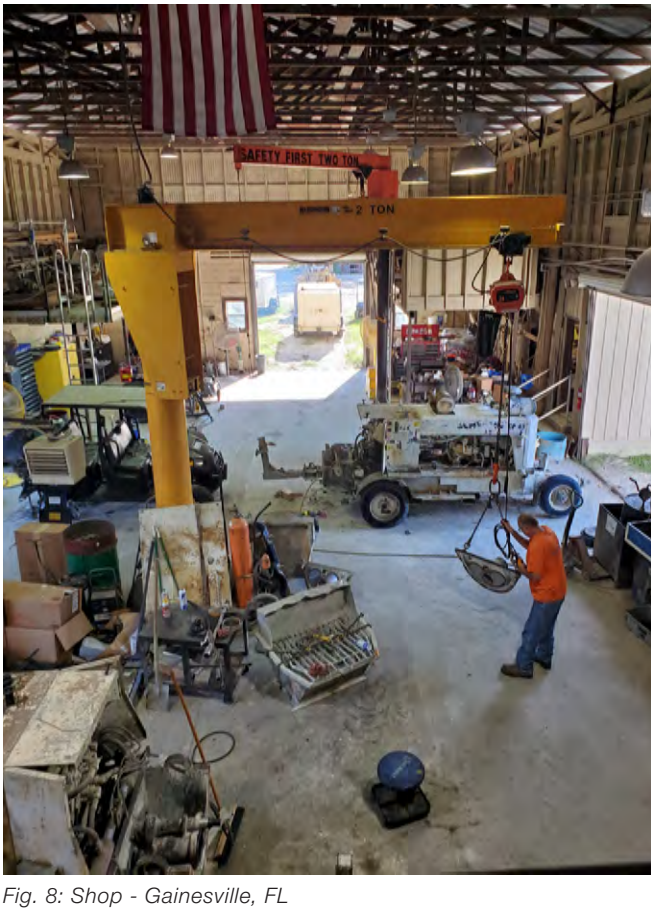


Fig. 8: Shop - Gainesville, FL

of time getting this added to project specifications to ensure only qualified shotcrete contractors are competing for the work.

All of our nozzlemen began their careers as laborers learning while working alongside our more experienced, skilled employees. The first step to becoming a nozzleman is learning the process. They start out dragging hose, shoveling rebound, running the gun, operating the pump, and, back in the day, busting bags on a "Gunite rig." It is very important that the nozzlemen have a detailed understanding of every aspect of the shotcrete operation.

After they master these skills and show interest in learning how to become a nozzleman, the real training begins. They are taught the importance of surface preparation. These are just a few of the countless items our certified nozzlemen always check for before starting the shotcrete application:

- Has all laitance been removed?
- Is the surface clean?
- Is the formwork stable?
- Is the steel reinforcing properly placed and secured?

They learn the importance of "impact velocity" to ensure that reinforcing bars are properly encased. The way encasing steel was explained to me was that "the nozzleman is the last person to ever see that steel before it is going to be encased forever if it is encased properly." Without the proper impact velocity, the material will build up on the surface of the reinforcing bars instead of flowing around and encasing them, which will cause voids left behind the bars.

Fig. 9: Nozzlemen - Nicholasville, KY

Only with time, and working under the direct supervision of certified nozzlemen, will new nozzlemen develop the skills that will become second nature to them. When approaching their projects, they will recognize potential problems with the shotcrete placement, such as protrusions, corners, and any areas that may allow overspray or rebound to build up. These issues need to be addressed before beginning the shotcrete placement, which often means they need to stop

Fig. 10: Nozzlemen - Nicholasville, KY

Fig. 11: Nozzlemen - Nicholasville, KY

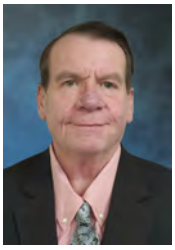
and clean. Other considerations include identifying whether the area is properly dampened to a surface saturated dry (SSD) condition. If not, the nozzleman must stop and get it properly prepped.

The hardest thing a new nozzleman has to learn about productive shotcrete application is that there is no substitute for quality; the areas that will be shot must first be prepared and then finished properly after shotcrete placement.

At the end of the day, the nozzleman is responsible for checking with the other team members to ensure that the shotcrete has been finished correctly and that proper curing has begun. They must also check to be sure that test samples have been stored in a safe place to avoid possible damage.

Summary

A high-production shotcrete operation, when operating at maximum efficiency, looks very organized and can appear to be easy. This is far from the reality. There are countless hours spent teaching and training all the team members on their assigned tasks. The efficient construction by the field teams is dependent on the team members that make up the support staff at the office and shop. It takes every individual performing their assigned tasks to produce the quality product we see in the field.



Bruce Russell *is the Field Operations Director for CROM. He has been involved in the construction of ground water storage tanks ranging from 100,000 gallons to 10,000,000 gallons in the water and wastewater industries since 1984. In 1987, he became a dry-mix "CROM Certified Nozzleman" under the strict performance standards that Ted Crom (founder of CROM in 1953) created, and which he insisted on for all nozzleman to ensure quality shotcrete application. In 2004, Bruce became ACI Certified in wet-mix and remains certified today. In 2014, he took over CROM's nozzleman certification/re-certification program. He serves on the ASA Board of Directors, on the ASA Contractor Qualification Committee, and on the ASA Safety Committee.*

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On Productivity, Job Costing, and Successful Shotcreting

By Ryan Oakes

As a member of the International Honor Society in Economics and with a double BS in Finance and Banking, I came into the world of shotcrete prepared a little differently than most entrants to the field. That was over 20 years ago, but the principles of understanding Time, the Value of Money, and Opportunity Costs are indelibly ingrained into my psyche.

Currently, along with my business partner, who is also from a manufacturing and business background in an international playing field, we run a trucking company, a dry-mix shotcrete company, a PebbleTec company, and a design company all under one roof. Collectively, we have between 55 and 60 employees on any given day. In a business this size, productivity and understanding job costing are key to survival.

I have always found it interesting that within the trades, job costing is understood as "price per foot" or "unit pricing." It's a simple method, but it is as inaccurate as gauging the wind speed with a wet thumb.

We predominantly work with pool builders providing concrete shells for them, but we also do some industrial work. The two worlds, on some levels, couldn't be further apart; on other levels, they are quite identical. It is contracting after all, and the world of contracts often involves a certain number of risks and wild-ass guesses.

Many of our peers in the shotcrete industry price their work based on market rates, and they really don't understand costs. It is an interesting method of pricing, considering our costs can swing wildly and widely with variables such as labor, fuel, overhead, size of job, how the job is priced, distance to the job, and the time consumed for the job overall.

LABOR COSTS

Let's start with the topic of labor. Labor can come in the form of hourly wages, salaried employees, and piecemeal. This all refers to the field workers in most cases, but labor should also consider dispatchers and logistics people, salespeople, warranty or field technicians, loader operators, plant managers, mechanics, management, office staff, executives, etc. All of these non-field workers are still "labor" and have to be considered when understanding overhead costs. I'll dig into overhead later.

> Opportunity cost is a big factor in understanding how to be successful.

> Regardless of the payment method or combination of payments made to field workers, a real understanding of costs accrued by staff, and fairness to staff, need to be understood before setting pricing for a job.

When considering field workers, which is a large portion of labor typically in the shotcrete industry, we have to look at the payment method. Let's take the simplest form first: hourly-wage earners. The average work week can range from 65 to 80 hours. Overtime can play a very real role in the cost of wages for these workers and in the expected earnings of said workers. Taking productivity studies aside (there is a lot of evidence that less hours worked in a given week will produce a more productive crew), the crews like to work, and the clients have rigid timelines, so we all acquiesce and work obscene hours. It's just the nature of shotcrete and concrete construction in general.

Another common form of payment in our industry is piecemeal: pay per pool or per cubic yard (m^3) of concrete. It is really just an average when it comes down to it, and it isn't entirely different than hourly pay. Theoretically, there is an incentive to produce more in the same or less time. There is an upside to the company by fixing the cost per job or volume of concrete, and there is an upside to the employee by getting paid the same whether they finish late or early, possibly even getting another job in that day. The inherent downside is that sometimes employees are abused; other times, the employees take advantage of the company and therefore the client (i.e., they report more cubic yards shot than were used in order to increase their pay).

Finally, we often see salaried employees with foremen or staff who have proven their dedication but want a steady check regardless of the weather and other construction obstacles.

Sobre Productividad, Cálculo de Costos de Trabajo y Éxito en el Shotcrete

Por Ryan Oakes (Raúl Bracamontes, Editor de Traducción)

Como miembro de la Sociedad de Honor Internacional en Economía y con una doble licenciatura en Finanzas y Banca, ingresé al mundo del shotcrete preparado de manera un poco diferente que la mayoría de los que ingresan a esta industria. Eso fue hace más de 20 años, pero los principios de comprender el tiempo, el valor del dinero y los costos de oportunidad están indeleblemente grabados en mi psique. En la actualidad, junto con mi socio comercial, quien también proviene de un entorno de fabricación y negocios en un campo internacional, dirigimos una empresa de transporte, una empresa de concreto lanzado vía seca, una empresa de PebbleTec y una empresa de diseño, todo bajo un mismo techo. En conjunto, tenemos entre 55 y 60 empleados en cualquier día dado. En un negocio de este tamaño, la productividad y la comprensión de los costos laborales son clave para sobrevivir.

Siempre me ha parecido interesante que en los oficios, la evaluación de costos de trabajo se comprende como "precio por pie" o "precio por unidad". Es un método simple, pero tan inexacto como intentar medir la velocidad del viento con el dedo mojado.

Principalmente trabajamos con constructores de piscinas fabricando estructuras de concreto para ellos, pero también realizamos algunos trabajos industriales. Los dos mundos, en algunos aspectos, podrían ser completamente diferentes, pero en otros son muy similares. Al fin y al cabo, se trata de contratos, y el mundo de los contratos a menudo implica cierta cantidad de riesgos y estimaciones aproximadas.

Muchos de nuestros colegas en la industria del concreto lanzado fijan sus precios basados en tarifas del mercado y realmente no comprenden los costos. Es un método interesante de fijación de precios, considerando que nuestros costos pueden variar ampliamente debido a variables como la mano de obra, el combustible, los gastos generales, el tamaño del trabajo, la forma en que se fija el precio del trabajo, la distancia al trabajo y el tiempo total necesario para el trabajo.

> El costo de oportunidad es un factor importante para entender cómo tener éxito.

> Independientemente del método de pago o de la combinación de pagos realizados a los trabajadores de campo, es necesario comprender realmente los costos acumulados por el personal y ser justos con el personal antes de establecer los precios para un trabajo.

COSTOS LABORALES

Comencemos con el tema de la mano de obra. La mano de obra puede ser en forma de salarios por hora, empleados asalariados y pago por trabajo. Esto se refiere principalmente a los trabajadores de campo, pero también se debe considerar a los despachadores y personas de logística, vendedores, técnicos de campo, operadores de maquinaria, gerentes de planta, mecánicos, directivos, personal de oficina, ejecutivos, etc. Todos estos trabajadores que no están en el campo siguen siendo "mano de obra" y deben considerarse al comprender los costos generales. Profundizaré en los gastos generales más adelante.

Cuando se considera a los trabajadores de campo, que son una gran parte de la mano de obra típica en la industria del concreto lanzado, debemos analizar el método de pago. Comencemos con la forma más simple: los trabajadores asalariados por hora. La semana laboral promedio puede variar de 65 a 80 horas. Las horas extras pueden desempeñar un papel importante en el costo de los salarios para estos trabajadores y en las ganancias esperadas de dichos trabajadores. Dejando de lado los estudios de productividad (hay mucha evidencia de que trabajar menos horas en una

Regardless of the payment method or combination of payments made to field workers, a real understanding of costs accrued by staff, and fairness to staff, need to be understood before setting pricing for a job.

KEEPING IT ALL RUNNING

So what keeps the wheels turning in a shotcrete business? In our case, a staff of heavy equipment and diesel mechanics, a fleet manager for a fleet of 40+ vehicles, truck drivers, a logistics coordinator who schedules jobs, crews, hotels, materials procurement, office staff, technical staff, and executive staff. All of these personnel have a cost that has to be allocated to each productive or non-productive day of the year. That's tricky if one day a crew yields only 35 cubic yards and the next day they produce 70. Many of the fixed costs are still inherently the same, yet the cost per cubic yard is vastly different—a hundred percent different when dealing with fixed overhead.

Speaking of fixed overhead, when contemplating costs to operate, one needs to consider their cost of capital. What is that? It is how much it costs you to borrow money, or the opportunity cost of not deploying your own money somewhere else such as in the stock market, in real estate, or in other investments. For most of us, it's the cost of borrowing money. All money has a cost to it.

So, let's consider a simple example: the cost of a pump and truck with an air compressor for a wet-mix crew. Estimate that equipment costs $350,000, amortized over 5 years with an interest rate of 5%. That works out to approximately $6605 per month. If a crew produces 1000 yd^3 every

Fig. 1: Labor considerations: access, coordination, and skill sets all play a role in costing out your team.

semana determinada producirá un equipo más productivo), a los equipos les gusta trabajar, y los clientes tienen plazos rígidos, por lo que todos aceptamos y trabajamos una gran cantidad de horas. Es simplemente la naturaleza del concreto lanzado y la construcción de concreto en general.

Otra forma común de pago en nuestra industria es el pago por unidad: pagar por piscina o por yarda cúbica (m^3) de concreto. En realidad, es solo un promedio cuando se reduce a ello, y no es muy diferente del pago por hora. Teóricamente, existe un incentivo para producir más en el mismo o menos tiempo. Hay un beneficio para la empresa al fijar el costo por trabajo o volumen de concreto, y hay un beneficio para el empleado al recibir el mismo pago, ya sea que terminen tarde o temprano, posiblemente incluso obteniendo otro trabajo en ese día. El inconveniente inherente es que a veces los empleados son abusados; otras veces, los empleados se aprovechan de la empresa y, por lo tanto, del cliente (es decir, informan más yardas cúbicas lanzadas de las que se utilizaron para aumentar su pago).

Finalmente, a menudo vemos empleados asalariados con capataces o personal que han demostrado su dedicación pero desean un cheque constante independientemente del clima y otros obstáculos de construcción.

Independientemente del método de pago o la combinación de pagos realizados a los trabajadores de campo, es necesario comprender realmente los costos incurridos por el personal y ser justos con el personal antes de fijar el precio de un trabajo.

Fig. 1: Consideraciones laborales: el acceso, la coordinación y las habilidades desempeñan un papel en la evaluación de costos de su equipo.

Fig. 2: Equipment & material costs: owning, maintaining, transporting and storing should be considered.

month of the year, that's only $6.61 per yd^3, but if a crew produces half that, then well, it's $13.21 per yd^3. If it's an occasional crew that shoots a pool a month, well that equipment costs $132.1 per yd^3, and that's before labor, insurance, and all of that other overhead I just mentioned. What does that mean? First, it's unlikely that one could justify the cost of a shotcrete pump unless they shoot at least a few pools a week; second, it really takes a pool or a job a day to make it pay for itself and be profitable.

Now that we are running every piece of equipment every day, we need mechanics, whether in-house or subcontracted, to work on that equipment. So, one needs to figure out the staff costs to keep that equipment working. Mechanics also need a place to work if it's in-house, so rent

Fig. 2: Costos de equipo y materiales: la propiedad, el mantenimiento, el transporte y el almacenamiento deben ser considerados.

MANTENIÉNDOLO TODO EN FUNCIONAMIENTO

Entonces, ¿qué mantiene en funcionamiento un negocio de concreto lanzado? En nuestro caso, un personal maquinaria pesada y de mecánicos diésel, un gerente de flotilla para una flota de más de 40 vehículos, conductores de camiones, un coordinador de logística que programa trabajos, equipos, hoteles, adquisición de materiales, personal de oficina, personal técnico y personal ejecutivo. Todos estos empleados tienen un costo que debe asignarse a cada día productivo o no productivo del año. Eso es complicado si un día un equipo produce solo 35 yardas cúbicas y al día

or a mortgage on a building, as well as other costs, go into play in this equation. How much space in your facility is allocated to your mechanics? Divide that number into your cost of owning or renting along with allocated insurance and tax for that space.

The same approach applies to office staff and all the other supporting staff roles I mentioned earlier. Every person needs a place to sit, file papers, have a workstation, etc. Restrooms, break rooms, and storage areas are all pertinent as well. Hidden costs come in the form of cleaning staff, exterior maintenance, vending machines, ice machine maintenance, air conditioning, heat, electricity, telephones, cell phones, internet, and the dreaded costs of insurance (inland marine, auto, work comp, general liability, etc.). Finally, take some percentage of any profit away for Uncle Sam! All of this must be divided into how many jobs you perform or how many yd^3 you produce each month or year. This is how we begin to understand the cost of operation.

HOW TO PRICE IT

Now that we are beginning to understand the true costs of our work, let's consider our pricing structure.

As I mentioned earlier, our industry is misguided—it sees work as a unit and not much more. So that puts us, as the suppliers or applicators, in the tough position of adhering to that method and not going out of business. Fair enough. We get to adapt, but we have to do so as informed business owners or managers and truly understand our costs to be able to understand how to price a job.

Take for example a basic swimming pool with a very simple set of steps that consumes 40 yd^3 of concrete. This pool can be finished in half a day, give or take a couple of hours. Add bar stools, a cover box, a vanishing edge, a tanning shelf, deep-end benches, and a large set of stairs or two, and now this pool will not only take a full day but probably two days. Maybe we added 10 yd^3 of billable material all in, but did that make up for spending all that labor and overhead, not just for a half day or a whole day, but for two whole days? With the additional labor required, we are only placing 25 yd^3 per day, not 40 or 50 yd^3, but for the same costs of two jobs that could have used 50 yards each. In other words, pricing by material used for this job is much less profitable than pricing for two simpler pools, placing more material with less time intensive work.

It's bad enough that we are going to spend all that energy for half the volume of concrete (the way most shotcreters invoice), but that loss is compounded by the lost opportunity cost of not shooting another job the next day. This is a very key point. For example, you can earn two days of revenue for $15,000 each day plus incur the costs of two days, or you can earn one day's revenue but incur two days of costs. There is a clear problem with this.

siguiente produce 70. Muchos de los costos fijos siguen siendo inherentemente los mismos, pero el costo por yarda cúbica es muy diferente: un cien por ciento diferente cuando se trata de gastos generales fijos.

Hablando de gastos generales fijos, al contemplar los costos operativos, uno debe considerar su costo de capital. ¿Qué es eso? Es cuánto le cuesta a uno pedir prestado dinero o el costo de oportunidad de no invertir su propio dinero en otro lugar, como en el mercado de valores, en bienes raíces u otras inversiones. Para la mayoría de nosotros, es el costo de pedir prestado dinero. Todo dinero tiene un costo.

Entonces, consideremos un ejemplo simple: el costo de una bomba y un camión con un compresor de aire para un equipo de lanzado vía húmeda. Supongamos que el equipo cuesta $350,000, amortizado en 5 años con una tasa de interés del 5%. Eso equivale a aproximadamente $6605 al mes. Si un equipo produce 1000 yardas cúbicas cada mes durante todo el año, eso son solo $6.61 por yarda cúbica, pero si un equipo produce la mitad de eso, bueno, son $13.21 por yarda cúbica. Si es un equipo ocasional que construye una piscina al mes, entonces ese equipo cuesta $132.1 por yarda cúbica, y eso es antes de considerar la mano de obra, el seguro y todos los otros gastos generales que mencioné anteriormente. ¿Qué significa eso? En primer lugar, es poco probable que uno pueda justificar el costo de una bomba de concreto lanzado a menos que lance al menos unas cuantas piscinas a la semana; en segundo lugar, realmente se necesita una lanzar piscina o un trabajo al día para que se pague por sí misma y sea rentable.

Ahora que estamos utilizando cada equipo todos los días, necesitamos mecánicos, ya sea internos o subcontratados, para mantenerlos trabajando. Entonces, uno necesita calcular los costos del personal para mantener ese equipo funcionando. Los mecánicos también necesitan un lugar para trabajar si están en la empresa, por lo que el alquiler o la hipoteca de un edificio, así como otros costos, entran en juego en esta ecuación. ¿Cuánto espacio en sus instalaciones se asigna a sus mecánicos? Divida ese número en su costo de propiedad o alquiler junto con el seguro y los impuestos asignados para ese espacio.

El mismo enfoque se aplica al personal de oficina y a todos los otros roles de apoyo que mencioné anteriormente. Cada persona necesita un lugar para sentarse, archivar documentos, tener una zona de trabajo, etc. Los baños, las salas de descanso y las áreas de almacenamiento también son pertinentes. Los costos ocultos incluyen personal de limpieza, mantenimiento exterior, máquinas expendedoras, mantenimiento de la máquina de hielo, aire acondicionado, calefacción, electricidad, teléfonos, teléfonos celulares, internet y los temidos costos de seguros (marítimo interior, automóvil, compensación laboral, responsabilidad general, etc.). Finalmente, ¡reserve un porcentaje de cualquier ganancia para el Tío Sam! Todo esto debe dividirse en la cantidad de trabajos que realiza o en la cantidad de yardas cúbicas que produce cada mes o año. Así es como comenzamos a comprender el costo de operación.

CÓMO FIJAR EL PRECIO

Ahora que estamos empezando a comprender los costos reales de nuestro trabajo, consideremos nuestra estructura de precios.

Como mencioné anteriormente, nuestra industria está desorientada, ve el trabajo como una unidad y no mucho más. Eso nos coloca, como proveedores o aplicadores, en una posición difícil de adherir a ese método y no quebrar. Está bien. Tenemos que adaptarnos, pero debemos hacerlo como propietarios o gerentes informados y comprender realmente nuestros costos para poder entender cómo fijar el precio de un trabajo.

Tomemos, por ejemplo, una piscina básica con un conjunto muy simple de escalones que consume 40 yardas cúbicas de concreto. Esta piscina se puede terminar en medio día, más o menos unas horas. Agregue taburetes, una caja de cobertura, un borde desvanecido, una plataforma para broncearse, bancos en el extremo profundo y un gran conjunto de escaleras o dos, y ahora esta piscina no solo llevará un día completo, sino probablemente dos días. Tal vez agregamos 10 yardas cúbicas de material facturable en total, pero ¿compensó eso los costos de mano de obra y gastos generales, no solo por medio día o un día completo, sino por dos días completos? Con el trabajo adicional requerido, solo estamos colocando 25 yardas cúbicas por día, no 40 o 50 yardas cúbicas, pero con los mismos costos de dos trabajos que podrían haber utilizado 50 yardas cada uno. En otras palabras, fijar el precio por el material utilizado para este trabajo es mucho menos rentable que fijar el precio por dos piscinas más simples, colocando más material con un trabajo menos intensivo en tiempo.

Es lo suficientemente malo que vamos a gastar toda esa energía para la mitad del volumen de concreto (como la mayoría de los aplicadores de concreto lanzado facturan), pero esa pérdida se suma al costo de oportunidad perdido de no lanzar otro trabajo al día siguiente. Este es un punto muy importante. Por ejemplo, puedes ganar dos días de ingresos de $15,000 cada día más incurrir en los costos de dos días, o puedes ganar los ingresos de un día pero incurrir en los costos de dos días. Hay un problema claro en esto.

Tomemos la industria de las piscinas como ejemplo. La mayoría de las empresas de concreto lanzado solo cobran por yarda cúbica de material sin importar cuán complicada sea la piscina. ¿Por qué? Como se demostró, su costo puede ser mayor que lo que facturaron por el trabajo. Como respuesta a esto, uno debe considerar todos los elementos que se agregan a un trabajo, incluyendo TODOS los elementos detallados: spas, bordes desvanecidos, cajas de cobertura, vigas elevadas, etc. Todos estos detalles tienen un costo adicional para realizarlos, por lo que uno debería cobrar un costo adicional por estos elementos.

En el mundo de la infraestructura e industrial, no es diferente. El tiempo es dinero y uno debe permitir el tiempo de espera para aprobaciones, inspectores, paneles de prueba, maquetas, etc. Pagar a un equipo experimentado de concreto lanzado para esperar a todos los mencionados

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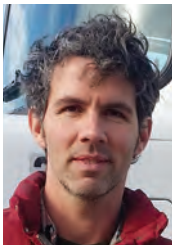
Let's take the pool industry for example. Most shotcrete companies only charge per yd^3 of material no matter how complicated the pool. Why? Their cost, as demonstrated, can cost more than what they billed for the job. As an answer to this, one should consider all the items that are added to a job, including ALL the detail items: spas, vanishing edges, coverboxes, raised beams, etc. All of these details cost extra money to perform, so one should charge extra money for these items.

In the infrastructure and industrial world, it is no different. Time is money, and one needs to allow for time waiting on approvals, inspectors, test panels, mock-ups, etc. Paying an experienced shotcrete crew to wait around for all of the above, only to shoot 2 ft^3 by the end of the day, is a very costly practice.

Speaking of time: we must consider travel. Travel can have the obvious costs of paying staff for windshield time and fuel costs, but the hidden costs of oil changes, tires, suspension, general maintenance, and, most importantly, the opportunity costs of not working somewhere more local. For example, can your crew do two jobs locally versus one job somewhere else? Did you drive three hours today, do the job, and drive three hours back today? Did you pay for hotel rooms? Pay for food? Could you have done two jobs in town? Did you drive today, work tomorrow, and drive home the next day? WOW! That could have been three jobs locally! Opportunity cost is a big factor in understanding how to be successful.

To be successful in this industry, one needs to have a bit of financial savvy and a lot of grit. Start paying attention to your costs and adjust your pricing accordingly. It does no good to anyone to work for just a paycheck. There is too much liability in our shotcrete businesses to not make a profit. A successful company knows their costs to do work and will be prepared to make and pay for mistakes. The successful shotcrete contractor should be in it for the long haul, allowing them to serve the industry for decades, not just a few years during boom times with high demand.

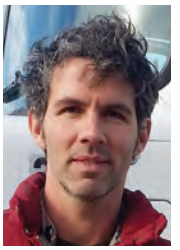


Ryan Oakes *is a Professional Watershape Designer and President of Clearwater Construction Group Inc., Revolution Gunite, and Revolution Pool Finishes, all of which are award-winning firms in their respective trade. Oakes is a faculty member at Watershape University, where he continually aims to raise the bar in the swimming pool and the watershape construction industry. As a member of the leadership team for the International Watershape Institute (IWI) and through educational outreach to a vast pool builder network throughout the United States, he aims to improve the building techniques and methods of constructing swimming pools. Oakes is a member of ACI Committee 506, Shotcreting, and ACI Subcommittee 506-H, Shotcreting Pools. He serves on the ASA Board of Directors and also serves as Vice Chair of both the ASA Pool & Recreational Shotcrete Committee and the ASA Contractor Qualification Committee.*

anteriormente, solo para lanzar 2 pies cúbicos al final del día, es una práctica muy costosa.

Hablando de tiempo: debemos considerar los viajes. Los viajes pueden tener los costos obvios de pagar al personal por el tiempo en carretera y los costos de combustible, pero también los costos ocultos de cambios de aceite, neumáticos, suspensión, mantenimiento general y, lo más importante, los costos de oportunidad de no trabajar en algún lugar más cercano. Por ejemplo, ¿puede su equipo hacer dos trabajos localmente en lugar de uno en otro lugar? ¿Manejan durante tres horas hoy, hacen el trabajo y manejan durante tres horas de regreso hoy? ¿Pagaron habitaciones de hotel? ¿Pagaron por la comida? ¿Podrían haber hecho dos trabajos en la ciudad? ¿Manejaron hoy, trabajaron mañana y manejaron de regreso a casa al día siguiente? ¡VAYA! Eso podría haber sido tres trabajos en la zona local. El costo de oportunidad es un factor importante para comprender cómo tener éxito.

Para tener éxito en esta industria, uno necesita tener un poco de conocimiento financiero y mucha determinación. Comience a prestar atención a sus costos y ajuste sus precios en consecuencia. No sirve de nada trabajar solo por un salario. Hay demasiada responsabilidad en nuestros negocios de concreto lanzado como para no obtener beneficios. Una empresa exitosa conoce sus costos para realizar el trabajo y estará preparada para cometer y pagar errores. El contratista exitoso de concreto lanzado debe estar en esto a largo plazo, lo que le permitirá servir a la industria durante décadas, no solo durante unos pocos años durante tiempos de auge con alta demanda.



Ryan Oakes *es un Diseñador Profesional de Watershape y Presidente de Clearwater Construction Group Inc., Revolution Gunite y Revolution Pool Finishes, todas las cuales son empresas galardonadas en sus respectivos campos. Oakes es miembro del cuerpo docente en Watershape University, donde se esfuerza constantemente por elevar el estándar en la construcción de piscinas y watershapes. Como miembro del equipo de liderazgo del International Watershape Institute (IWI) y a través de la divulgación educativa a una amplia red de constructores de piscinas en todo Estados Unidos, su objetivo es mejorar las técnicas de construcción y los métodos de construcción de piscinas. Oakes es miembro del Comité ACI 506, Shotcreting, y del Subcomité ACI 506-H, Shotcreting Pools. También forma parte de la Junta Directiva de ASA y se desempeña como Vicepresidente tanto del Comité ASA Pool & Recreational Shotcrete como del Comité ASA Contractor Qualification.*

Enhancing Efficiency and Safety in Concrete Shaft Restoration: A Shotcrete Success Story

By Jacqueline Ipema

In September 2021, American Concrete Restorations Inc. was contracted to perform 60 yd³ (46 m³) of concrete repairs to an existing shaft that is used to access an underground tunnel system in a southern suburb of Chicago, IL. The job was for the Metropolitan Water Reclamation District of Greater Chicago, Thornton Construction Shaft. The dimensions of the shaft are 250 ft (76 m) deep and 30 ft (9 m) in diameter, and the only access is from the top using a crane basket. The project specifications called for the use of a polymer-modified, bagged product using the form-and-pour method to replace the old concrete.

After an initial sounding of the shaft, it was evident there would be additional material required. Upon demolition, the depths of the patches increased as well—some up to 18 in. (450 mm) deep and exposing two layers of rebar. We saw a perfect opportunity to submit shotcrete as an approved alternative to the originally designed form-and-pour method.

Fig. 1: Photo looking down shows several of the large repairs extending the whole circumference of the shaft.

Fig. 2: Photo from the work basket showing distance to some of the further repairs.

Fig. 3: Photo showing large repair areas with complex shapes making it difficult to form.

Fig. 4: Large Repair area.

Fig. 5: Large repair that was converted from a form-and-pour to a shotcrete method repair.

We submitted a 6000 psi (41 MPa) ready-mix concrete mixture with steel fibers. After careful review, it was accepted and approved. Our request for doubling the thickness of a spray-on curing compound to enhance curing was also approved.

Using shotcrete placement, we were confident we could increase productivity. However, supply chain issues affected the availability of ready-mix shotcrete, specifically with

Fig. 6: Finished repair.

Fig. 7: Completed shaft repairs.

the specialty admixtures needed for shotcrete. Overall, using shotcrete placement increased productivity when compared to the original schedule that used form-and-pour. The biggest factor in saving time was not having to install and remove formwork. Because the shaft is circular, special curved formwork would have been required, along with additional reinforcing of the formwork to prevent blowouts from the liquid concrete pressure during casting. Additionally, using a curing compound on the shotcreted surface eliminated the time needed to remove the formwork and patch any imperfections to the formed surfaces of the repairs.

Using shotcrete's versatility and efficiency clearly demonstrated its many advantages when compared with form-and-pour. Not only was shotcrete the solution for greater productivity, it was also the solution for numerous safety concerns. All of the shotcrete work was performed from the top of the shaft, including the delivery of concrete from the ready-mix trucks. The mounted steel delivery line, air, and water hoses going down the shaft offered considerably less risk than lowering and manhandling lumber in mass quantities for formwork. Also, if a problem with concrete placement had occurred in the middle of an unreachable patch, it would have required the removal of the form to remedy the issue.

Shotcrete placement by ACI-certified nozzlemen could be completed immediately after preparing the old concrete substrate with sandblast or high-pressure water blasting of the area to be patched. The shotcrete process allows immediate visual confirmation of the encapsulation of the embedded reinforcing steel as opposed to pumping concrete blindly into a form that could easily result in voids if not fully vibrated and consolidated.

Because of the inherent versatility and efficiency of shotcrete placement, we were able to place high-quality and durable concrete while improving safety measures and saving time.

Jacqueline Ipema *is the President of American Concrete Restorations Inc (ACR). was established in 2003 and specializes in concrete repairs and restoration to key infrastructure and industrial projects. Jackie graduated with a bachelor's degree from Bradley University in 2010 and has had a variety of business-related jobs until starting at American Concrete in 2020. With a family history in concrete and business ownership, she has always been interested in the construction industry and is thrilled to be part of such a great community.*

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Advances in Shotcrete Technology for Ground Support in Tunnels and Mines in North America

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ABSTRACT

In recent years, shotcrete has been widely used for ground support in civil tunnels and mines in North America. Shotcrete technologies have advanced with robust robotic sprayers, high-performance shotcrete mixture designs, and high-performance fiber reinforcement in conjunction with rigorous qualification of shotcrete nozzlemen and QC inspection and testing programs. Design engineers and contractors are using shotcrete more and more often for various underground applications including ground support and final linings in tunnels in soft ground and hard rock mines, as well as in repair and rehabilitation projects in railway tunnels and other underground openings. Large underground caverns have been constructed using shotcrete as the initial liner in San Francisco and Los Angeles, and for both the initial liner and final liner in New York and Washington D.C. This article focuses on recent underground shotcrete technology developments from project experience and provides lessons learned. It also demonstrates that proper quality control and shotcrete qualification programs are critical for successful shotcrete projects.

CHARACTERISTICS REQUIRED OF SHOTCRETE MATERIALS FOR SUCCESSFUL UNDERGROUND SHOTCRETE APPLICATION:

- Workable, i.e., cohesive
- Have proper slump and consistency, not segregating during transport or pumping
- Pumpable, i.e., have good workability for pumping
- Shootable, i.e., work compatibly with the shotcrete pump, hose, and nozzle, and be efficiently managed/controlled by the nozzleman
- Constructable, i.e., the shotcrete mixture as batched, supplied, and transported must be able to be applied as designed/planned, and not cause any delay to the construction schedule
- Incidents, such as excessive loss of slump or temperature rise, flash set, hose plugs, and shotcrete fallout occurrences should be minimized during construction.

Introduction

Shotcrete is a process for pneumatically conveying concrete materials at high velocity to a receiving surface to achieve in-place compaction. While shotcrete has been used for over a century, the use of shotcrete for ground support in tunnels, mines, shafts, and other underground structures has become increasingly popular during the past decade (Ref. 1-9). Advances in shotcrete technology include using high-performance shotcrete mixtures, advanced robotic sprayers operated by a remote controller, alkali-free accelerator, and high-performance fibers, including both macro-synthetic fibers and steel fibers.

During the past decade, the authors have worked on a number of major civil tunnel and mining projects across the US and Canada. The authors have provided shotcrete mixture designs, monitored trial shoots, and tested shotcrete both in the field and in the laboratory. Through these projects, the authors have accumulated over a decade of data on shotcrete performance and project experience as discussed in this paper.

Shotcrete mixture design for underground support

Shotcrete can be used as an initial liner for ground support during the tunneling process. In soft ground tunneling methods, such as The New Austrian Tunneling Method (NATM), also known as the Sequential Excavation Method (SEM) or Sprayed Concrete Lining method (SCL), shotcrete is a critical component for tunnel construction. Large SEM caverns include Beacon Hill station, Seattle, 2006; Chinatown Central Subway station, San Francisco, 2016; Regional

Connector, Los Angeles; and Purple Line transit, Washington D.C. Shotcrete can also be used for hard rock mining with tunnel boring machines (TBM) or with drill and blast methods to provide final liner support. These projects include hydro-electrical tunnel projects such as John Hart Dam underground tunnel, Campbell River, BC; Upper Lillooet Hydroelectrical Project, Pemberton, BC; Kemano T2 completion project, Kemano, BC; and water supply tunnel projects, such as the Seymour-Capilano Completion project, North Vancouver, BC. All of these projects required shotcrete to be applied in both overhead and vertical orientations; to develop sufficient early age compressive strength (up to 24 hrs) for ground support; to meet specified compressive strength at 7 & 28 days; to achieve specified bond strength to the rock; and to meet durability requirements. Typical specified performance requirements are listed in Table 1.

Mixture Design

Shotcrete mixtures are designed to meet the specified performance requirements and to provide suitable constructability. Compared to cast-in-place concrete, shotcrete mixtures typically have:

- A higher cementitious materials content to minimize rebound and provide suitable shootability.
- Enhanced workability for pumping, and dispersion of liquid accelerator addition at the nozzle (when used).
- Lower coarse aggregate content, i.e., higher sand content to minimize rebound and facilitate pumping and shooting.
- An extended slump retention time to meet the construction schedule requirements.

Supplementary cementitious materials (SCMs) are widely used in shotcrete. These include, but are not limited to, fly ash, silica fume, and slag. SCMs react with calcium hydroxide, a by-product of the cement hydration process, to form Calcium-Silica-Hydrate (CSH) through the pozzolanic reaction process. This results in reduced porosity and enhanced compressive strength and durability in the applied shotcrete. SCMs have similar or smaller particle sizes than cement, and based on that, they can help compact or densify the mixture through grain-size distribution. In addition, fly ash and silica fume particles are mainly spherical in shape, which enhances the pumping and shooting characteristics of the mix. Each type of SCM is added at a certain percentage by mass of total cementitious materials for the shotcrete to meet performance and constructability requirements. Table 2 shows a typical wet-mix shotcrete mixture design for ground support.

Water : cementitious ratio (w/cm)	Max. 0.45
Early age compressive strength:	1.5 hrs > 1 MPa, 6 hrs > 4 MPa, 24 hrs > 10 MPa
Compressive Strength:	10 MPa at 3 days, 20 MPa at 7 days, 35 MPa at 28 days,
Permeability:	Boiled Absorption: <8%; Volume of Permeable Voids: <17%
Set time:	Initial set <15 minutes; Final set <50 minutes
Slump (wet-mix):	150-200 mm
Shotcrete Temperature:	10-25 °C
Flexural strength:	Minimum of 4 MPa at 28 days
Flexural toughness performance (TPL) to ASTM C1609:	Level III at 7 days
Flexural toughness to ASTM C1550:	250 Joules (3 days); 350 Joules (7 days); 450 Joules (28 days)
Air content:	3-6% as-shot
Air void spacing factor:	Maximum of 300 um
Chloride ion permeability:	Maximum 1000 Coulombs at 56 days
Bond strength:	Minimum of 1 MPa at 28 days

Table 1: Typical Performance Requirement for Shotcrete in Underground Applications

Material	**Mass per m^3 SSD Agg, [kg]**
Cement Type GU	410
Silica Fume	40
Coarse Aggregate (10-5 mm, SSD)	430
Fine Aggregate (SSD)	1320
Estimated Water, L	185
Superplasticizer, L	1
Macro synthetic Fiber	7
Hydration Control Admixture, L	1
Air Content (4.5-6.5%)	3.5
Total	2394

Table 2: Wet-mix design from the Upper Lillooet Hydroelectric Project (Ref. 9)

Alkali-free accelerator

Alkali-free accelerator (AFA) is added into wet-mix shotcrete at the nozzle to accelerate the setting time and early age compressive strength development from 1-24 hours. The rate of early-age compressive strength development is critical for ground support as it will reduce the construction cycling time for excavation and ground support. Since early 2000, AFA has been used in the shotcrete industry to replace alkali-based accelerators.

AFA has a pH value of 2-4, which is similar to carbonated cola drinks. AFA can be added as a liquid chemical admixture at the nozzle for wet-mix shotcrete applications or as a powder chemical admixture that is preblended into the shotcrete mixture for dry-mix shotcrete applications.

For most ground support requirements, an early-age compressive strength of 1.0-2.0 MPa (145-290 psi) is required for the applied shotcrete to facilitate construction activities. AFA must be added at the proper dosage to achieve suitable early-age compressive strength development. Based on the authors' experience with many tunneling projects, it generally takes an AFA dosage of about 4-6% by mass of cement to reach the required strength in about 1-3 hours. Variations in the early-age compressive strength development are dependent on the shotcrete mixture design, including the type of cement and chemical admixtures used, the accelerator brand and performance, the shotcrete temperature, the ambient temperatures, and the proper handling and dispensing of accelerator and shooting skills of the shotcrete nozzlemen. Fig. 1 shows typical early-age compressive strength development with AFA dosage when plotted to the J1-J2-J3 curve template developed by the Austrian Concrete Society (Ref. 10, 11). J2 is generally considered the minimum performance requirement for shotcrete early-age compressive strength development for most ground support projects.

When different types of cement are used, such as Type V or Type GUL (Type GU with 15% limestone), the set time may be delayed. Therefore, a higher dosage of AFA is required to develop the early-age compressive strength properly. AFA will, however, reduce the later-age compressive strength, including the 7 and 28-day compressive strengths. Fig. 2 shows the compressive strength development for a wet-mix shotcrete with 0, 4%, 6% and 8% AFA. It shows that with 8% AFA added into the shotcrete, the compressive strength at 28 days could reduce from 62 MPa (9000 psi) to about 36 MPa (5200 psi). Therefore, it is important to add the accelerator at the design/specified dosage to minimize adverse effects on later-age compressive strength development.

Fiber-reinforced shotcrete advancement

The most significant property of fiber-reinforced shotcrete (FRS) is the energy absorbed after the shotcrete cracks, i.e., the flexural toughness. After shotcrete cracks, fibers are pulled out or fractured during the cracking process, thereby

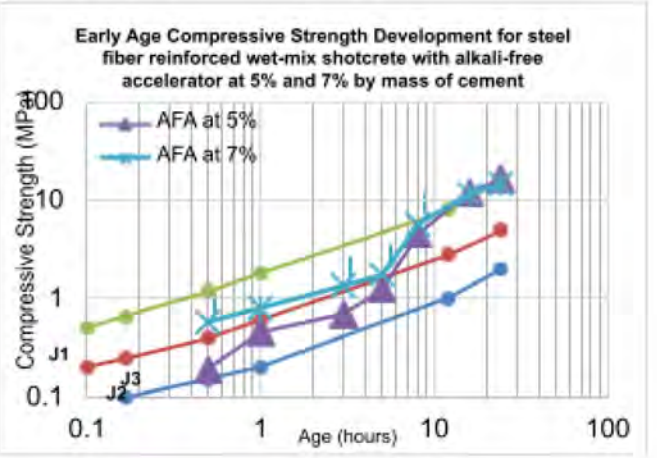

Fig. 1 Early age compressive strength development for steel fiber reinforced shotcrete mixture with 15% fly ash at 5% and 7% AFA

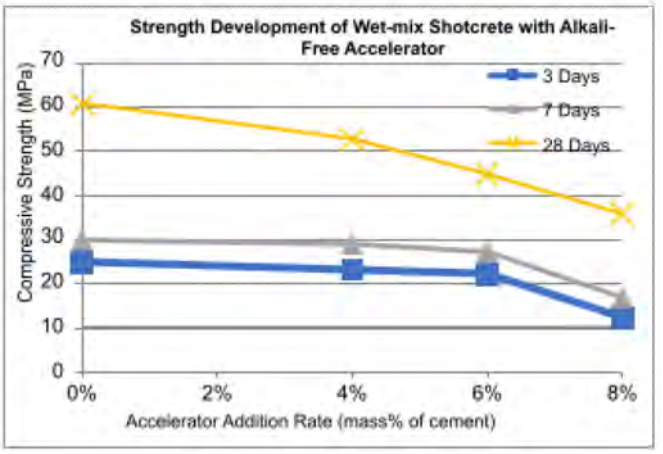

Fig. 2: Effect of Accelerator Dosages on Compressive Strength from 3 to 28 days

redistributing loads and controlling crack propagation as the FRS lining system experiences deformation. Both macrosynthetic and steel fiber are used in wet-mix shotcrete in underground applications throughout North America. The fibers are used to replace, either partially or completely, the steel mesh in the ground support system, reduce the construction cycle time, and generally provide overall better performance in ground support. Combining fiber-reinforced shotcrete with a suitably designed rock anchor system is one of the most efficient ground support systems used in many mines and civil tunnels.

Design of the FRS is commonly based on performance-based design methods which utilize flexural toughness testing results. Typical flexural toughness test methods include the following:

- ASTM C1550 Determination of Flexural Toughness with Central Loaded Round Panel Test
- ASTM C1609 Determination of Flexural Toughness with Third Point Loaded Beam Test
- RILEM TC 162-TDF: Test and design methods for-steel fiber-reinforced concrete (notched beam test)
- British Standard (BS) EN 14651 Test for metallic fiber concrete – measuring flexural tensile strength (notched beam test)

The flexural toughness, the residual strength, and the peak load (peak strength) are the most important factors when evaluating the performance of fiber-reinforced shotcrete.

During the past decade, the authors have conducted over 5000 flexural toughness and residual tensile strength tests for FRS used in underground projects across the US and Canada. Examples of these test results will be analyzed and published in a future paper. Based on project experience, there are three typical project specifications for flexural toughness performance requirements for FRS utilized in North America.

Toughness performance level (TPL) based on the ASTM C1609 test

When the TPL is specified, it requires the shotcrete test panel to be cut into beams with dimensions of 100x100x350 mm (4x4x14 in.) and tested to ASTM C1609. Sometimes, shotcrete samples can be shot directly into 150x150x550 mm (6x6x22 in.) beam molds, with both ends slanted to prevent accumulation of rebound. Over 3000 FRS beams have been tested by the authors to ASTM C1609 since 2011. It has been found that if the TPL meets the Toughness Performance Level III, it generally meets the support requirements for most ground conditions.

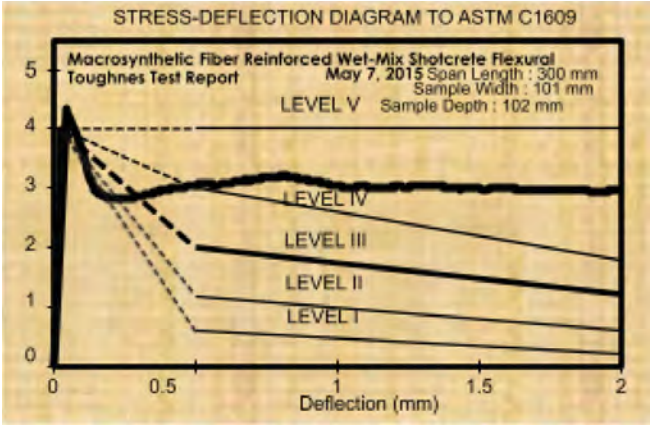

Fig. 3: Stress-Deflection Curve for Flexural Toughness Test to ASTM C1609

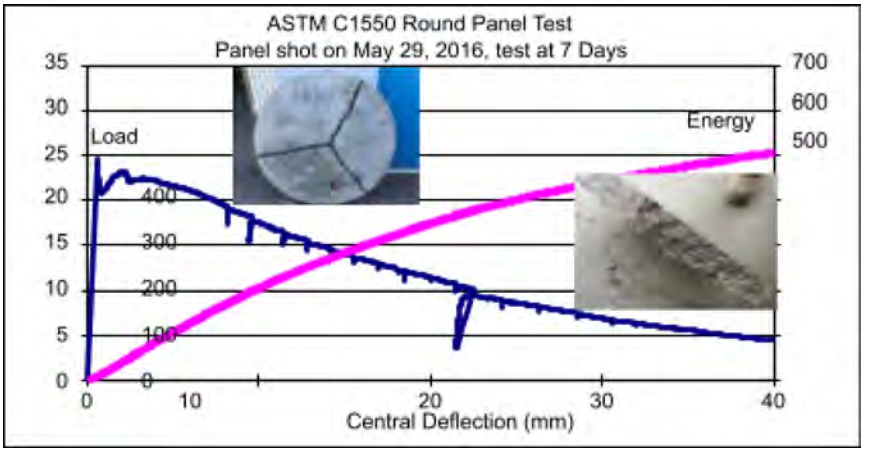

Fig. 4: Stress-Deflection Curve for Flexural Toughness Test to ASTM C1550

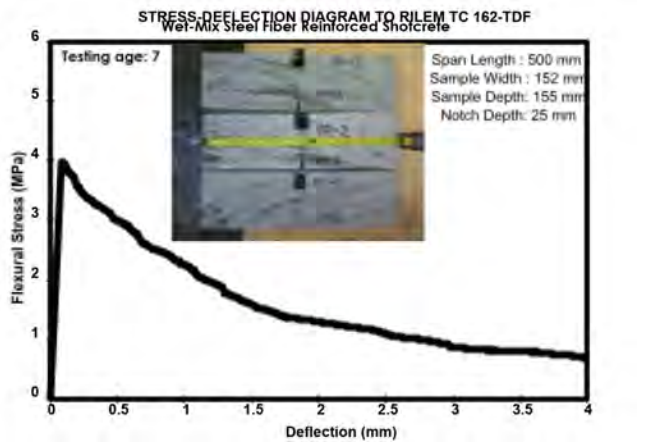

Fig. 5: Residual Tensile Stress vs Deflection for FRS Beam to BS EN 14651 / RILEM-TC-162-TDF

Round determinate panel (RDP) method based on ASTM C1550 test method

When the RDP method is specified, it requires samples of round determinate panels (RDP) to be shot with dimensions of 800 mm (31.5 in.) in diameter and 75 mm (3 in.) in thickness. The RDPs are tested to ASTM C1550 and the total energy absorbed up to 40 mm (1.6 in.) deflection is reported. Fig. 4 shows a typical flexural toughness load vs. deflection test result. Over 2000 FRS round panels have been tested to ASTM C1550 by the authors since 2011. If the flexural toughness exceeds 320-450 Joules, it generally meets the support requirements for most ground conditions. For hard rock tunnels, a flexural toughness of over 320-350 Joules has been commonly specified to meet the general ground support requirements. For soft ground, such as SEM, flexural toughness of 450 Joules has been specified to meet the ground support requirements.

Notched beam method based on BS EN 14651 / RILEM-TC-162-TDF residual tensile strength

The residual tensile strength of FRS can also be tested by the BS EN 14651 notched beam test method. The shotcrete beam is pre-cracked by saw cutting a notch 25 mm (.98 in.) deep into the bottom of the 150 mm x 150 mm (6x6 in.) cross-section beam at its center. A three-point bending load is applied to the beam. Fig. 5 shows a typical residual tensile stress vs. deflection curve for the notched beam test.

Both ASTM C1609 and ASTM C1550 can provide sufficient information on flexural toughness for FRS. They are applicable for either steel fiber or macrosynthetic-fiber-reinforced shotcrete. BS EN 14651 / RILEM-TC-162-TDF employs a notch in the beam, introducing stress intensity. This test method was originally developed by RILEM to study the residual tensile strength based on fracture mechanics, though it is generally agreed that a crack

will propagate through the notch. The authors have tested approximately 50 beams with this test method in the past decade. Most specifications for civil tunnel shotcrete require either ASTM C1609 or ASTM C1550 tests or both. Few specifications in North America require the BS EN 14651 or RILEM-TC-162-TDF tests.

Qualification of shotcrete mixtures and nozzlemen

Before construction, the project specification requires the shotcrete mixture to be prequalified. This is typically conducted at least 60 days prior to shotcrete placement. For very large projects where shotcrete is part of the tunneling or mining ground support process, such as SEM, qualification of the shotcrete mixture could start as early as 6 months before construction start. Mixture qualification normally requires the shotcrete mixture to be applied with the same equipment and crew that will be used for the construction to ensure that shotcrete can be placed properly throughout the project. During the mixture qualification, test panels are shot. Plastic properties of temperature, air content, and slump (as batched), as well as air content and slump (as shot) are tested. When accelerator is used, the initial set and final set time are tested to ASTM C1117 and the early-age compressive strength is tested for up to 24 hours using the end beam test method. Cores are extracted from the test panels and tested for compressive strength, boiled absorption and volume of permeable voids, rapid chloride ion penetration, etc. Beams are cut from the test panels for flexural toughness testing to ASTM C1609. Round determinate panels (RDP) are shot and tested for flexural toughness to ASTM C1550. All of the test results should meet the project specification requirements.

An accelerator is commonly used in underground shotcrete applications. The accelerator dosage determines the set time and rate of early-age compressive strength development for shotcrete. The dosage of the accelerator should be calibrated with the accelerator dosing pump and the shotcrete pump to be used. Proper calibration of the accelerator dosage is one of the most important parts of the mixture qualification. Detailed information on accelerator dosing pump calibration can be found in (Ref. 12, 13). After the shotcrete mixture is prequalified, the shotcrete nozzlemen also need to be qualified for the project. Nozzlemen qualification requires the nozzlemen properly apply shotcrete to achieve the specified performance and ground support requirements. More specifically, qualification of the shotcrete nozzlemen requires the following:

- Nozzlemen need to understand the basics of concrete and shotcrete technology. This includes how the cement hydrates, temperature effects on shotcrete, and the effects of accelerator and other chemical admixtures on shotcrete performance.
- Workability, pumpability, and shootability: the nozzlemen should understand that the slump, or consistency of the shotcrete mixture, is critical for transport, pumping, and shooting. Overhead and vertical applications pose different challenges for shotcrete application.
- Preparation of the substrate, including cleanliness, roughness, and the receiving surface moisture condition should be saturated surface dry (SSD) to achieve optimized bond.
- Proper calibration of the accelerator dosing pump.
- Proper application of shotcrete at the specified orientation, including overhead, vertical, at 45 degrees, etc.
- Proper control of nozzle angle, distance, and shooting pattern to minimize rebound and overspray.
- Proper procedure to apply thick layers of shotcrete, including multi-layer shotcreting.
- If shotcrete falls off, either from overhead or vertical surfaces, the nozzlemen should be able to determine immediately what went wrong and how to make the necessary corrections.

The nozzlemen qualification process is essential to a successful project as it accomplishes the following:

- Educates the nozzlemen on shotcrete materials, equipment, concrete technology, and the effects of chemical admixtures including accelerator
- Prepares them for the project. Typically, the most difficult component to be shot in the shotcrete support system is selected for nozzlemen qualification shooting.

Usually, the nozzlemen qualification mockup is specifically designed for each project. Sections with the most congested reinforcement, including spliced reinforcement, lattice girders, steel sets, and other types of reinforcements and embedments are required to be shot (Fig. 6). Every nozzlemen that works on the shotcrete application for the project needs to be qualified.

Fig. 6: Reinforcement for nozzlemen qualification panels: left) spliced 25M rebar; center) lattice girder; right) Robotic sprayer nozzleman qualification for overhead and 45-degree orientation

Fig. 7: In-place set time test

Fig. 8: Early-age compressive strength test

Construction quality control inspection and testing

During shotcrete construction, a quality control inspection and testing plan is required and needs to be executed to ensure that the in-place shotcrete meets the project specification requirements, and if not, appropriate remedial actions are conducted immediately.

Field inspection for shotcrete is normally conducted with other tunnel inspection activities, such as ground monitoring, excavation progress, etc. and it normally conducted full-time by an engineer or technologist appointed by the project owner or by a shotcrete consultant appointed by the contractor.

Inspection activities typically include the following:

- Evaluation of surface roughness, free of loose particles and moisture condition prior to shotcrete application
- Shotcrete application: nozzlemen shooting skills, including control of rebound and overspray, thickness of shotcrete, and accelerator dosages if used
- Checking for any defective shotcrete, including voids, cracks, signs of accelerator overdosing, potential shotcrete failures, etc.

Field testing for shotcrete is conducted by qualified testing technicians or engineers to ensure that the plastic shotcrete meets the specified performance requirements for shotcrete pumping and application. Typically, slump, air content, and temperature for as-batched and as-shot shotcrete are tested when shotcrete is delivered to the site. Slump should be tested at the batch plant, as well as at the location where shotcrete is discharged from the transmixer into the shotcrete pump inside the tunnel. If shotcrete is required to be kept for long hauls or longer retention times, such as more than 1 shift of 12 hours, a hydration control admixture is normally used to keep the shotcrete workable. Whenever there is a significant loss of slump, such as a slump loss of more than 50 mm (2 in.), immediate action of retempering the shotcrete with admixture or disposal of shotcrete needs to be executed to avoid shotcrete setting inside the transmixer.

Fig. 9: In-place overhead shotcrete core extraction; visual inspection of core hole to evaluate shotcrete consolidation, shotcrete thickness, and bond.

Fig. 10: In-place shotcrete bond strength test and laboratory shotcrete bond strength test

Set time testing is conducted to ASTM C1117. With accelerator added at a proper dosage, the initial set, i.e., the time when shotcrete completely loses its slump or pumpability, is less than about 15 minutes, and final set, i.e., the time when shotcrete starts to develop compressive strength, is less than about 50 minutes.

Fig. 7 shows an in-place set time test with a penetrometer needle to ASTM C1117.

Fig. 8 shows early-age compressive strength testing for shotcrete samples with the end beam testing method. If early-age compressive strength is required for ground support, such as 1.0 to 2.0 MPa (150 to 300 psi) for re-entry or to resume construction activities underneath the freshly applied shotcrete, testing needs to be conducted at multiple ages such as 2 hours, 4 hours, 6 hours, and up to 24 hours. Testing set time and early age compressive strength is common for tunneling where immediate compressive strength development is required, such as SEM tunneling.

When shotcrete hardens, in-place shotcrete consolidation, shotcrete thickness, and bond to the substrate can be evaluated by visual inspection of the core hole. Bond strength can be tested to evaluate the tensile bond strength between the shotcrete liner and the substrate rock. Bond strength can be conducted by coring and in-place testing or by extracting cores and testing bond strength in the laboratory. Tensile bond strength is sometimes specified to be a minimum 1.0 MPa. Fig. 9 shows an in-place shotcrete core hole. Fig. 10 shows in-place bond strength testing and laboratory bond strength testing. It should, however, be cautioned that some weaker rock types may fail at values below 1.0MPa in bond testing resulting in a failure of the substrate not the shotcrete bond.

New developments: mass shotcrete for underground structures

During the last few decades, more and more underground permanent structures have been built with shotcrete. Among them, mass structural shotcrete walls constructed using the "hybrid" (shoot and vibrate) method are recent developments. Heavily reinforced underground station structures with dimensions from 200 to 1500 mm (8 to 60 in.) thick are now being constructed with shotcrete. This involves a combination of structural shotcrete and underground shotcrete application technologies. The larger shotcrete structures develop higher internal temperatures due to cement's heat of hydration. When the shotcrete structures are thick enough, the heat dissipation will be of concern and will require a thermal control and protection plan.

To prevent mass concrete structures from thermal cracking, a thermal control plan (TCP) is developed as a design document. The TCP specifies the necessary measures to meet the thermal control requirements including the use of low-heat concrete mixtures, reducing shotcrete placement temperature, providing thermal blanket protection, and using internal cooling pipes. A recent mass shotcrete structural wall project in Vancouver, BC implemented a TCP using cooling pipes and thermal blankets (Ref. 14). Fig. 11 shows a shotcrete wall with heavy reinforcement and a wall with cooling pipes.

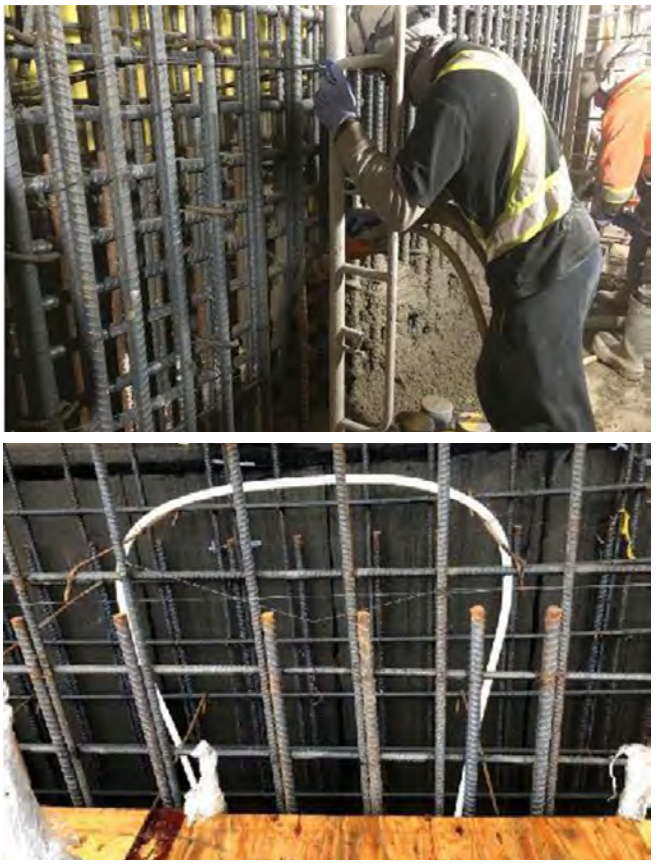

Fig. 11: Top - A mass structural wall for a sewer treatment facility constructed with mass shotcrete. Bottom: Two layers of 25M rebar with cooling pipes at 1.0 m spacing were constructed with mass shotcrete

Durability of shotcrete

More and more civil tunnels are being designed to have a service life of 70 years or more, some even with 100 years of service life. Service life for a civil tunnel primarily relies on the service life of the structure that supports the tunnel, including the final liner and other structures. When a concrete structure is designed, service life and durability requirements will override minimum structural requirements of mechanical performance including compressive strength, elastic modulus, bending moment, and tensile strength, etc.

It is critical to consider durability factors when designing for a long service life. Durability factors such as resistance to weathering, corrosion, chemical attack, alkali-aggregate reaction, carbonation, and freeze-thaw deterioration are all influenced by the concrete mixture design and transport properties of the concrete during the service life of the structure. Civil underground structures including tunnels, shafts, caverns, and others are often exposed to one or more of the above factors. Therefore, the service life of the structure is primarily dependent on the service life of shotcrete structures. The durability of the shotcrete structures is dependent on the concrete mixture design and the application process.

A question is sometimes raised about shotcrete: will it be as durable as cast-in-place concrete? A recently completed research project (Ref. 15) compared the transport properties for shotcrete to the cast-in-place concrete. Results show that properly applied shotcrete will achieve equal or better transport properties to cast-in-place concrete. Based on the research, service life was modeled using an advanced service life prediction modeling program (STADIUM), with different exposure conditions and structures. Shotcrete generally exhibits an equal or a longer time for initiation of reinforcing steel corrosion providing an extended service life (Ref. 15).

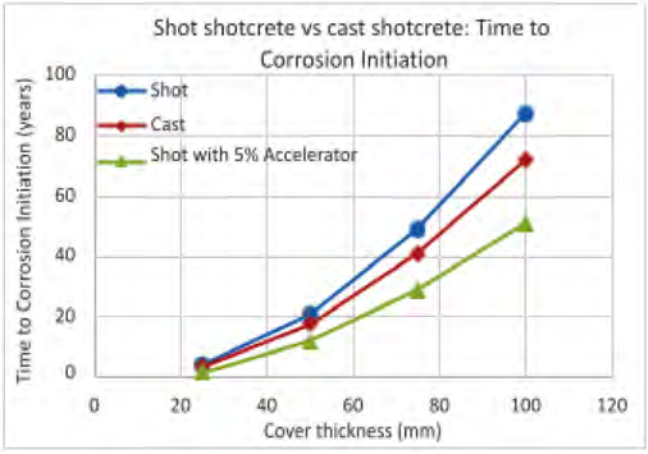

Fig. 12: Effect of accelerator for wet-mix shotcrete vs. cast-in-place concrete on time to corrosion initiation

This research also indicated equal or better durability for shotcrete provided that a moderate dosage of set accelerator is used. When accelerator is used, the quality of the shotcrete matrix tends to be degraded. While accelerator increases the rate of cement hydration and heat evolution

and provides earlier strength development, it also results in a more pervious hardened concrete matrix. The chemical ions tend to migrate faster and with less resistance when accelerator is used. For example, when accelerator is added at 5% by mass of cement in shotcrete, the transport properties tend to be reduced and therefore result in reduced service life (Fig. 12, Ref. 15). While accelerator is critical for underground support to achieve rapid setting and hardening, and reliable early-age compressive strength development, the dosage of accelerator used should be closely controlled so that the shotcrete structure can achieve both the required ground support and the required durability.

Codes and standards development

Shotcrete codes, standards, and guide documents are developed and regularly updated by the American Concrete Institute (ACI) Committee 506. Project specifications are typically prepared by the design engineer with consultation and/or review from the shotcrete specialist. Here are some of the most commonly used shotcrete guides and specifications in North America:

- ACI 506.5-2018, "Guide for Specifying Underground Shotcrete." This document was updated in 2021
- ACI 506R-2015, "Guide to Shotcrete"
- ACI 506.2-2018, "Specification for Materials, Proportioning and Application of Shotcrete"
  ACI ACI - CP-60 Craftsman Workbook for ACI Certification of Shotcrete Nozzleman

These guides and specifications, together with other related documents from ACI, ASTM, CSA, AASHTO, and the US Army Corps of Engineers, provide the basis for development of a suitable QA/QC program.

Most recently, ACI 318-19 Building Code Requirements for Structural Concrete has included requirements for structural shotcrete placement (Ref. 16).

Conclusions

Shotcrete is used more and more for ground support in underground construction. The use of alkali-free accelerators (AFA) and fiber-reinforcement are two major advancements in shotcrete use in the underground environment during the past two decades. AFA is efficient in reducing shotcrete set time and development of early age compressive strength. Fibers have greatly changed ground support design and construction methods. Quality shotcrete for ground support requires the following:

- High performance shotcrete mixture
- Proper mixture qualification and nozzleman qualification program
- Rigorous construction monitoring and testing program

Shotcrete is being used much more for the final liner in tunnel construction. Examples include water conveyance tunnels for hydroelectric and water treatment projects, and road and rail tunnels. Structural shotcrete is also used increasingly in underground construction for subway stations in major metropolitan areas in North America. Mass shotcrete structures, including heavily reinforced walls, can be properly constructed with the hybrid (shoot and vibrate) structural shotcrete process together with the provision of a proper thermal control plan.

Durable shotcrete placement for ground support is critical for building durable underground structures. In particular, with many more underground structures required to have a service life of over 100 years, durability for shotcreted materials and the resulting structures, including resistance to chemical attack, is an important consideration. Research conducted by the authors has demonstrated that properly designed and applied shotcrete can provide equal or better durability compared to cast-in-place concrete.

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Natural Fibers for Sustainability in Shotcrete Applications

By Joe McJunkins, Jessica Silva Ph.D., & Jisha Hechel

INTRODUCTION

The global construction industry consumes millions of tons of non-renewable resources every year. Conventional construction materials are known to be produced from sources that require an extremely high energy demand and, therefore, produce a large carbon footprint. The use of renewable, natural fiber resources plays a significant role in the development of eco-friendly building practices.

Natural fibers, derived from sustainable plant sources, have been shown to perform as well as synthetic fibers composed of polypropylene and fiberglass. This reduces the environmental impact of the raw materials, as well as creates a high-performing, robust shotcrete formulation that is resistant to microcracking and physical stress.

BACKGROUND

Microcracking and drying shrinkage present major challenges to the construction industry. When natural fibers are included in the concrete matrix, they can help reduce internal microcracking and contribute to both increased compressive and flexural strength, as well as cement hydration.

Natural fibers have been found in building and construction materials since the dawn of time. These fibers can be from both plant and animal-based sources. History teaches us that the Egyptians used straw and horsehair to produce bricks and other construction materials several thousand years ago. Throughout history, many different types of natural fibers have been used in construction, such as flax, straw, jute, hemp, kenaf, bamboo, cane, horsehair, and wool.

Shotcrete ASTM C 1480	No Fibers	PP 6 mm	PP 12 mm	Fiberglass 13 mm	Hemp 6 mm	Flax 6 mm	Banana 6 mm	Kenaf 6 mm	Kenaf 6 mm-m	Kenaf 12 mm-m	Fique 6 mm	Fique 6 mm-m	Fique 12 mm
Ingredients	%	%	%	%	%	%	%	%	%	%	%	%	%
Cement (Type I/II)	28	28	28	28	28	28	28	28	28	28	28	28	28
Sand	66.922	66.622	66.622	66.622	66.8095	66.772	66.82825	66.847	66.622	66.622	66.7907	66.622	66.7907
Red Microsilica	5	5	5	5	5	5	5	5	5	5	5	5	5
BASF PCE superplasticizer	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075
Air entrainer	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Fiberglass – 13mm				0.3									
Polypropylene – 6 mm		0.3											
Polypropylene – 12 mm			0.3										
Hemp – 6 mm					0.1125								
Flax – 6 mm						0.15							
Kenaf – 6 mm								0.075	0.3				
Kenaf – 12 mm										0.3			
Fique – 6 mm											0.1313	0.3	
Fique – 12 mm													0.1313
Banana – 6 mm							0.09375						
Total	100	100	100	100	100	100	100	100	100	100	100	100	100
Water (Q 12.4-14.6%)	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2

Table 1: Basic shotcrete formulations with respective dosages of fibers

The fiber source of choice was heavily influenced by local availability.

Plant-based fibers consist of two categories: bast and leaf. Bast fibers come from the core of the stalk or stem and are made up of several groups of fiber cells that are extracted from the core. Examples of bast fiber include flax, jute, hemp, and kenaf. Leaf fibers, as expected, come from the leaf of the plant. Examples of leaf fibers include banana, pineapple, and sisal. In recent years, several advances have been made in treating natural fibers to further enhance their physical and mechanical properties, and their benefits in construction.

TESTING

Azelis, a global distributor of specialty chemicals and additives, including MiniFIBERS, had their Construction Solutions Lab investigate using natural fibers in shotcrete. The objective was to understand if the natural fibers could provide comparable properties relative to synthetic fibers when used in shotcrete. If the natural fibers perform similarly, there is a sustainable benefit to using them. Five types of natural fiber (hemp, flax, banana, kenaf, and fique), were evaluated against synthetic fibers of a similar length, which were made of polypropylene and fiberglass. These were also evaluated against a control group, containing no fibers.

Historically, ancient mortars containing natural fibers made of animal hair and plant fibers withstood the environment of mortars over hundreds of years. However, to start the investigation, the potential for the material to degrade in the basic environment of concrete was tested. The natural fibers were subjected to a solution of calcium hydroxide at a pH of 11.5 to determine if they would degrade in the highly alkaline concrete environment. This was done by rinsing the fibers with water over a 325 µm sieve, then drying and weighing them. The fibers were then soaked in the calcium hydroxide solution for 24 hours, and then once again rinsed with water over a 325 µm sieve. Finally, they were dried and weighed. The resulting mass change was only 0.1%, showing that the natural fibers would likely not degrade in the alkaline environment of concrete.

After the initial evaluation to determine the stability of the natural fibers, a formulation was created to test them in shotcreted concrete. This investigation was conducted to understand the impact of MiniFIBERS natural fibers on density, flow, setting time, dimensional stability, and hardened state strength (tensile, compressive, and flexure) properties.

TEST DESIGN

The test system used a basic concrete mortar formulation containing 28% Type I/II cement, 5% RED Industries microsilica, a small dose of BASF Melflux polycarboxylate ether superplasticizer, air entrainer, graded sand, and varying dosages of MiniFIBERS natural fibers, MiniFIBERS polypropylene fibers, and commercially obtained fiberglass fibers. Water was added at a rate of 13.2% based on total dry material weight.

Two additional studies were run to understand the impact of fiber quantity and length on the mortar. Since some fibers were lower in density than synthetic fibers, a set of tests were run to evaluate if the increased volume of fibers would influence the mortar by using a constant weight of fiber, effectively increasing the volume of fibers in the mortar. This could be beneficial to sustainability targets or to lightweight mortar targets. To evaluate the impact on length change, kenaf and fique were used at the lengths of 6 mm (0.25 in.) and 12 mm (0.5 in.). (Table 1)

PLASTIC STATE MORTAR TESTING

Azelis labs evaluated the plastic state properties of MiniFIBERs natural fibers in comparison to a mortar with no fibers, with synthetic fibers composed of fiberglass, and with synthetic fibers composed of polypropylene. Calorimetry, density, air content, and flow were tested.

Calorimetry was evaluated with thermocouples imbedded in insulated and covered mortar samples of equal volume. The calorimetry showed minimal impact on the cement heat of hydration. The peak heat output was very similar in duration and temperature for each type of fiber.

Mortar density testing was performed following ASTM C185 (modified). The results correlated with air measurements. Air content was targeted at 6-8%*. Air content was measured using a 0.026 ft^3 (0.75 liter) mortar air meter employing the same method as a standard 0.25 ft^3 (7.08 liter) air meter used in ASTM C 231. The air entraining admixture dosage was selected based on the mixture containing fiberglass fibers. This dosage was then held constant for all mixtures so the impact of the fibers on air content could be understood.

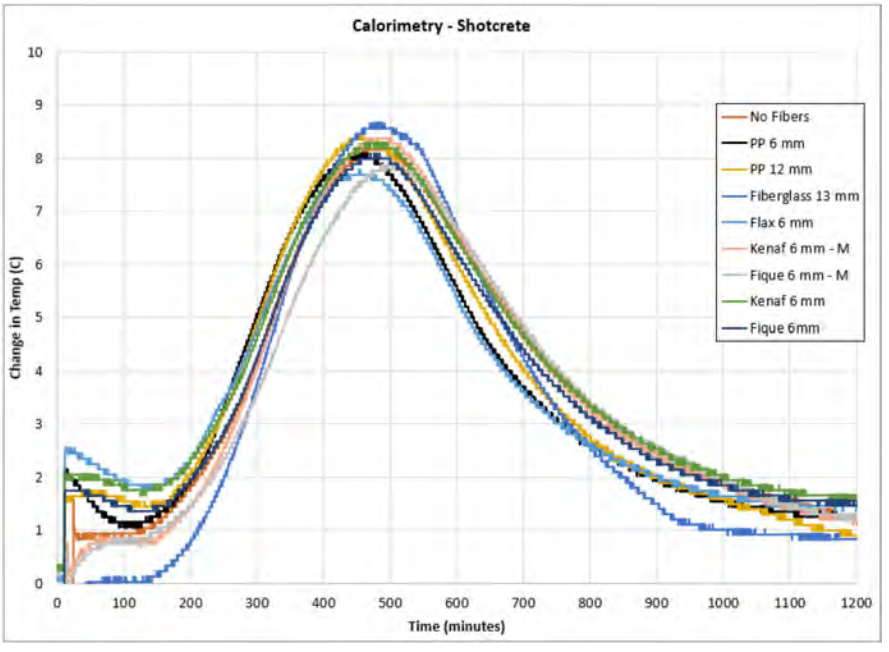


Table 2: Calorimetry - Shotcrete

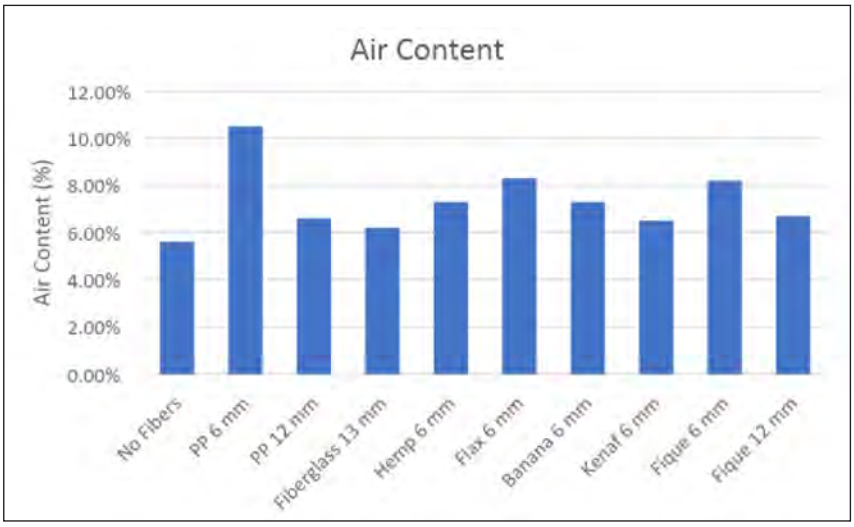


Table 3: Air Content

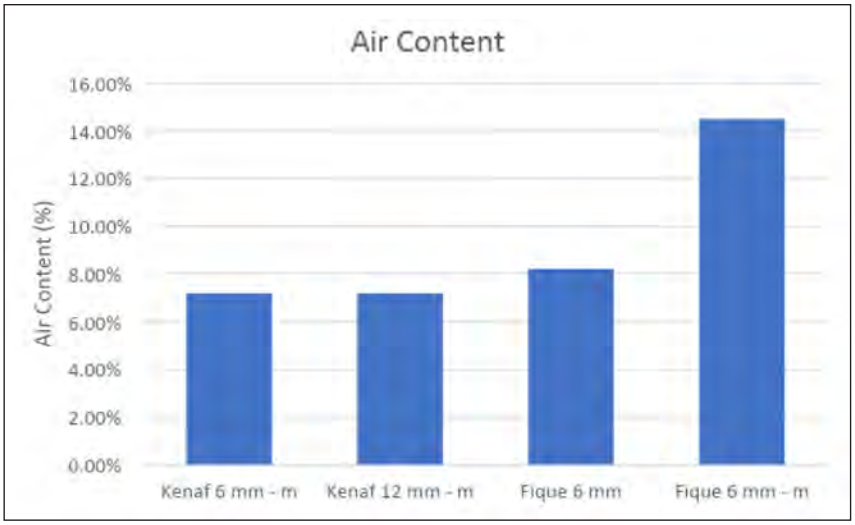


Table 4: Air Content

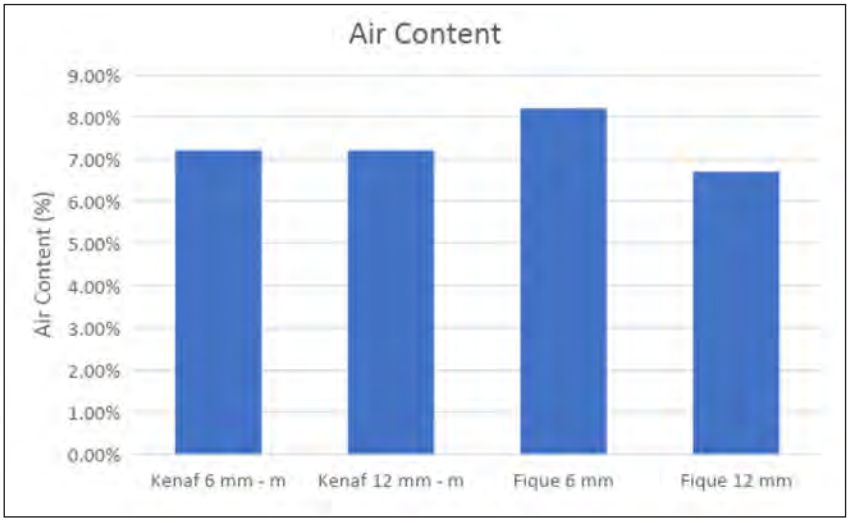


Table 5: Air Content

All the natural fibers maintained an air content at 6.2% - 8.2%, just above the synthetic 12 mm polypropylene and 13 mm fiberglass containing materials. All natural fibers caused less impact to entrained air content than 6mm polypropene fiber when the dosage of natural fibers was added based on density of the fiber.

An additional test was run, increasing the amount of fibers to match the mass of the fiberglass fibers. In this case, there was higher measured air when using fique. This was an expected change based on the material's properties. The increased volume of kenaf maintained a constant air content.

Length of fiber did not have a consistent impact on the density of the mortar when volume of fiber addition was constant.

Flow can be a very important attribute to shotcrete since it must be reliably pumped and sprayed. Typically, the addition of fibers reduces the flow rate in cementitious mortar. Actual spray testing was not conducted, so flow was used as an indicator of the rheology. Flow was determined following ASTM C 1437 using a shocking table.

Fig. 1: Photo of unwound kenaf fiber in shotcrete mortar Hardened State Mortar Testing

**Note: a targeted 6% air was chosen to better understand "as shot" hardened state properties. It is understood that high air content of 12% before shotcrete is placed would typically be targeted assuming 50% of the air is removed in the application process. Since the material could not be pumped and shot for hardened state tests, a typical "as shot" air content was targeted to avoid high air contents impacting hardened state properties.*

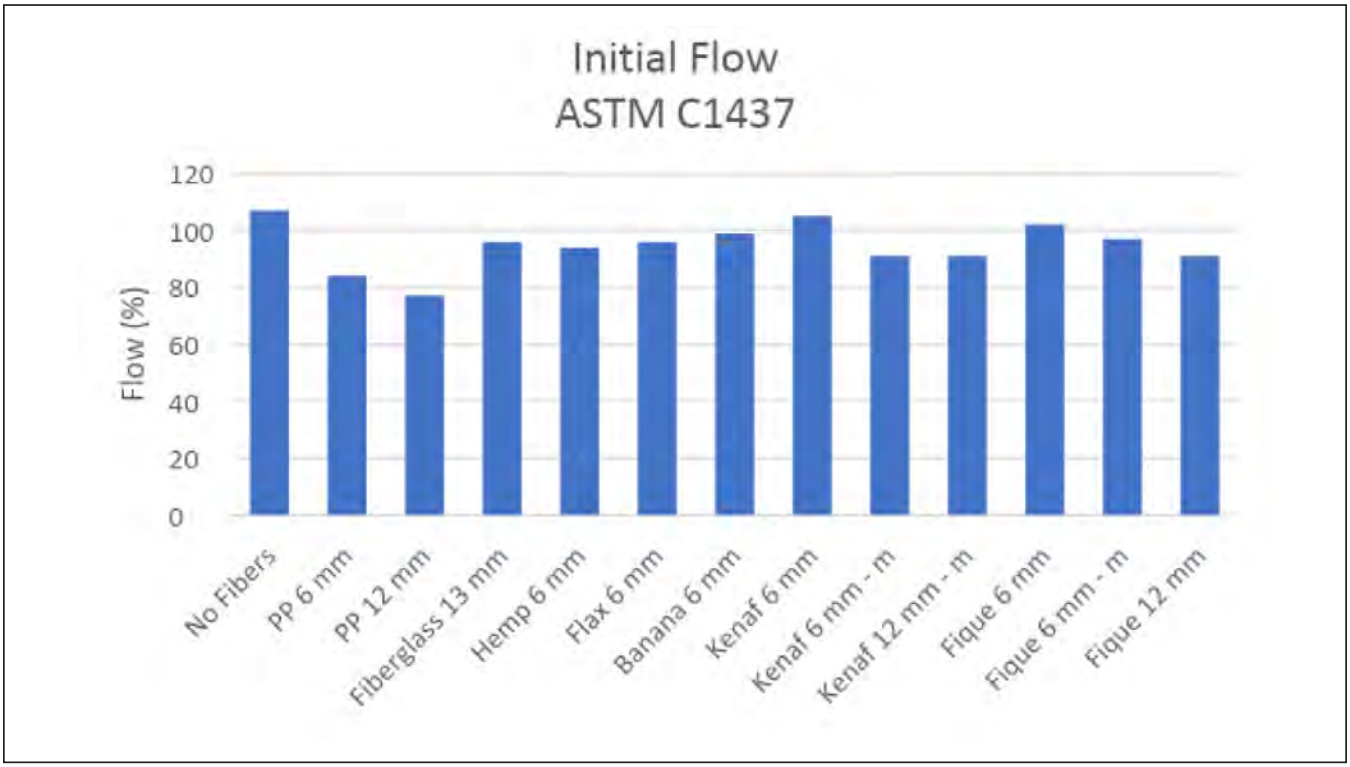


Table 6: Initial Flow ASTM C1437

The natural fibers had no negative impact to flow, and in all cases, they had equal or higher flow than the mortars containing synthetic, polypropylene fibers.

It was observed that the fibers are of a wound nature. During mixing, the fibers tended to uncoil and lengthen in the wet mortar. The mixed fiber was longer than the initial cut length and less rigid, signaling it had lengthened or uncoiled in the mixing process. It is hypothesized that this allowed for a higher flow in the mixture. (Fig. 1)

HARDENED STATE MORTAR TESTING

The mortar was cured for 28 days in 50% RH at 73°F (23°C), and the specimens were tested for compressive strength, split tensile strength, and flexural strength. Length change was also monitored over the curing period. Compressive strength was measured using 2 in. (50 mm) cubes following ASTM C 109. Split tensile samples were tested following ASTM C 496. Flexibility testing (following ASTM C 580) was run on specimens used for length change measures (following ASTM C 157).

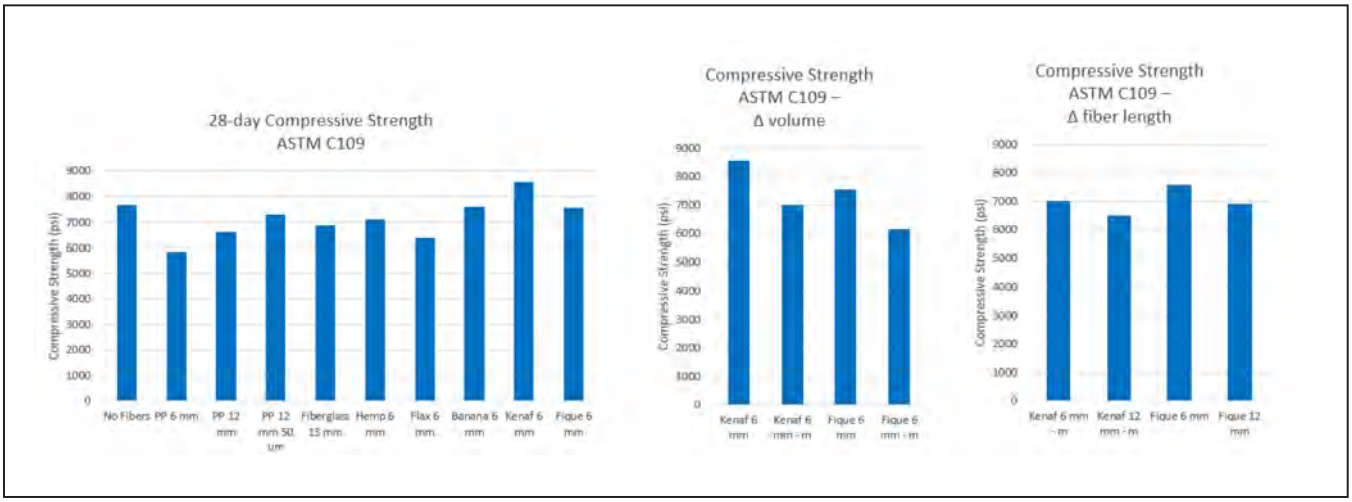


Table 7: Compressive Strength

All mortar containing natural fibers achieved compressive strength (Table 7) over 6000 psi (41 MPa) at 28 days, with the kenaf fiber mortar reaching over 8000 psi (55 MPa) and outperforming the synthetic fiber mortars. Increasing the volume of natural fibers of the same length led to a reduction in compressive strength. Mortar containing 6 mm length natural fibers had higher compressive strength than mortar containing equal amounts of 12 mm length fibers.

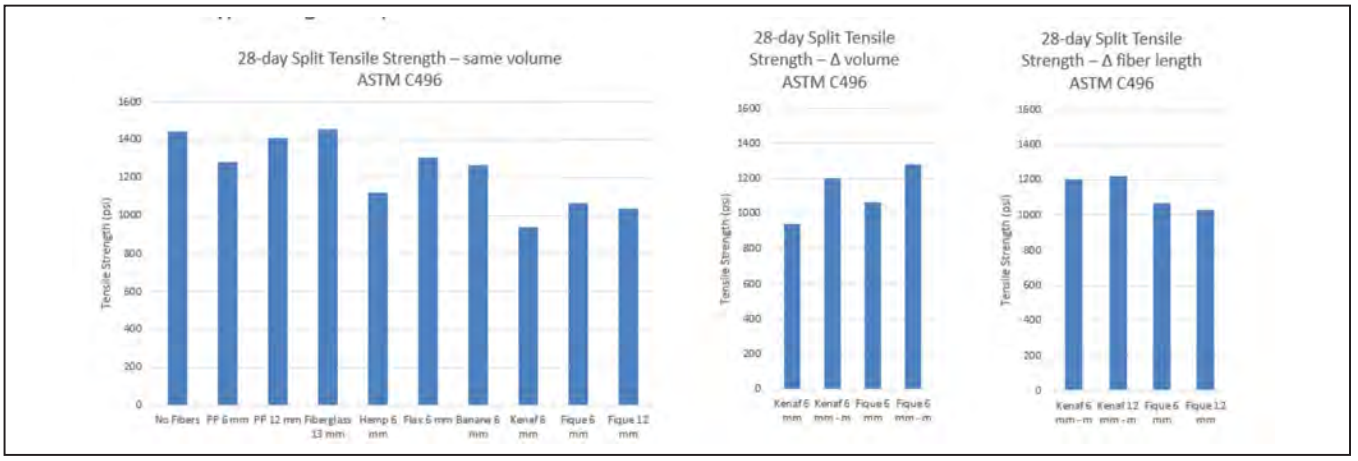


Table 8: Split Tensile Strength

Mortars containing natural fibers had lower split tensile strength (Table 8) than the control or synthetic fibers; however, with a typical target above 900 psi (6.2 MPa), all natural fibers exceeded this requirement. Increasing the volume of natural fibers increased the split tensile strength. This indicates there is an ability to further optimize a mixture design to achieve a higher tensile strength of the mortar if desired. Increasing the length of the fiber did not impact the tensile strength.

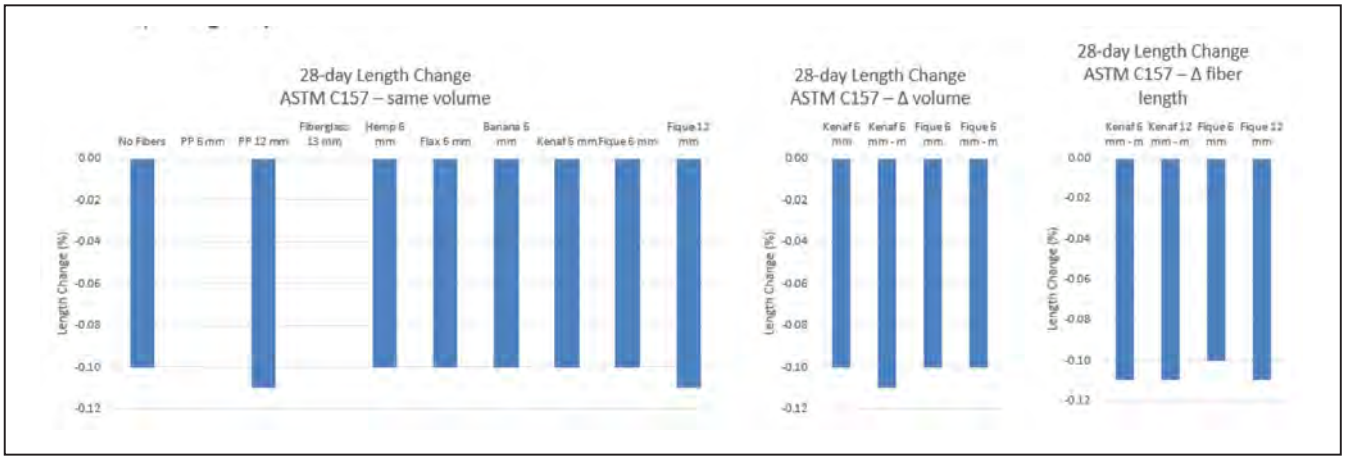


Table 9: Length Change

The dimensional stability was monitored for 28 days (Table 9) according to the ASTM C 157 method. None of the fibers had a great impact on length change. All were within 0.01% change in length.

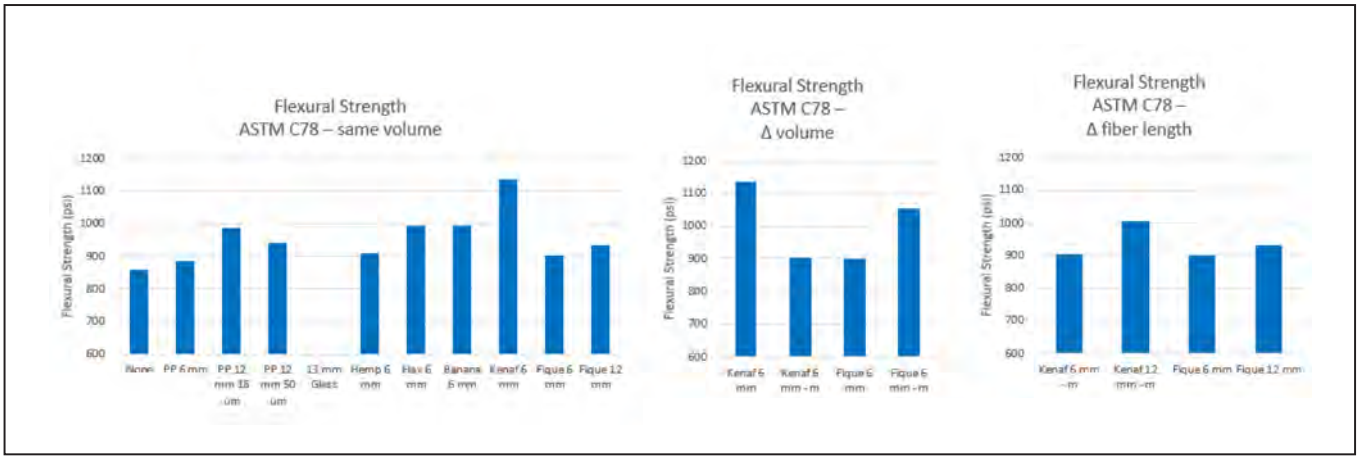


Table 10: Flexural Strength

All mortars containing fibers outperformed the control without fibers in flexural strength (Table 10). The fiber with the least impact was the 6 mm polypropylene fiber. Mortar containing 6 mm kenaf fiber showed the greatest increase in flexure strength. Longer fibers further increased the flexural strength of the mortar. Kenaf fibers contributed to the greatest increase in flexural strength in this regard as well.

Evaluation Summary (Natural compared to polypropylene synthetic)					
	flow	compression	tensile	shrinkage	flexural
Synthetic					
Fique	low				low
Flax		low	high		
Hemp	low				low
Banana					
Kenaf	highest	highest	low		highest
	lows are fine	lows are fine	*	All same	lows are fine

Table 11: Natural materials do not have high performance characteristics in tensile strength, but some match synthetic materials. Increased amounts of fibers improved the tensile strength.

CONCLUSION

The Azelis labs used a basic sand shotcrete mortar formulation to evaluate the impact of MiniFIBERS natural fibers. The typical performance requirements referenced were for "as-shot" mortar containing a targeted 6% air. The Azelis labs have concluded that utilizing natural fibers in mortar allowed the shotcrete formulation to perform to meet typical performance targets, while allowing for a lower carbon footprint due to the use of sustainable materials. The summary chart (Table 11) reviews the highest and lowest performing material; however, all natural fibers produced a material with sufficient properties.

Further analysis can be run to determine subjective properties such as workability, smoothing, and ease of use. "Shot" characteristics have not been evaluated in this study, but this could be done, and additional application testing could be conducted to further understand the natural fibers' impact on the mortar.

Processing natural fibers presents its own set of challenges. Due to their inherent nature, each fiber type has different cutting and processing characteristics. Currently, there are an extremely limited number of fiber processing companies that are capable of producing a consistent natural fiber cut that is less than 10 mm (.39 in.) in length. MiniFIBERS Inc. has state-of-the-art fiber cutting technology and is a world leader in fiber processing.

Joe McJunkins *is the Director of Technical Service & Product Management for MiniFIBERS Inc. located in Johnson City, Tennessee, USA. Mr. McJunkins is based in the Cleveland, Ohio area and is responsible for global activities related to CASE, Construction, and Industrial markets.*

Mr. McJunkins earned his BS in Chemistry in 1980. Joe possesses over 35 years of combined formulation and product development experience. His background covers a wide range of applications such as non-woven textiles, architectural polymers, coatings, adhesives, inks, and minerals. Mr. McJunkins holds a variety of patents for aqueous & non-aqueous coatings, polymers, inks, and functional fillers.

Jessica Silva, Ph.D*, is the Azelis Director of Labs - Americas in the Wisconsin Applications Lab in Oak Creek, WI, USA. She has 15 years of experience in application areas utilizing concrete and cementitious mortar systems. Her areas of expertise include formulation consulting, concrete pavement materials, concrete repair products, construction grouts, leveling and topping, precast concrete, tile installation products, and specification testing.*

Jisha Hechel *is the Laboratory Manager of Construction Solutions at Azelis at the Wisconsin Applications Lab in Oak Creek, WI, USA. She has 10 years of experience formulating cementitious building materials. She uses Azelis's specialty additive portfolio to innovate and exceed performance in cementitious mortars and concrete. Her passions are in breakthrough technology and environmental sustainability.*

Mapei's London Underground Bank Station's Capacity Upgrade

By Enrico Dal Negro, Stefano Anzani, & Steven Price

Deep in the heart of London's financial centre, work has been continuing to make one of the world's largest stations safer and easier for passengers to use. Finding your way around the existing labyrinth of tunnels, connecting five London underground lines, is a task worthy of the most experienced navigator.

Fig. 1: Waterproofing System Application

Banks Station Capacity Upgrade (BSCU) was a project driven by London Underground Limited (LUL) and delivered by Dragados to increase the capacity of the already busy station whilst transforming the experience of commuters and making navigation both safe and easy.

An ambitious and complex project, the Bank Station upgrade has increased the station's capacity by 40%. It includes a new railway tunnel and a wider southbound platform for the Northern line; step-free access to the Northern line for the first time, and improved step-free access to the DLR platforms; new station entrances, interchange routes, moving walkways, lifts, and escalators; and approximately 1400 m (4600 ft) of new tunnels. The installation spanned a tunnel surface of approx. 24,000 m² (260,000 ft²).

The waterproofing system (Fig. 2), which was developed by Mapei UTT in collaboration with Dragados, Dr. Sauer & Partners, and Transport for London, consisted of a low-dust, regulating layer of Mapegrout Gunite FSD and spray-applied Mapelastic TU System. The solution was also used to waterproof reinforced concrete works in areas including shafts.

Mapegrout Gunite FSD (Fig. 3 and Fig. 4) is a fast-setting, ready-to-use fiber-reinforced cementitious mortar developed for concrete, stone, and masonry structures including tunnel linings, shafts, and foundations. It provides

Fig. 2: Waterproofing System Application

Fig. 3: Mapegrout Gunite FSD

excellent bonding strength and speed of application with low dust emissions. The waterproofing membrane, Mapelastic TU System (Fig. 5), is a one-component, ready-to-use sprayable synthetic membrane developed for tunnels and underground structure waterproofing. Featuring excellent tensile strength and adhesive properties, the membrane creates a flexible, seamless waterproofing barrier and can be used in new tunnels and to replace existing systems. Other Mapei products specified included two fast-drying hydraulic binders: Lamposilex (a water plug) and Topcem for final screeding layers; and two paint finishes: Silexcolor (a silicate-based, vapor-permeable protective paint) and Mapecoat ACT (a mold, virus, and bacteria-resistant cleanable enamel paint).

Tunneling operations commenced in late 2016 and lasted into 2020. One major decision common to all tunnel construction projects is how to control water ingress. There are many papers written that highlight the importance of water management; options range from fully drained

systems to fully watertight systems with pros and cons on both sides of the argument.

Given the required design life for the station, the decision was made to install a system that provides a fully watertight solution; this decision was also made because the design is an integral part of the structure and will provide a maintenance-free service life.

A key consideration for this approach was constructability, as well as the health and safety of the workers. The upgrade project includes shotcrete-lined tunnels with varying profiles. The single point of access prohibited complex scaffolding that would restrict vehicle movements within the tunnel construction. (Fig. 6 & Fig. 7)

Fig. 4: Preparation of Mapegrout Gunite FSD

Fig. 5: Mapelastic TU System Application

Fig. 6: Nozzlemen at a tunnel entrance

Fig. 7: Tunnel with lift and equipment

In 2016, an application was made to London Underground for inclusion in their approved product register, and in February 2017, the product was authorized for use in London's deep tunnels network.

Following a detailed technical assessment and review of the system by Dragados and the technical consultant, Dr. Sauer and Partners, a Mapelastic TU System was selected for waterproofing the SCL tunnels at BSCU. A key point for the successful installation was a complete knowledge of the requirements of the system and the application of the product. To achieve this, a training course was developed for both engineers and applicators which consisted of technical theory and practical application.

The first training for the Mapelastic TU System was provided at Mapei's London Specification Center, a purpose-designed space in the heart of London for presenting systems and solutions from the Mapei product line.

The training was then delivered on-site to all workers, with an emphasis on the safety and well-being of the crews as well as the technical performance of the system.

With trained personnel readily available, planning was less challenging, and utilization was tailored to match other construction operations, all of which made an efficient overall program of construction.

Like all systems, the key to a successful application is in the preparation. The SCL surface condition was defined and accepted, the material consumption rates were calculated, and the as-placed sections checked for correct thickness. The system was applied in two layers to ensure complete coverage; additionally, the product was manufactured in 2 contrasting colors: a light bluish-green and a white (Fig. 10).

A unique point of the system was the use of airless spray technology. This provided two distinct advantages:

Fig. 8: Nozzleman applying Mapegrout Gunite FSD

Fig. 9: Application

Fig. 10: Nozzleman applying waterproofing layer

Fig. 11: Full tunnel view with waterproofing

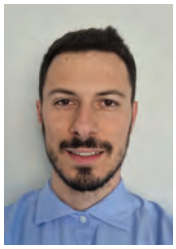
firstly, compressed air was readily available on the project and enabled the use of reliable, robust air-driven pumps; secondly, the direct airless placement of the Mapelastic TU System product led to zero rebound and minimal waste.

Zero rebound and the water-based safe formulation were major steps forward for the applicators, and this was a key factor in the decision to use the system. In 2018, Mapelastic TU System design and application in BSCU won the New Civil Engineer (NCE) Tunnelling Award in the Safety category.

As well as safety, spray-applied systems offered other benefits to the project. Complex geometry was easily waterproofed, and the fully bonded monolithic construction allowed a reduction in final lining thickness; this resulted in lower costs on materials and a significant reduction in CO_2 emissions. The spray-applied solution was also designed to work with an adjacent, loose-laid PVC waterproofing system thanks to a special transition element. In this way, a hybrid waterproofing system was designed in the newly constructed or rehabilitated tunnels to exploit the different characteristics and performances of both systems.

BSCU has taken many innovative ideas and put these into practice by paving the way for better tunnel construction; waterproofing is just one small part, but it will change the future.

***Enrico Dal Negro**, Global Director, Mapei UTT.*



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The Jetcreter – The First Continuous-Feed, Dry-Mix Gun

By Ted Sofis

During the summer of 1970, on my 18th birthday, my father woke me up and told me they needed me on a job. I drove out that morning in July to the Crucible Specialty Steel plant in Midland, PA. It was my first experience working on a Gunite job. We were gunning refractory in a vessel, and I was throwing 100 lb (46 kg) bags of pre-packaged refractory into a paddle mixer to pre-dampen the material. We emptied the paddle mixer on sheets of plywood and shoveled the pre-dampened refractory material into the dry-mix shotcrete gun's hopper. The Jetcreter was a continuous-feed gun, and it was tough for us to keep up with it. It was a very long day for me because it took 15 hours to complete the gunning. I left the house that morning in the dark and returned home in the dark. That was my introduction to "Gunite" (now referred to as dry-mix shotcrete).

The Jetcreter was the very first continuous-feed gunite machine. It was manufactured by Engineered Equipment, Inc. in Waterloo, IA. It had a rotor with round pockets and worked on the rotating air-lock principle, which was a completely new idea. The material could be continuously added as needed without interruption. As the rotor turned, the pockets filled and then discharged material. With the sealing plates above and below the rotor, it worked much like a revolver: as each chamber came over the gooseneck opening, it discharged the material in a continuous flow through the gooseneck and through the gunning delivery hose to the nozzle.

The 240 Jetcreter had a gasoline-powered Ford engine and a four-speed transmission to turn the rotor. It had a "four on the floor" gear shift, just like you would have in a Ford pick-up truck of the day. The 240 model also had a built-in, dual-piston high-pressure water booster pump. We had two Jetcreters: a gas-powered unit, which we used on most projects, and another with an electric motor to drive the gun for industrial projects where it was necessary to set up indoors. We typically used a 600 CFM (17 m^3/min) compressor with each model.

Fig. 1: A current photo of an electric powered Jetcreter.

Prior to the introduction of the Jetcreter, gunite machines were either batch-type or double-chamber guns. With the batch-type gun, one batch would be introduced and fully discharged before another batch could be loaded. The double-chamber guns, like the Allentown N Gun (Fig. 1), work in a coordinated, two-step process. Material is loaded into the upper chamber while the sealed-off lower chamber is discharging material into the delivery line; after it is emptied, the material in the upper chamber is dropped into the lower and the procedure is repeated. When I started in the early 1970s, our double-chamber guns were already sitting discarded on the hillside behind our shop. It was just faster and easier to perform our work with rotary guns.

The model 240 Jetcreter with the Ford engine and the four-speed transmission was a beast. When it was in 3rd or 4th gear, it was difficult to keep up with. In the summers of 1973 and 1974, I worked on the 31st Street Bridge in Pittsburgh, PA, repairing the bridge piers with dry-mix shotcrete. We mixed sand and cement in a paddle mixer, shoveled the mix into one ft^3 (0.03 m^3) boxes for precise measurement, and dumped the boxes of material into the Jetcreter.

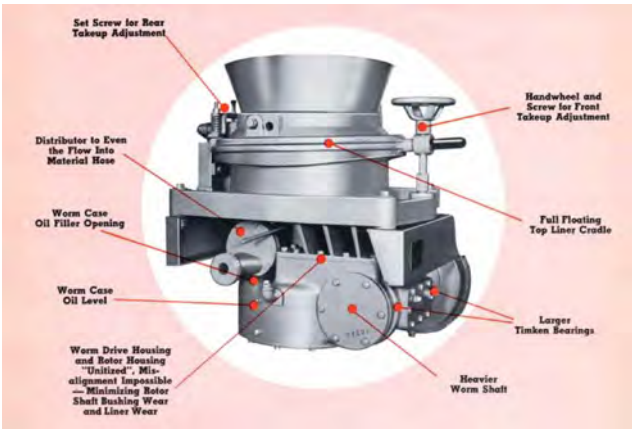

Fig. 2: The original Jetcreter with the Ford gas-powered engine. Originally published in Shotcrete magazine Summer 2009 from the library of Chris Zynda.

In 1974, we needed more machines, and we purchased several Reed "bowl-type" rotary guns (Fig. 2). They were affordable, smaller machines easier to stage in multiple steel mill locations for gunning refractory in the steel ladles. As time went on, we began to use bowl-type guns on all our projects. In the early 1980s, we sold our Jetcreters to a contractor in Milwaukee who performed decorative rock work in zoos. Although they were only used occasionally, I was still sad to see them go.

The Piccola and Aliva guns in use today, with a rotor and a straight-drop feed, are continuous-feed guns based on the original design of the Jetcreter. Reed introduced the first bowl-type rotary gun. Both types of rotary guns are commonly used in a variety of dry-mix shotcrete applications.

Ted Sofis *recently retired as owner of Sofis Company Inc. with 47 years of experience in the shotcrete industry. He is an ACI Nozzleman Examiner and has served on the ASA Executive Board of Directors, the ASA Board, and 11 years as the Chair of ASA Publications Committee, as well as being a member on several other committees. Ted began performing shotcrete work during summers while in college from 1971 to 1974. After graduating from Muskingum College in 1975, he began full time as a nozzleman and gun operator gunning refractory in ladles and blast furnace troughs in the steel industry. Ted has worked in the shotcrete industry performing work in the power generation and steel industries, and on bridges, tunnels, dams, spillways, slope-protection, and a variety of other installations over the years.*

Robust Contentment

By Bill Drakeley

This article originally appeared in WaterShapes magazine. It is being reprinted with permission.

Fig. 1: A swimming pool can never visually compete with the ocean. For this project, the elegant pool design serves as a perfect complement to the spectacular setting.

This beautiful project, nestled on the Connecticut shores of the Long Island Sound, required a careful balance of robust construction and design, and careful adherence to environmental codes protecting the adjacent oceanic rock formations and biologically sensitive tide pools. “It was a steep challenge,” explains Bill Drakeley, but he and his company welcomed the opportunity.

This project started with a spectacular setting. It’s located in Connecticut in an area known as the Gulf Coast on the Long Island Sound. It’s in an exclusive, private community where people both enjoy the outdoor lifestyle but are also mostly very private. It’s not a place where they have neighborhood block parties.

These particular clients are exceedingly wealthy, making a fortune in finance. They have an extremely low profile and treasure their contented lifestyle. They are also thankful for their success, and are very athletic, healthy people who use swimming as part of their fitness regimen.

The pool we created for their home was designed to reflect and serve all of those qualities. It’s both beautiful, fits neatly with the setting, and is also built for swimming.

ACROSS THE WATERS

The property is right on the water in an area that features protected coastal rock formations and tide pools. It’s an enormous property that includes a number of small satellite

Fig. 2: Aerial view showcasing the unique five-sided shape, the beautiful landscaping, and the oceanic rock formations that make this pool both aesthetically appealing and environmentally conscious.

Fig. 3: Executing the precise edge detail required zero tolerance construction and dogged adherence to all applicable workmanship standards.

islands just off shore. Even working at the so-called high-end of the market, it's rare to work on a property with its own archipelago.

The pool was being built as part of a complete property renovation. It's big and is basically a rectangle with an angled cut out on the deep end that makes it technically a five-sided polygon. It's 60-ft (18 m) long, 20 ft (6 m) on the shallow end, and 16 ft (5 m) at the narrow end, which is 9 ft (2.7 m) deep.

From the start, we were told the pool was built for swimming; the clients and their grown children are all athletic and regular swimmers. They've been all over the world scuba diving, sailing, deep-sea fishing, and very much living an adventurous, aquatic lifestyle. They needed a pool that was not dainty, so that's what we gave them.

The interior is designed with narrow, 2 ft (0.6 m) steps and a long bench that runs the length of the pool to take advantage of the view while, at the same time, leaving as much room for swimming as possible.

It also had to be beautiful. It's an all-perimeter overflow designed by Janice Parker Landscape Architects based in nearby Greenwich, CT. She's a truly gifted designer who pays attention to both the big picture and the fine details; she is always working to find the best solution for the project parameters in play.

In this case, the aesthetic is relatively simplistic and based on the idea that you don't visually want to compete with the natural setting; instead, the aesthetic forges a visual connection between the landscape and the view of the ocean. Hence, the edge detail that raises the reflective surface of the water to grade, creating a powerful yet subtle visual transition. It looks great from all angles.

EDGE ON A LEDGE

Parker brought us into the project and asked us to submit a bid to the general contractor who builds super-high-end residential projects. When we were introduced to the project team and the owners, we immediately started talking about some of the specific challenges involved with building the pool so close to the water.

Fig. 4: Working so close to the shore can create challenges when it comes to the needed substructure and dealing with ground water or sandy soil conditions.

The pool abuts a rock ledge that's part of the coastline's natural geology, which includes beautiful and environmentally sensitive tide pools. Additionally, we had to work around a pine tree immediately adjacent to the pool that is growing up through a rock outcropping, which is the reason for the angled portion of the pool shape.

Working against what amounts to a natural seawall, there was also water constantly moving into the ground, so we had to run a dewatering system throughout the entire course of the project. In that setting, we would build a big pool with a 360° perimeter overflow detail and surge tanks – all without disturbing so much as a single snail.

The pool structure itself is carved out of solid rock, so there was no need for piles, grade beams, or any kind of elaborate foundation. We made sure the rock was stable and drainable, which it was, but we also installed hydrostatic relief valves throughout the pool. The excavation required some heavy-duty jackhammering, but it was done in such a way to leave the natural rock untouched.

Fig. 5: That was not the situation here. The solid-rock shoreline in this area served as the form for the pool structure, an advantage that simplified the process.

Fig. 6: So often, the true art and craft of construction resides in details that will go unseen once complete. The near-perfect formwork on this project is a prime example.

Drakeley Pools was chosen largely because of our experience in large, complex projects—both residential and commercial. We're good at construction details and also at explaining to building departments, health departments, and city officials how a pool needs to work and what won't work.

Fig. 7: It's a basic consideration, but properly elevating the steel above the ground is critical for structural integrity. Simple details matter. As is true of all-perimeter overflow systems, the forming, reinforcing steel, and shotcrete had to be installed to the highest possible standards and low tolerances. Suffice it say, this was not a job for a novice builder.

SURGE ELEVATION

Because of the environmental regulations, we cannot locate pool equipment in the storm surge. Our circulation system had to be designed with surge tanks below grade that circulate to an equipment pad that's 60 ft away and 15 ft (4.6 m) above grade in a secondary outbuilding. Specifically, FEMA regulations prohibit filtration systems at sea level.

The code language in FEMA 4 states that "where appropriate" all mechanical systems need to be above the storm surge line. In this case, working with a gravity edge-flow system, there is no way to pump the water uphill with pumps at a higher elevation. I pounded on that concept and explained that, in this case, the requirement for all equipment to be elevated was decidedly not feasible. It simply wouldn't work. Fortunately, that argument was convincing enough for them to approve a variance.

The plumbing comes off the overflow gutter manifold and in suction outlets on the bench inside the pool. It flows to a surge tank beneath the garage of the main house where we have four pumps pulling from a tank and pushing the water uphill.

From there, it is pumped up to the second building where the filters, heater, and treatment systems are located. The flow is divided between the edge overflow, the filtration and heating systems, and a third that feeds the ozone/chemical treatment system.

The return flows back to the pool via the same path, back down the hill, around the surge tank, and back to a series of flow returns in the pool floor. It's a tricky hydraulic set up that we engineered in-house.

It took quite a bit of convincing, lobbying, and repetition, but in the end, the powers that be approved the plan and we were able to go forward.

And through it all, the precious pine tree still stands and commands the view, and the inhabitants of the tide pools didn't even know we were there and remain as content as can be.

William "Bill" Drakeley *is an award-winning shotcrete technologist specializing in concrete science and construction, particularly shotcrete applications, techniques, and standards. He has thirty-plus years of experience in shotcrete installation, waterfeature and geotech design, and construction. He is co-founder of Watershape University.*

Framing Smartphone Photos for Shotcrete Jobs Using the Rule of Thirds

By Cindy Spires, Managing Editor

With the improvements in smartphone technology over the last decade, many of the phones we have in our hands are just as good at taking quality photos as some point-and-shoot cameras. In the absence of a professional photographer to follow us around and shoot pictures at our job sites, it turns out we have the next best thing in our pockets!

The only catch is that we might need to use a modified approach to framing our shots to maximize our photos so they depict the craftsmanship and aesthetics of our work. A photo can be a piece of art. Your shotcreting is a work of art—regardless of whether its function is as a tunnel lining or as an intricately sculpted water feature in a magnificent home's backyard.

Some job site photos end up in *Shotcrete* magazine, and I bet many of them end up on your websites or social media channels as promotion for your businesses. So, taking a few extra moments to set up a photo is worth it because it may ultimately also serve as a marketing or promotional tool for your business or in an article for *Shotcrete* magazine.

Even if you don't have the newest iPhone or Android phone, you still have a sweet piece of easily accessible technology at your fingertips to accomplish this task!

Let me introduce what is referred to as the Rule of Thirds and compare it to the classic style of framing the focal point in the center of the image. If you've never considered the Rule of Thirds before, I hope this provides context for how to start integrating the technique as you take photos of your shotcrete jobs.

RULE OF THIRDS

This one is relatively easy to do once you understand the method. First, you divide your smartphone's camera screen into nine equal squares in a grid with three rows and three columns.

Most smartphones allow us to turn on a grid for our cameras in the Settings, though some might not. If you have an iPhone, for example, go to Settings > Camera > Grid, and turn on the toggle for the grid.[1] Most Android phones have Camera Settings > Grid lines.

If you don't have the ability to turn on a grid on your smartphone's camera, you can still use your imagination to frame images this way. I will show you some examples to help you with this.

According to Adobe.com[2], "the rule of thirds is a composition guideline that places your subject in the left or right third of an image, leaving the other two thirds more open."

To be more exact, you place the subject along the right or left gridlines where the squares intersect: "you can think of it as giving you four crosshairs to target a shot's important elements. This will help you balance your main subject with negative space in your shot to nail an effective photographic composition that will draw the viewer's eye." [2]

Let's look at an example of a centered focal point (Fig. 1 and Fig. 2) against the Rule of Thirds being used (Fig. 3-6).

As you can see in these photographs of a zinnia from my flower garden, the zinnia is centered in the image (Fig. 1).

Please note that The Rule of Thirds is also in play when we make sure that the top and bottom spaces of the image are in equal distribution—it is technically still in play with

Fig. 1: A zinnia flower as the centered focal point.

Fig. 2: Smartphone gridlines overlaying a centered zinnia.

Fig. 3: Zinnia flower framed on right using the Rule of Thirds.

the direct centering of the point of focus in Figure 1. Think also about taking a photo of a beautiful sunset at Del Mar, CA on the Pacific Ocean: the horizon is dead center and there are equal amounts of sky and water flanking the horizon above and below. That is also the Rule of Thirds because the horizon is in the center-third.

However, for the purposes of this article, I want to focus on another aspect of the Rule of Thirds: the slight, off-centering that we will come to understand is an excellent way of framing an image.

In Figure 2, the gridlines show how the focal point is directly in the middle of the nine boxes that make up the three rows and three columns of the grid. The grid lines intersect in four corners, in this case, framing the zinnia perfectly in the center square.

This photograph is intended to showcase the single flower directly in the center of the foreground. It has accomplished its purpose to be framed this way. It is not a bad photograph or incorrectly framed; in fact, it is quite well-balanced in terms of the size of the flower relative to the size of the boxes on the grid. It is just centered. Part of what the Rule of Thirds asks us to do, however, is to slightly off-center the focal point with the purpose of framing the photo differently.

The intersecting grid lines we see in Figure 2 are where we will now build our understanding of how to accomplish taking a photograph that follows this aspect of the Rule of Thirds.

Here are two more sets of photos (Figure 3 and Figure 4), of the same zinnia, that illustrate the Rule of Thirds in practice.

Using the Rule of Thirds, I have framed the zinnia to be slightly off-center to the right (Fig. 3). In Figure 4, the grid lines showcase the centering of the image along the two intersection points on the right. The top and bottom of the magenta flower's petals are balanced between those intersecting grid lines on the right. This framing opens the background up a little differently than what is seen in the centered images (Fig. 1 and Fig. 2).

Fig. 4: Smartphone gridlines overlaying zinnia flower framed using the Rule of Thirds.

Is this photo better or worse than the images where the zinnia is perfectly centered in the frame? This is up to the viewer to decide which is more aesthetically appealing or functional. There is nothing wrong or right about either method. What we learn when we practice the Rule of Thirds is that we are being more deliberate with how we are framing our focal point, especially when whatever is in the background of the photo is still contributing to the accentuation of our slightly off-centered focal point.

In Figure 5 and Figure 6, I have taken a photo of the same zinnia using the Rule of Thirds, but I have centered the flower along the intersecting points on the left.

It creates a different aesthetic because now the purple flowers in the lower right of the background are actually visible, whereas they were previously covered up when I framed the zinnia on the right. (Fig. 3 and Fig. 4) Which is better? Viewer's choice! (I kind of like this one better, to be honest!)

Fig. 5: Zinnia flower framed on left using the Rule of Thirds.

Fig. 6: Smartphone gridlines overlaying zinnia flower framed using the Rule of Thirds.

USING THE RULE OF THIRDS FOR JOBSITE PHOTOS

This Rule of Thirds framing will come into play when you are photographing a shotcrete job that, for example, may have a nozzleman shooting a wall. While the nozzleman is going to be the focal point of the image, you still might want to have a sizeable amount of the wall in the image too. In this case, you would treat the nozzleman like my zinnia—lining him up along the intersecting gridlines on the right (or left), so that you can get the nozzleman, the wall, and the shotcrete equipment all documented in a deliberately framed way.

Here is a great example of the Rule of Thirds being used to frame a shotcrete job that is exactly what I just described. This image was submitted as part of ASA's recent Outstanding Shotcrete Awards issue (2nd Quarter 2023) featuring Shawn Radomski, Lloyd Keller, Daniel Sanchez, and Rusty Morgan's job, Mt. Pleasant Station: Eglington Crosstown LRT. (Fig. 7)

As you can see here (Fig. 7), the two nozzlemen are framed off center to the left along the imaginary intersecting

Fig. 7: Nozzleman and blow pipe operator shooting a congested test panel; framed using the Rule of Thirds.

grid lines I showed you in my earlier figures. The rebar is filling the space to the right giving context to the area they were working in. With this framing, following the Rule of Thirds, the viewer gets a great idea of the scope of what was happening in this action-based moment.

Here is another great example of a vertically oriented image following the Rule of Thirds (Fig. 8). Bruce Russell submitted this photo for his article on High-Production,

Figure 8: Scaffolding and finishers on a water tank; framed using the Rule of Thirds.

Quality Shotcrete, appearing in this issue (3rd Quarter 2023), from his job in Nicholasville, KY.

As you can see in this impactful image, the sheer size of the water storage tank and the multitude of platforms on the scaffolding create quite an awe-inspiring impression of the size of this shotcrete job. It is framed following the Rule of Thirds with the scaffolding off-center to the right and with the area between the men and the scaffolding lined up directly along those imaginary gridlines' rightmost intersections. In this case, using the Rule of Thirds showcases the enormous size of the concrete tank for a dramatic perspective. Had this particular image been framed with the men and the scaffolding centered, you'd have more of the sky and the trees on the right and less emphasis on the craftsmanship that was at play in this shot, as well as less emphasis on the size of the structure. This shot, in particular, has a wow factor because of how it was framed.

Both of these photos showcase the Rule of Thirds at play and how effective this type of framing can be for shotcrete-specific photography.

IN CONCLUSION

Sometimes we take photos using the Rule of Thirds out of instinct because it makes sense based on what we see in front of us, and sometimes we take them because we learned something new about the Rule of Thirds, and we want to spice things up a bit to really represent our work in a more deliberate, impactful way.

I encourage you to consider using the Rule of Thirds the next time you take photos of your shotcrete jobs. All it takes, really, is a keen eye to take in the elements you see in your smartphone camera's viewfinder and a small, deliberate movement of your hands to frame the shot!

In fact, try this: take three versions of a photo with the same point of focus, just like I've shown you in this article. Take one photo with the point of focus centered, one with it following the Rule of Thirds aligned to the right, and the last following the Rule of Thirds aligned to the left. Then decide which works best for your purposes. You might send in the left-aligned photo for your next article submission to *Shotcrete* magazine, and the one that is centered might be best used on your social media. Best case scenario: you have three photos to choose from, all of which look just a little differently from one another, like my zinnia photo examples.

With that being said, sometimes we throw the Rule of Thirds out the window because a beautiful sky above our primary point of focus is like icing on the cake, and we absolutely must get it all into one photograph without trying to be artistic about it. Sometimes centering the focal point dead center in the middle is the best choice because you thought about it and that's what you're going to do. Sometimes taking an extreme closeup is necessary to show texture, and the entire image becomes the focal point. And sometimes, some other framing is what that particular photo calls for. Regardless, you are the judge as you juxtapose your focal point against impactful, efficient, or aesthetically driven framing.

I encourage you to play around with the Rule of Thirds when taking photographs of your shotcrete jobs. Frame your images using this method, and see what you come up with! Then you can do two things: tag #artofshotcrete on social media, and send those images to us at *Shotcrete* when you write articles for the magazine or when you submit your jobs for the next Awards issue!

WHY USE THE RULE OF THIRDS?

- Context – insights to what's going on
- Perspective – insight into scope of work, magnitude of work
- Balance – visually highlights focal point
- Space – allows comments for marketing purposes
- Interest – allows the eye to travel

Cindy Spires *recently joined the American Shotcrete Association (ASA) as the Managing Editor of Shotcrete magazine. Her background is in teaching writing at the university level and in developmental and copy editing for professional and academic writers. Originally from the deep south, Cindy moved to San Diego in 2000 and earned a B.A. in English from San Diego State University. She has lived in the Detroit area since 2005 when she came to Wayne State University to earn her M.A. in English. One of Cindy's greatest strengths is helping writers communicate their intended purpose through their writing.*

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Coastal Gunite Construction Company Celebrates 40 years in Business

Coastal Gunite Construction Company delivers shotcrete construction services to build, maintain and rehabilitate concrete structures. Founded in 1983, Coastal Gunite Construction Company has developed a reputation for quality, integrity, and meeting strict performance requirements for both large and small projects. Their specialized experience in structural shotcrete construction allows them to provide owners and project engineers with cost-effective and enduring solutions to concrete infrastructure construction and maintenance needs.

2023 marks Coastal Gunite Construction Company's 40th anniversary, and ASA salutes your commitment to the industry!

Figure 1: 1987, Herbert C. Bonner Bridge, Oregon Inlet, NC, Pile Cap Rehabilitation

Figure 2: 2017, Washington, DC, Elliptical Sewer Rehabilitation

By specializing solely in shotcrete construction services, Coastal Gunite has developed a team of well-trained, highly experienced tradesmen. Coastal Gunite has more than 125 years of shotcrete experience among their site superintendents and over a dozen trained and ACI-certified shotcrete nozzlemen. Each Coastal Gunite site superintendent has a minimum of 25 years of shotcrete construction experience.

Coastal Gunite performs structural shotcrete construction services for projects of all sizes and duration. Depending on the project, they can dispatch single or multiple mobile crews to complete any project cost-effectively and ahead of schedule. Whether it's a small culvert, miles from the nearest road, or a cooling tower stretching to the sky, Coastal Gunite has the capability to efficiently and effectively get the job done.

Coastal Gunite is experienced in both wet-mix and dry-mix shotcrete placement and can modify the process as needed to provide integrity, compressive strength, durability and to prevent migration of corrosive agents. Currently, Coastal is

Figure 3: 1987, Herbert C. Bonner Bridge, Oregon Inlet, NC, Shooting Pile Cap

Figure 4: 2007, St. John's Towers, Jacksonville, FL, Cooling Tower Rehabilitation

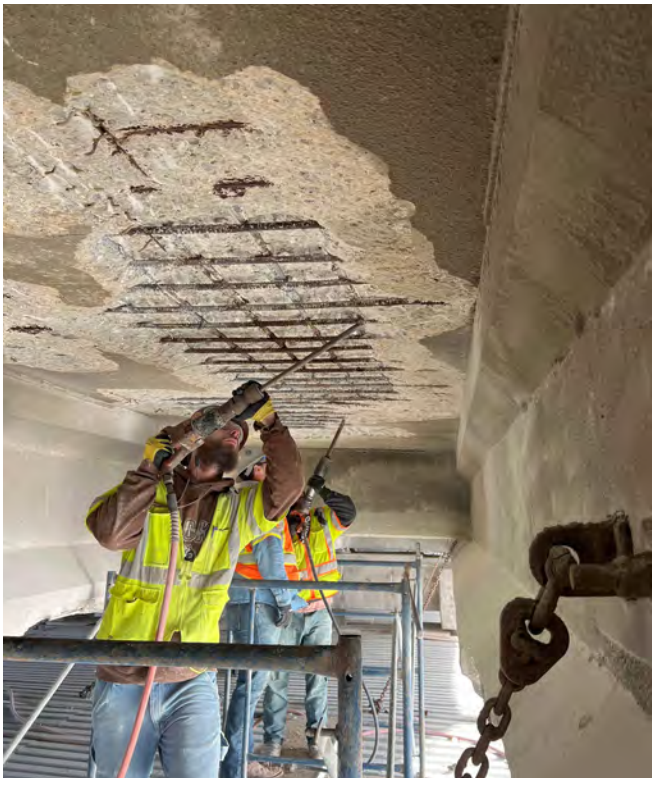

Figure 5: 2023, Chipping at Banks Channel Bridge, Wrightsville Beach, NC

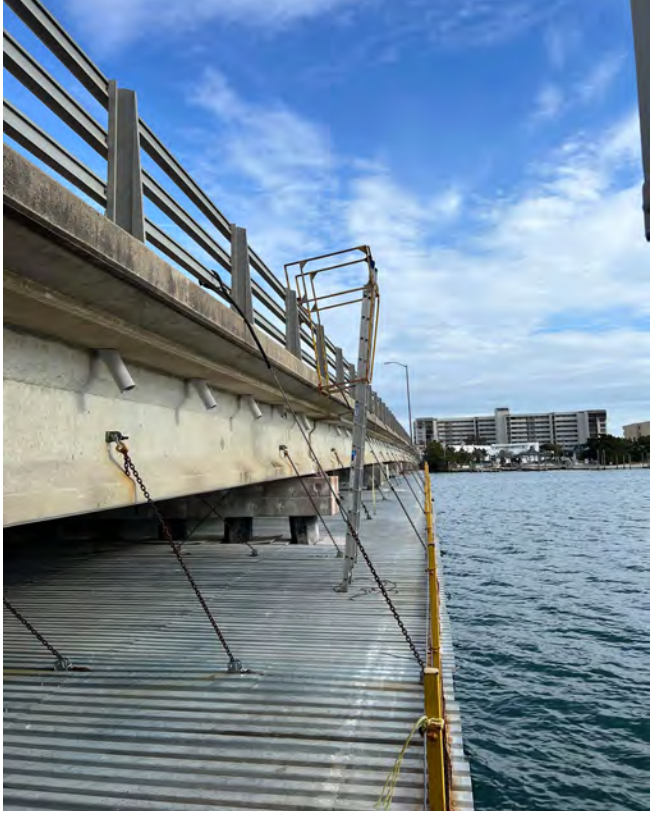

Figure 6: 2023, Scaffolding at Banks Channel Bridge, Wrightsville Beach, NC

a Level II ASA Qualified Shotcrete Contractor in the Dry-Mix process.

Coastal Gunite has developed a proven track record in both quality and safety. As a result, Coastal Gunite has been pre-qualified for work with Departments of Transportation in over 20 states and has developed vast experiences as well with Federal, State, and Local agencies, including various airport authorities, power utilities, and the US Army Corps of Engineers. All Coastal Gunite work is licensed, bonded, and insured.

Coastal Gunite is also the recipient of several awards and accolades. In recent years, the company has been recognized for outstanding achievement by the American Shotcrete Association and the International Concrete Repair Institute.

Today, Coastal Gunite provides services from offices located in Maryland, North Carolina, Tennessee, and Florida. For additional information, please contact their main office in Palmetto, Florida or visit their website listed below.

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SIKA'S RECO$_2$VER® CONCRETE RECYCLING TECHNOLOGY

In August 2023, Sika announced that its reCO$_2$ver® technology, which "involves a novel concrete recycling process that allows old concrete to be entirely reused while facilitating the sequestration of CO$_2$," has received a commitment by Switzerland's Climate Cent Foundation, which is "guaranteeing the purchase of CO$_2$ certificates" in the amount of approximately $11.2 M USD ($10 M CHF) by the end of 2030.[1]

Fig. 1: Sika's reCO$_2$ver® recycling technology.[3]

According to MIT's Climate Portal, Carbon offset certificates are "tradable 'rights…linked to activities that lower the amount of Carbon dioxide (CO$_2$) in the atmosphere. By buying these certificates, a person or group can fund projects that fight climate change instead of taking actions to lower their own carbon emissions. In this way, the certificates "offset" the buyer's CO$_2$ emissions with an equal amount of CO$_2$ reductions somewhere else".[2]

Because CO$_2$ emissions from the construction and building industries account for approximately 40% of global emissions, and the cement industry, in particular, accounts "for more than 8% of greenhouse gas emissions," Sika has developed the reCO$_2$ver® technology to "make it possible to completely recycle concrete demolition waste".[1]

Sika's reCO$_2$ver® technology separates old concrete into its individual components (gravel, sand, and cement stone), and it binds "additional CO$_2$ through a chemical process" which is later "optimized using Sika additives." Since October 2021, Sika has operated a pilot facility for this process in Switzerland, and now that the test phase is over, the recycled concrete can be "repurposed as a substitute for cement in concrete production".[1]

Congratulations to ASA Sustaining Corporate Member, Sika, on this major accomplishment in developing and funding sustainable practices within the concrete and construction industries.

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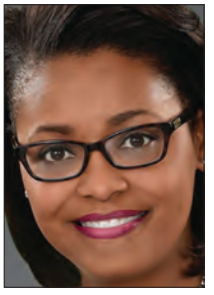
ON THE MOVE!

Cindy Spires

ASA is thrilled to announce changes in ASA staff. Cindy Spires joins us as our new *Managing Editor* for *Shotcrete* magazine! Cindy comes to us not only with a strong editorial background but a passion for coaching writers as well. You may have already been in contact with Cindy, who offers her services to help put your insights into words for your next article! Though Cindy's main focus will be the magazine, she will also be picking up additional responsibilities with ASA's certification efforts.

Tosha Holden, having passed on *Shotcrete* magazine responsibilities to Cindy, has shifted her title to *Member Engagement and Marketing Manager*. Tosha will continue to oversee ASA's social media and marketing efforts, but she will pick up additional responsibilities to support and enhance membership initiatives and the work of ASA Committees that came out of ASA's updated strategic plan.



Tosha Holden

ASA believes these new staff changes will bolster ASA's service to both the Association and the industry.

ASA's Strategic Plan

Updates to ASA's mission and goals can now be found online: **shotcrete.org/wp-content/uploads/2023/07/ASA_Strategic_Plan_2023-2027.pdf** You will be hearing more from each of our Committee Chairs in upcoming issues as programs unfold to support the strategic plan.

WORLD OF CONCRETE 2024

January 23 – 25, 2024
Las Vegas Convention Center
Las Vegas, NV
Don't miss out on the savings!

Use ASA's source code **A17** for the lowest-discounted, exhibit-only admission pass, stop by to see us at booth #S10919 in the South Hall, and attend our General Membership meeting and reception on Tuesday after the show. Registration is now open. **Discounted $25 Exhibit Only registration available online until December 12, 2023.** Rates increase to $120 afterwards! Register now to take advantage of Early Bird Rates!

ASA hosts a number of events at World of Concrete. Complete details can be found at **shotcrete.org/asa-at-world-of-concrete**. Events include:

ASA Shotcrete Nozzleman Education
Tuesday, January 23, 2024 | 8:00 AM – 4:00 PM
Registration code: ASATU

ASA WOC 2024 General Membership Meeting & Shotcrete Reception
Tuesday, January 23, 2024 | 5:00 PM – 7:00 PM

Quality Shotcrete – Know It When You See It
Wednesday, January 24, 2024 | 8:00 AM – 4:00 PM
(without exam registration code: **ASAWE**; until 6:00 PM with exam registration code: **ASAWEX**)

ACI Shotcrete Nozzleman Certification – Wet Mix
January 25 – 26, 2024 | World of Shotcrete | Henderson, NV
Register: **www.worldofshotcrete.com/**

RECOGNIZING QUALITY SHOTCRETE

Tuesday, February 6, 2024
ACI MidWest Resource Center | Elk Grove, IL
8:00 AM – 4:00 PM (without exam; 6:00 PM with exam)

Contractors, though you may have used shotcrete contractors for years on your projects, do you know what to look for to confirm you're getting the best quality for your money? Though shotcrete is a placement method for concrete, the process has fundamentally different equipment, material selection, crew responsibilities, application techniques, testing, curing, and protection that need to be considered for producing the high-quality and durable shotcrete you, as a contractor, and the owner expect.

This seminar from ASA provides guidance on over 40 critical elements of shotcrete applications for those onsite to properly evaluate the overall quality of shotcrete placement. These include an overview on material selections, equipment, placement techniques, finishing, curing, protection, testing, and safety as it relates to the shotcrete process. For shotcrete contractors, this seminar will help you verify the quality of your work to your general contractors and inspectors.

The ACI Shotcrete Inspector Certification exam will be offered immediately after the seminar.

SHOTCRETE CONVENTION & TECHNOLOGY CONFERENCE

March 3 - 5, 2024 | Lakeway Resort & Spa | Austin,TX

CONVENTION REGISTRATION IS NOW OPEN!

ASA will host our annual ASA Shotcrete Convention and Technology Conference at the Lakeway Resort and Spa, located in the heart of Texas Hill Country along Lake Travis. Our annual ASA convention is a unique opportunity to explore shotcrete applications and innovations as well as future advancements in the industry with 12 presentations. Attendees are also invited to attend and participate in ASA's 2024 Spring Committee meetings. Additionally, ASA will celebrate our 2023 Outstanding Shotcrete Project Award winners at our Annual Awards Banquet on Tuesday. Join us for this wonderful networking and learning experience!

Registration is now available: **shotcrete.org/convention**

CONTRACTOR QUALIFICATION EDUCATION SEMINAR

Sunday, March 3, 2024 -
Pre-convention Seminar,
additional fees apply
Lakeway Resort & Spa Austin, TX

One of the mandatory requirements in ASA's Contractor Qualification Program (CQP) is the attendance of a company representative (aka Qualifying Individual) 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.

Topics covered in the seminar include:

1. Overview of the CQP
2. Site planning/Logistics
3. Diversity of Shotcrete Applications
4. Concrete Knowledge
5. Shotcrete Equipment
6. Shotcrete Knowledge
7. Shotcrete Testing
8. Equipment Maintenance
9. Shotcrete Specific Safety
10. Financial Responsibilities

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

SHOTCRETE CONVENTION & TECHNOLOGY CONFERENCE

March 3 - 5, 2024 | Lakeway Resort & Spa | Austin,TX

BECOME A SPONSOR!

Make sure your company is recognized among the leaders of the shotcrete industry by sponsoring the 2024 ASA Shotcrete Convention & Technology Conference! As a sponsor, you will receive a variety of exposure opportunities:

- Convention Venue
- Awards Banquet (reception, dinner, & awards program)
- 1st Quarter 2024 Awards Issue of Shotcrete magazine
- ASA What's In The Mix (eNewsletter) & Social Media promotions
- ASA Website, Convention page – all year

Lock in your sponsorship TODAY in one of the following sponsorship categories:

BIG SHOOTER ($5000) - Exposure with most prominent placement of company logo throughout all promotional materials; one complimentary tabletop exhibit (first come, first served—must confirm interest at time of application); and unlimited Half Price Awards Banquet Tickets.

GOLD ($2500) - Exposure, and prominently placed logo (after Big Shooters) throughout all promotional materials; one complimentary tabletop exhibit (first come, first served—must confirm interest at time of application); and (1) Half Price Awards Banquet Ticket.

SILVER ($1000) - Exposure, and prominently placed logo (after Gold Sponsors) throughout all promotional materials.

JOIN OUR SHOTCRETE MAGAZINE ADVERTISERS!

2024 Media Kit is now online! Place your insertion orders now to ensure inclusion in all four 2024 issues of *Shotcrete* magazine!

Advertising in *Shotcrete* magazine will position your company at the top of the minds of the people in the shotcrete industry. Reach the companies and people that you need to grow your business with *Shotcrete* magazine's competitive pricing, with an average savings of 25% or more compared to other leading trade association magazines. These rates certainly provide you with the most "bang" for your advertising dollars! Visit **shotcrete.org/MediaKit** for more information or contact us info@shotcrete.org to submit your insertion order.

NEW ASA MEMBERS

american shotcrete association

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abpoolsub.com
Primary Contact: Burke Barclay
burkebarclay@gmail.com

CROM LLC
Gainesville, FL
www.cromcorp.com
Primary Contact: Bruce Russell
brussell@cromcorp.com

Western Shotcrete Equipment
West Haven, UT
Wseshotcrete.com
Primary Contact: Jill Harpole
jillharpole@wseshotcrete.com

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www.dbmcontractors.com
Primary Contact: Jim Sexton
jim.sexton@dbmcontractors.com

Groupe Northstone
Quebec, Canada
thenorthstonegroup.com
Primary Contact: Mark Fournier
mark.fournier@groupenorthstone.com

Rousseau Services LLC
Kahului, HI
Primary Contact: Pierre Rousseau
info@rousseauservicesllc.com

Superior Shotcrete Inc.
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Primary Contact: Ed Erdman
superiorshotcrete@comcast.net

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Kissimmee, FL
verobuildingsystems.com
Primary Contact: Kent Hendricks
khendricks@verobuilt.com

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Cecilia Soria
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Fort Worth, TX

Robert Sulak
A&B Gunite
Fort Worth, TX

Joseph Swann
CROM LLC
Gainesville, FL

CORPORATE ADDITIONALS

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Blastcrete Equipment LLC
Allentown, PA

Rob Dyer
The Quikrete Companies
Sacramento, CA

ACADEMICS

Orin Harris
Northeastern Illinois University
Chicago, IL

Wei Victor Liu
University of Alberta
Alberta, Canada

Paraskevi Yiouta-Mitra
National Technical University
Athens, Greece

INTERESTED IN BECOMING A MEMBER OF ASA?

Read about the benefits of being a member of ASA and find a Membership Application under the ASA Membership tab of **www.shotcrete.org**.

ACI SHOTCRETE INSPECTOR CERTIFICATION UPDATE

ACI C661 – Shotcrete Inspector Certification, the certification committee overseeing the shotcrete inspector certification program, approved two changes to the policy proposed at ACI's Spring Committee meetings this past April in San Francisco, CA. First, the performance exam component of the ACI Concrete Field Testing Technician – Grade I certification has been withdrawn. Only the written exam is now required and may be completed at any of the following: at your local ACI Chapter, at a Prometric testing center, or via a Prometric remotely proctored exam. This, in combination with the ACI Shotcrete Inspector Certification written exam, if taken within a one-year time period, completes the requirements for the ACI Associate Shotcrete Inspector Certification. Secondly, the time duration for the ACI shotcrete inspector certification written exam has been extended from 90 minutes to 120 minutes for completion.

The third component required for the ACI Shotcrete Inspector Certification, i.e., three years of satisfactory shotcrete work experience, may be submitted at any time within the five years of your Associate Shotcrete Inspector Certification to be upgraded to Shotcrete Inspector status. ASA's "Recognizing Quality Shotcrete" aka "Quality Shotcrete – Know It When You See It" seminar is an approved educational offering that provides a 12-month credit towards the inspector work experience requirement. ASA has been working with the ACI SoCal & MidWest Resource Centers to offer the ASA Quality Shotcrete seminar followed by the opportunity to take the ACI Shotcrete Inspector Certification written exam. Further details may be found on calendars from **www.concrete.org** or **www.shotcrete.org.**

BUILDING OFFICIALS CERTIFICATION DOCUMENT

Certification Staff have been working closely with the ACI Codes and Standards Advocacy and Outreach (CSAO) staff to assist in drafting this FREE document that summarizes where and how ACI certifications are required in commonly-used industry documents. Get your free copy through the link below and provide this link to others!

Link to: **concrete.org/store/productdetail.aspx?ItemID=BOPD**

ASCC'S POSITION STATEMENT #46: "WATER-CEMENTITIOUS MATERIAL RATIO FOR CONCRETE TO RECEIVE A TROWEL FINISH."

The American Society of Concrete Contractors (ASCC), St. Louis, MO, USA has published its forty-sixth Position Statement, "Water-Cementitious Material Ratio for Concrete to Receive a Trowel Finish." ASCC Position Statements clarify the concrete contractors' point of view for architects, engineers, owners, and others.

Position Statement #46 explains that the ACI 318-19 Building Code requires a maximum water-cementitious material ratio (w/cm) in accordance with the severity of the anticipated exposure of members, and varies from N/A to 0.55, 0.50, 0.45, and 0.40. Many specifications, however, require a maximum w/cm for interior concrete, often as low as 0.40, which is undesirable for the surface finish.

ACI 302.2 R-06, "Guide for Concrete Slabs that Receive Moisture-Sensitive Flooring Materials," recommends a w/cm of 0.50 as the best compromise between drying rate and finishing performance. ACI 302.1R-15 "Guide to Floor and Slab Construction" states that specifying a maximum w/cm for concrete workability is not useful, and further recommends a w/cm in the range of 0.47 to 0.55 for concrete floors to receive a trowel finish.

It concludes with the recommendation that concrete contractors should encourage specifiers to consider ACI 302.1R-15 and ACI 302.2R-06 for w/cm for concrete to receive a trowel finish.

The PS #46 includes additional references from ACI, as well as the National Ready Mixed Concrete Association (NRMCA) and ASTM International. To read PS #46, visit ascconline.org/Technical/Position-Statements.

BEKAERT OBTAINS SBTI VALIDATION FOR THE GROUP'S CARBON REDUCTION TARGETS

Bekaert announced that its near-term and long-term greenhouse gas emissions reduction targets have been validated by the Science Based Targets initiative (SBTi). The SBTi defines and promotes best practices in science-based target setting and independently assesses companies' targets.

Bekaert has committed to actions to align emissions reduction targets to the 1.5-degree target of the Paris agreement. As part of an overall commitment to become Carbon Net Zero by 2050, the company has set ambitious targets for its value chain, covering Scope 1, Scope 2, and Scope 3 emissions, including reducing greenhouse gas emissions, enhancing the energy efficiency of its operations, and increasing the proportion of its renewable energy supply.

"As the world is transitioning to a zero-carbon economy, it is the responsibility of industrial companies like Bekaert to lead the way in decarbonization actions, in boosting

innovation, and in driving smart, safe and sustainable solutions in the end-markets," says Oswald Schmid, CEO of Bekaert.

To reach its objectives, Bekaert will engage with suppliers and customers to commit to carbon reduction targets and to measures based on circular principles across the value chain.

To learn more, visit **bekaert.com/en/sustainability**.

Bekaert

BEKAERT RECEIVES 2022 EXCELLENCE IN ECONOMIC OUTCOMES AWARD

Bekaert, along with its project partners including Acciona Samsung Bouygues Joint Venture, received the 2022 Excellence in Economic Outcomes Award from the Australian Infrastructure Sustainability Council (ISC) for the M4-M5 Link Tunnels in Sydney, Australia. This project was also the recipient of the American Shotcrete Association's Outstanding International Project of the Year in 2021.

The world's first shotcrete application tunnel lining was constructed using Bekaert's high performance Dramix® 4D65/35 steel fibers within the shotcrete mix. Bekaert was heavily involved in the original value proposition which drastically reduced the required materials, costs, time, and embodied carbon of the project. This lowered the overall cost by some AUD$ 11,000,000.

Congratulations to all the partners who made this project a real success.

To learn more, **visit bekaert.com/en/sustainability**.

ASA MEMBERS WIN ENR MIDWEST BEST PROJECT AWARDS

On August 22, 2023, ENR Midwest announced its 2023 Best Project Awardees. According to their press release, the judging of 63 submittals led to 19 awards for "projects that represent outstanding quality of work, spurred innovative ideas, and overcame intriguing challenges."

Of these awardees, two are ASA members:

Bulley & Andrews won the Award of Merit in the Renovation/Restoration category for their project, The Belden-Stratford, in Chicago, IL, USA.

Geostabilization International (GSI) won Best Project in the Residential/Hospitality category for their project, Riverview Drive Retaining Wall Stabilization, in Alton, IL, USA.

Congratulations to Bulley & Andrews and GSI for their hard work in earning these awards!

SHOTCRETE CALENDAR

Please check with the meeting provider as some meetings may be postponed or cancelled after publication of this issue of Shotcrete.

NOVEMBER 4, 2023	**Quality Shotcrete – Know It When You See It (Shotcrete Inspector Seminar)** Dees-Hennessey Inc. | San Francisco Bay Area, CA
NOVEMBER 13 - 15, 2023	**International Pool | Spa | Patio Expo 2023** Las Vegas Convention Center – West Hall | Las Vegas, NV
NOVEMBER 13, 2023	**Quality Shotcrete – Know It When You See It (Shotcrete Inspector Seminar)** International Pool | Spa | Patio Expo 2023 | Las Vegas, NV
DECEMBER 3 - 6, 2023	**ASTM – C09 Concrete & Concrete Aggregates** Washington Hilton | Washington, DC
JANUARY 7 - 11, 2024	**Transportation Research Board – 103rd Annual Meeting** Washington, DC
JANUARY 23 - 25, 2024	**The Pool & Spa Show 2024** Atlantic City Convention Center | Atlantic City, NJ
JANUARY 23 - 25, 2024	**World of Concrete – 50th Anniversary (Use Source Code A17)** Las Vegas Convention Center | Las Vegas, NV
JANUARY 23, 2024	**ASA Shotcrete Nozzleman Education** Las Vegas Convention Center | Las Vegas, NV
JANUARY 23, 2024	**ASA WOC 2024 General Membership Meeting & Shotcrete Reception** Las Vegas Convention Center | Las Vegas, NV
JANUARY 24, 2024	**Quality Shotcrete – Know It When You See It (Shotcrete Inspector Seminar)** Las Vegas Convention Center | Las Vegas, NV
JANUARY 25 - 26, 2024	**ACI Shotcrete Nozzleman Certification | Wet-Mix** World of Shotcrete | Henderson, NV
FEBRUARY 6, 2024	**Recognizing Quality Shotcrete** ACI MidWest Resource Center | Elk Grove, IL
FEBRUARY 21, 2024	**Everything Under the Sun – Specialty Education** **Quality Shotcrete – Know It When You See It (Shotcrete Inspector Seminar)** Orange County Convention Center – West Hall E | Orlando, FL
FEBRUARY 23 - 24, 2024	**Everything Under the Sun** Orange County Convention Center – West Hall E | Orlando, FL
MARCH 3 - 5, 2024	**2024 Shotcrete Convention & Technology Conference** Lakeway Resort and Spa | Austin, TX
MARCH 3, 2024	**ASA Contractor Qualification Education** Lakeway Resort and Spa | Austin, TX
MORE INFORMATION	To see a full list, current updates, and active links to each event, visit www.shotcrete.org/calendar.

SHOTCRETE CONVENTION & TECHNOLOGY CONFERENCE

March 3 – 5, 2024 | Lakeway Resort & Spa | Austin, TX

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REGISTER TODAY!

CONVENTION HIGHLIGHTS:

- 3 TRACKS: POOL, UNDERGROUND, & GENERAL
- WHISKY TASTING
- INDUSTRY EXHIBITORS
- CONTRACTOR QUALIFICATION SEMINAR
- QUALITY SHOTCRETE SEMINAR (POOL CERTIFICATE)
- COMMITTEE INVOLVEMENT OPPORTUNITIES
- NETWORKING EVENTS

Register at shotcrete.org/convention

SHOTCRETE FAQs

As a service to our readers, *Shotcrete* magazine includes selected questions and 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 www.shotcrete.org/FAQs.

Question: *We are a shotcrete company in Southern California, and I have a technical question about an issue that has recently come up. Is there any official ASA or ACI guide/spec that recommends or lays out the use of a certified nozzleman on a job that he was not "job site" approved for? For instance, a nozzleman who did not shoot a test panel was overseen by the approved nozzleman for that job site.*

I understand that the approved nozzleman can oversee another ACI-certified nozzleman on the job so that he can rest and oversee production. Seeing as the approved man is overseeing the nozzleman, is it the same as him shooting the wall himself?

Answer: It appears you are talking about a nozzleman who has not been pre-qualified by shooting a mockup panel on a specific project. There is no official ASA or ACI document that addresses this issue. However, this situation is similar to what ACI guidance provides regarding ACI-certified Shotcrete Nozzlemen and Nozzlemen-in-training.

ACI's Certification Program Policy for Shotcrete Nozzleman and Nozzleman-In-Training Section 1.04 states:

"ACI Shotcrete Nozzleman-In-Training (NIT) certification is available to applicants who do not possess 500 hours of work experience but do possess a minimum of 25 hours of hand nozzling work experience in the process being sought (vertical orientation only). The examiner of record may require an ACI-certified nozzleman to be present during the performance exam; however, the ACI-certified nozzleman's interaction with the examinee is strictly limited to the safety of the shooting operation."

Note: *A Nozzleman-in-Training must accumulate additional work experience hours (time directly operating the nozzle) to reach the full certification requirements. It is the intent of ACI Committee 506 - Shotcreting as expressed in ACI 506R, Guide to Shotcrete that a Nozzleman-in-Training is qualified to accumulate hours on projects requiring ACI-certified shotcrete nozzlemen by shooting under the direct supervision of a currently ACI-certified shotcrete nozzleman whose certification(s) reflect the process and orientation being shot. The certified nozzleman directly supervising the NIT must be in a physical position to visually monitor all aspects of the shotcrete placement when the NIT is operating the nozzle, and the certified nozzleman supervising is fully responsible for the quality of shotcrete placement when an NIT is operating the nozzle."*

Using this as an example of a certified nozzleman closely supervising another less qualified nozzleman would seem applicable. Quality shotcrete placement requires close attention to the visual aspects of the concrete as it is placed. Thus, mirroring the certification policy, the project-qualified nozzleman must be physically in a position to visually monitor all aspects of the shotcrete placement when the non-qualified nozzleman is operating the nozzle. The project-qualified

nozzleman supervising is fully responsible for the quality of shotcrete placement when the non-qualified nozzleman is operating the nozzle.

The final decision on whether to accept this approach is the responsibility of the engineer-of-record (EOR). If the EOR does not accept this approach, you will likely need to have one or more additional nozzlemen to shoot mockup panels for evaluation as the originally qualified nozzleman did. If the EOR would like to discuss this approach, they should feel free to contact the ASA Technical Director, Charles Hanskat by email (Charles.Hanskat@Shotcrete.org).

Question: *Please direct me to the proper guidelines for the hydration of shotcrete.*

Answer: By hydration, I'm assuming you are referring to curing of freshly placed concrete. A minimum of 7 days of continuous wet curing is recommended. Continuous means the exposed concrete surface is wet the entire duration. Not just "watered" twice a day as has sometimes been suggested by contractors. Use of a spray-on curing membrane is an option if for some reason water curing is not practical.

If you are looking specifically at swimming pools, this ASA Pool and Recreational Shotcrete Committee Position Statement "Curing of Shotcrete for Swimming Pools" provides more details: shotcrete.org/wp-content/uploads/2022/01/218216_SCMSummer21_PS7v2.pdf

Also, for a more detailed look at curing, the American Concrete Institute (ACI) document, ACI PRC-308-16 Guide to External Curing of Concrete is an excellent reference. You can find this at ACI's bookstore (concrete.org/store.aspx).

Finally, a good reference on the basics of concrete, from materials to placement and curing, is the Portland Cement Association's "Design and Control of Concrete Mixtures, 17th Edition." You can find this on the PCA website bookstore.

Question: *We are having a pool installed and would like to know if shotcrete should be placed when severe weather is forecasted for late in the day or the next day? Is it possible to cover the area after application to protect it?*

Answer: Shotcrete is a method for placing concrete. Concrete has a set time that provides hardness of the in-place concrete. Final set may take anywhere from an hour to several hours depending on the concrete mixture and the weather. Hot weather has a faster set time than cold weather with the same concrete mixture. If the pool is shot in the morning, it may be hard enough to tolerate a rainstorm in the late afternoon. The concrete should certainly be set by the next day unless there is a very cold overnight temperature or a problem with retarder in the concrete mixture.

Tarps could be placed over the vertical walls to protect them from a sudden rainstorm. The floor may be harder to protect as the rainwater wouldn't necessarily drain off the floor. If concrete is exposed to rain and the surface isn't washed off in any way, the concrete should be good.

Similarly, if you are expecting freezing temperatures overnight, the fresh concrete must be protected from freezing. This may require using vented heaters and insulated blankets. The goal of the cold weather protection is to keep the surface temperature of the fresh concrete above 50°F (10°C). More details on cold weather protection can be found in ACI PRC-306-16 Guide to Cold Weather Concreting available directly from ACI's bookstore (concrete.org/store.aspx).

Disclaimer: The technical information provided by ASA's technical team is a free service. The information is based on the personal knowledge and experience of the ASA technical team and does not represent the official position of ASA. We assume that the requester has the skills and experience necessary to determine whether the information provided by ASA is appropriate for the requester's purposes. The information provided by ASA is used or implemented by the requester at their OWN RISK.

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