shotcrete MAGAZINE

A quarterly publication of the American Shotcrete Association

VOLUME 26, NUMBER 1 • 1ST QUARTER | 2024

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OUTSTANDING SHOTCRETE PROJECT AWARDS

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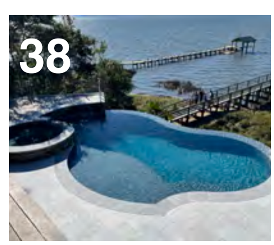
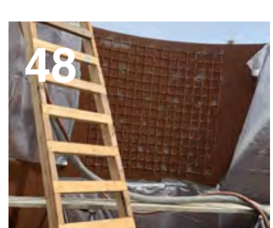
shotcrete MAGAZINE

Volume 26, Number 1 • 1st Quarter | 2024

FEATURES





Shotcrete is a quarterly publication of the American Shotcrete Association. For information about this publication or about membership of the American Shotcrete Association, please contact ASA Headquarters at:

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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).

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ALSO FEATURING

DEPARTMENTS

Outstanding Architecture | New Construction Project: COST of Wisconsin Blends Art and Engineering to Help Create New Gilder Center at AMNH. Photo Courtesy of COST of Wisconsin. Read about this project on page 16.


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Knowledge: Shotcrete's Most Valuable Resource

By Oscar Duckworth

As 2024's incoming ASA President, I've been asked to write a brief introduction. For those who do not know me, I am not an academic or engineer. Rather, I am a nozzleman. Yet with over 30 years of daily practice in shotcrete placement, I have not mastered the craft.

The art of the nozzleman is a craft that can never be mastered. It can only be continually refined.

My shotcrete career started with buying a small concrete pumping company in 1990. It was at that point that I began to learn the value of knowledge. The previous owner's educational lesson appeared clear and easy to understand:

"The concrete goes in here and comes out over there."

Later, I found out he was only half right.

Similar experiences followed as our concrete pumping work moved to primarily wet-mix shotcrete placement. Actually, poor shotcrete placement. My daily nozzleman duties involved beating hoses, cleaning fallouts, and shoveling massive amounts of concrete waste.

We quickly realized that mastery of shotcrete was not a test of strength, equipment, or mechanical aptitude. Rather, successful shotcrete placement appeared to be dependent on countless variables that we did not understand and could not control.

Success in shotcrete evaded us. We needed help. Moreover, we needed knowledge. Aside from advice, which was widely available (and worth what we paid for it), genuine educational resources for shotcrete were not widely available at the time.

Back then, scavenging for knowledge meant trial and error, spying on and imitating others, and attending trade shows. It was at one of those trade shows that I first became aware of the American Shotcrete Association. After a brief visit and a handout in their small booth at the World of Concrete trade show in the late 1990s, I was hooked. We received the very first *Shotcrete* magazine, and with each of the following editions, we read them cover to cover.

I had the pleasure of meeting many of ASA's founding members during the inaugural ASA meeting held at the American Concrete Institute (ACI) Fall 1998 Convention in Los Angeles and at other events, including George Yoggy, Pete Tatnall, Rusty Morgan, Lars Balck, and Ray Schallom. These legends freely shared their vast knowledge with me as a young nozzleman who they did not know. Knowledge brought clarity to the countless variables that we did not understand and could not control. Significant improvements in our shotcrete placement followed.

In 2001, I participated in and became certified at the very first ACI Shotcrete Nozzleman Certification Session in Las Vegas. Shortly afterward, Merlyn Isaak, a founding member of ASA, influenced me into becoming involved with both ACI and ASA. It was Merlyn's strong belief that involvement and knowledge have strong ties and are the backbone of improvement.

I became an ACI Examiner in 2007, and in 2012, I served as ASA Chair of the Safety Committee for two terms, and ASA Chair of Education for the last nine terms. It is with these experiences that I have done my best to pay back the knowledge that was freely shared with me long ago.

Involvement with ASA has given me the opportunity to meet a wide variety of people who share similar stories and who have an obvious passion for shotcrete. Some of these young professionals will become our industry's future leaders.

During my term as President, I look forward to working with these future leaders and will help continue the work of those who have come before me. I urge you to become involved. Merlyn Isaak's words are as valid now as they were then: "involvement and knowledge have strong ties and are the backbone of improvement."

ASA is currently the world authority for all shotcrete-related educational resources. Although with over 25 years of daily practice, we have not mastered the craft. The art of being a global resource for shotcrete is a craft that can never be mastered. It can only be continually refined.


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History: Shotcrete's Most Valuable Safety Resource

By Oscar Duckworth, ASA Education & Safety Committee Chair

It is said that history tends to repeat itself. Similarly, shotcrete placement-related hazards that lead to injuries tend to repeat themselves.

History is the world's greatest educator. Unfortunately, due to the rapid growth of shotcrete placement, workers with a long history in the craft are rapidly being replaced by relatively new workers who may not recognize past hazards.

By recognizing shotcrete's unique hazards learned from history, we can predict hazards that will occur in the future. What are these unique hazards? Might a small, often overlooked item cause a significant safety risk? Are easily preventable injuries still occurring?

Over the last 25 years, *Shotcrete* magazine has published more than 75 safety-related articles. These articles were written by an amazing diversity of highly experienced shotcrete professionals from nearly every facet of the shotcrete industry.

Although each of these authors may work with completely different facets of shotcrete, they share one thing in common: these authors, through firsthand experience, have written about a clear shotcrete safety hazard and have recommended a solution.

You can look through the magazine article archives on our website at **www.shotcrete.org**.

Over the next few months, members of the ASA Education & Safety Committee will be reviewing *Shotcrete* magazine's archive of 25 years. These safety-related articles will be revisited to review the rich history of identified safety hazards as presented by their authors. ASA will make updates, as appropriate, and compile these articles into a new resource that is relevant to today's work environment; through these efforts, ASA will provide a valuable resource to an entirely new generation of shotcrete workers. This compilation will be an ASA member benefit for Sustaining and Corporate members and will be accessible via our Communities website. We envision this resource to be a valuable asset for your Toolbox Talks, providing bite-sized safety tips for your crews.

Unfortunately, overlooked and often easily preventable shotcrete-related injuries continue to occur. Utilizing history's important, safety-related lessons could go a long way to help prevent shotcrete work-related hazards from repeating themselves.

ASA EDUCATION & SAFETY COMMITTEE

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Lars Balck | Consultant
Marc Jolin | Laval University
Marcus von der Hofen | Coastal Gunite Construction Company

Onward into a New Year – Bye Bye 2023

By Charles S. Hanskat, P.E., F.ACI, F.ASCE, ASA Executive Director

Wow! Where did 2023 go? Seems like we just attended the World of Concrete in 2023, and then we were doing it again already in 2024. As we look back on our achievements of 2023, they give rise to expecting even greater progress by ASA on a variety of topics that help accelerate the adoption of shotcrete placement in concrete applications.

In 2023, we presented seminars or sessions about the value and creativity of shotcrete at 21 events in the United States, Canada, Mexico, and Brazil. With these sessions, we reached nearly 1100 attendees, many of whom, before the session, knew little about shotcrete or may have had misconceptions about what shotcrete was and what it could do. In January 2024, ASA coordinated a Shotcrete Workshop at the annual Transportation Research Board convention in Washington, DC with over 50 attendees from DOTs, universities, and consulting firms.

In 2023, we coordinated and staffed 75 shotcrete nozzleman certification sessions, which resulted in 579 certifications. 55% of the total were new full or nozzleman-in-training certifications – so the good news is we are seeing new nozzlemen enter our workforce. This is essential because we need to have experienced people available to meet the demand. We also are looking to potential nozzleman and inspector sessions in Mexico, Brazil, Peru, Australia, and New Zealand. We also coordinated and staffed seven shotcrete inspector sessions with 75 attendees, many of whom took the ACI Shotcrete Inspector certification exam. Based on our backlog of session requests, we expect 2024 to be as good as, or better than, 2023.

But where are we, as an association, headed next in 2024? First up is our ASA Annual Shotcrete Convention and Technology Conference to be held from March 3 to 5 at the Lakeway Resort outside Austin, TX. We've already seen great interest from members and have confirmed the value of this unique shotcrete community event. Certainly, the ability to network among leaders in the shotcrete industry, to participate in committee meetings, and to attend shotcrete-specific education sessions is a draw. But on top of that, we have our annual Outstanding Shotcrete Project Awards celebration, congratulating a wealth of shotcrete projects representing the cool concrete projects we accomplish with shotcrete placement. We have two full-day pre-convention seminars – "Shotcrete Contractor Education" and "Quality Shotcrete – Know It When You See It" targeted to pool builders. And new this year will be a "Savor the Taste: Exploring Austin's Distilled Delights & Exhibitor Showcase" during our opening Sunday night reception.

This year we are also partnering with Watershape University to offer our "Quality Shotcrete – Know it When You See It" at three pool and spa shows in 2024. Venues include locations in Florida, Texas, and California. We are also rolling out a new Pool Shotcrete Contractor Qualification program to educate and recognize those shotcrete pool contractors doing quality work for the builders and owners. We're hoping that as the word spreads about ASA's commitment to education and contractor qualification for the pool market, we will attract more attendees and members.

Finally, after much work on the part of staff and our association management firm's web development team, we will be rolling out our new **shotcrete.org** website. It is designed to be more visually attractive and mobile-friendly. A primary goal is to give easier access to the vast amount of content we have on our site in the different market segments and programs we include. Feel free to provide us with your feedback as you use the new site.

Undoubtedly, 2023 was a great year. Review the projects highlighted as Outstanding Shotcrete Project Award winners presented in this issue. And with the commitment of our members, officers, Board, and staff, 2024 is shaping up to be a banner year.

asa Sustaining Corporate Members

Thank you, Sustaining Corporate Members, for your investment in the industry! ASA Sustaining Corporate Members show true dedication to ASA's vision to see "structures built or repaired with the shotcrete process accepted as equal or superior to cast concrete." These industry leaders are recognized for their exemplary level of support for the Association in a variety of ways.

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CanCrete Equipment Ltd.
www.cancrete.ca

Curtis Concrete Pumping
www.curtisconcretepumping.com

Saffo Contractors Inc.
www.saffocontractors.com

Dees-Hennessey Inc.
www.deeshenn.com

Maple Site Solutions
www.maplesitesolutions.ca

STS Shotcrete

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President's Award 2023

A highlight of an ASA President's responsibilities is to nominate a distinguished member for ASA's President's award. Since 2005, this award has recognized 17 individuals and an organization that have made exceptional contributions to the shotcrete industry. It is among ASA's highest honors and is the responsibility and honor reserved for the immediate outgoing President. This year that mantle falls upon Frank Townsend.

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

Marcus H. von der Hofen

This year's recipient is a Charter member who has brought over 30 years of shotcrete experience to the Association. He started his shotcrete career in the great Northwest with Johnson Western (now Superior Gunite), under the tutelage of Larry Totten, a past ASA President's Award winner and shotcrete legend in his own rights. In 2011, he moved to the Southeast and joined Coastal Gunite Construction Company, working alongside another legend, Curt White, who was also a past ASA President's Award winner and a sage mentor. Both companies have been leading forces in the shotcrete industry, and with thousands of shotcrete projects under his belt, it was an easy decision to name **Marcus von der Hofen** as this year's recipient.

Marcus has been an active ASA member since nearly its inception, publishing his first article with *Shotcrete* magazine in 2001! He is one of *Shotcrete* magazine's most prolific authors, publishing 19 articles over the last 23 years. His writing won ASA's Carl Akeley Award in 2016 for his "East End Crossing" article, which documented a tunnel project under an historic estate for an infrastructure project that would provide a major transportation connection between Kentucky and Indiana. Writing articles is just one of the ways Marcus shares his expertise and insights with the industry.

Marcus served multiple terms on ASA's Board of Directors before moving up through the Executive Committee, where he served as President in 2015. He is an active member of American Concrete Institute (ACI) Committees 506, Shotcreting, chairing ACI 506-0G – Shotcreting – Qualifications for Projects, and C660, Shotcrete Nozzleman Certification. His work in ACI 506-0G continued with the development of ASA's Contractor Qualification Committee, which he helped found and has chaired since it started. His leadership was instrumental in the development of ASA's Contractor Qualification program by bringing into reality the visions of his predecessors. Recognizing the team effort that contributes to a successful shotcrete project and company, Marcus worked tirelessly to bring this resource for identifying the appropriate, qualified contractors to perform shotcrete projects to the industry. He is a co-presenter for ASA's Contractor Education Seminar where he brings his experience and his shotcrete business knowledge to those who seek best practices for their shotcrete operations.

Marcus is a very passionate man who is focused on training the workforce and working towards the overall acceptance of quality shotcrete placement. His work has been invaluable in his advocacy for shotcrete within the construction community. He is a fighter, a very enthusiastic leader, a quick-witted personality, and an avid believer in teambuilding. Marcus has learned from great leaders and is a great leader himself.

Marcus von der Hofen is a friend, a colleague, a mentor for many of you, and he is my choice for ASA's President's Award this year.

Photo Courtesy of Coastal Gunite's Facebook Page

2023 Carl E. Akeley Award

Raúl Bracamontes

The 18th annual Carl E. Akeley Award was presented to Raúl Bracamontes for his article, "The Use of Rapid-Set Accelerators in Shotcrete," which was published in *Shotcrete* magazine, Volume 24, Number 3, 3rd Quarter 2022.

In this article, Bracamontes reviews the key performance indicators of shotcrete (setting time and strength), which are "decided by not only mixture design but also by the use of accelerator. The accelerator alters the hydration mechanisms of the cementitious material, influencing its strength development and setting time. Shotcrete rapid-set accelerator is a liquid admixture designed to be injected into the wet-mix shotcrete at the nozzle inside the air flow in some wet-mix applications." Further, Bracamontes writes that, "The principle behind the calibration of peristaltic pumps used for injecting accelerator is to determine the amount of accelerator admixture that must be pumped in one minute to meet the design requirements of the shotcrete. The amount of additive to be pumped is directly tied to the amount of cementitious material in the mixture design. For this reason, the volume released at each piston of the stationary concrete pump and the pumping speed expressed in strokes per minute must be known." His conclusions reiterate that "It's the nozzleman's responsibility to calibrate the pump and the admixture pump to guarantee quality shotcrete is placed…[and] when you are shooting around reinforcing bar, the level of acceleration has to be reduced to allow the concrete to flow around the bars with the shotcrete placement. It is usually recommended to use it at 3% of the weight of cement."

ASA established the Carl E. Akeley Award in 2005 to honor his founding of what is today referred to as the shotcrete process. This award is presented to the author(s) of the best technical article appearing in *Shotcrete* magazine in the past 12 months, as determined by the Akeley Award Committee of ASA.

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

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

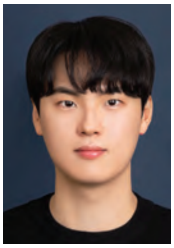
References

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

PAST AKELEY AWARD RECIPIENTS

- **2022—no awardee**
- **2021—Oscar Duckworth, "Slump—The Most Misunderstood Characteristic of Wet-Mix Shotcrete"**
- **2020—Antoine Gagnon, Marc Jolin, and Jen-Daniel Lemay, "Performance of Synthetic Sheet Waterproofing Membranes Sprayed with Steel Fiber-Reinforced Shotcrete Testing for Waterproofing Membrane Integrity After Spraying"**
- **2019 – William Clements and Kevin Robertson, "Compatible Shotcrete Specifications and Repair Materials"**
- **2018—Kyong-Ku Yun, "Cellular Sprayed Concrete"**
- **2017—Axel Nitschke, "Modeling of Load-Bearing Behavior of Fiber-Reinforced Concrete Tunnel Linings"**
- **2016—M. von der Hofen, "East End Crossing"**
- **2015—E. Yurdakul and K.-A. Rieder, "Effect of Pozzolanic-Based Rheology Control Agent as a Replacement for Silica Fume"**
- **2014—Dr. L. Zhang, "Variability of Compressive Strength of Shotcrete in a Tunnel-Lining Project"**
- **2013—Jolin, Nokken, and Sawoszczuk, "Sustainable Shotcrete Using Blast-Furnace Slag**
- **2012—R. Curtis White Jr., "Pineda Causeway Bridge Rehabilitation"**
- **2011—C. S. Hanskat, "Shotcrete Testing—Who, Why, When, and How"**
- **2010—Dr. L. Zhang, "Is Shotcrete Sustainable?"**
- **2009—Dufour, Lacroix, Morin, and Reny, "The Effects of Liquid Corrosion Inhibitor in Air-Entrained Dry-Mix Shotcrete"**
- **2008—E. S. Bernard, "Embrittlement of Fiber-Reinforced Shotcrete"**
- **2007—K. F. Garshol, "Watertight Permanent Shotcrete Linings in Tunneling and Underground Construction"**
- **2006— Dufour, Reny, and Vézina, "State-of-the-Art Specification for Shotcrete Rehabilitation Projects"**

2023 – 2024 Awardee



Jongbeom Kim *is a Ph.D. candidate in the Department of Civil and Water Engineering at Université Laval, Québec City, QC, Canada. His primary research is focused on developing concrete mixture design and placement methods to reduce shotcrete rebound. He aims to characterize the dynamic properties associated with the freshly sprayed materials and establish a correlation to rebound. He earned both his Bachelor's and Master's degrees in Civil Engineering from Kangwon National University in South Korea. During his Master's studies, he focused on research evaluating the air-void structure and the freeze-thaw resistance of wet-mix shotcrete mixtures containing natural fibers. With years of experience in conducting dry-mix and wet-mix shotcrete experiments and collaborations with industry partners, he has a strong understanding of shotcrete.*

KIM'S RESEARCH PROJECT

Toward Zero-Rebound Shotcrete: Rheology Based Mix Design & Placement

Dry-mix shotcrete is especially adapted for concrete repair, characterized by minimal waste and immediate control over mixing water and mixture consistency. However, the phenomenon of rebound losses during placement poses both economic and environmental challenges[1]. To fully understand rebound, it is imperative that we explore the mechanisms governing the behaviour of the fresh shotcrete substrate upon the impact of the incoming aggregates. In this context, rheology emerges as an essential element in interpreting these interactions.

> "Rheology is used to describe and assess the deformation and flow behavior of materials"
> – Anton Paar[5]

Dry-mix shotcrete introduces specific challenges when it comes to rheological measurements. While classical concrete rheological models, like the Bingham model, offer substantial insight into the material's specific properties, they fall short in accounting for the material's elastic deformation. A more pressing concern is that the equipment presently available for measuring rheological parameters is not adapted for concrete that exhibits little to no slump. Hence, alternative methods for evaluating rheology of fresh, dry-mix shotcrete must be developed.

Recent studies have put forward the existence of a *fluid zone on the substrate* that is present during placement (Laradh, 2020[2]; Paquet, 2021[3] and Dionne-Jacques, 2023[4]). This fluid zone has been observed on the substrate surface during shotcrete placement and is located directly under t he spray of impacting materials. It exhibits unique placement mechanisms, which in turn play a significant influence over the phenomenon of rebound. In parallel, utilizing automation placement, shotcrete trials are more consistent and minimize errors. This approach is crucial to allow for a sound comparison of different mixture designs.

OBJECTIVES

The main objective of the project is to achieve *zero rebound* in dry-mix shotcrete. To reach this goal, the research project is structured around the challenges and a specific research avenue that aims to address these questions systematically:

(1) Is it possible to validate the hypothesis concerning the existence of a fluid zone in the substrate of dry-mix shotcrete? Can it be also characterized?

(2) Can the properties of the fluid zone be controlled and modified to further reduce rebound? Further, can it be controlled and modified while maintaining adequate hardened shotcrete properties for long-term durability?

(3) Based on the newly acquired dynamic properties, is it possible to investigate the impact of different spray angles, or other spraying parameters, on rebound efficiency?

In answering the above questions, the approach to addressing the project-specific objectives is described as follows:

i) Create a tool or method to validate a *fluid* zone and characterize the dynamic properties of dry-mix shotcrete *during placement*.

ii) Explore and incorporate admixtures to create appropriate *fresh shotcrete dynamic properties (a rebound-friendly fluid zone)* to reduce rebound while maintaining proper hardened shotcrete properties.

iii) Adjusting spray angles to test dynamic properties in the lab is not reasonable. *Modeling* will be utilized to understand the impact of different spray angles on rebound efficiency.

By discovering how admixtures influence the dynamic penetration stress and its correlation with rebound, and developing a mixture design that achieves *zero rebound*, a significant reduction in material wastage can be realized, thereby, enhancing economic efficiency. Such advancements have the potential to make substantial contributions to the shotcrete industry and future shotcrete R&D work.

REFERENCES

1. Pfeuffer, M., and Kusterle, W. (2001). "Rheology and rebound behaviour of dry-mix shotcrete," Cement and Concrete Research, 31(11), 1619-1625.

2. Laradh, A. (2020). "Mise en place, énergie et rebond dans le béton prosprayé," [M.Sc.]. Université Laval.

3. Paquet, S. (2021). "Caractérisation du béton prosprayé par voie sèche : Une approche rhéologique et énergétique," [M.Sc.]. Université Laval.

4. Dionne-Jacques, S.I. (2023). "Le rebond en béton prosprayé par voie sèche : Influence de la rhéologie et de l'énergie sur le comportement de la surface réceptrice," [M.Sc.]. Université Laval.

5. Anton Paar quote, https://wiki.anton-paar.com/us-en/basics-of-rheology/

CROM – 70 Years of Excellence

Founded in 1953, CROM had a mission to change the water market with the newly innovated, wire-wrapped prestressed concrete tank technology. In 70 years, CROM has worked to exceed clients' needs and expectations through milestones and innovations in the water and tangential industries. Not only is CROM committed to designing and building tanks, but CROM also self-performs condition assessments, concrete rehabilitation and restoration, high-performance coatings, shotcrete placement, hydro-demolition, and specialty metal fabrication for America's aging water and wastewater infrastructure.

Fig. 1: Egg-Shaped Digester Tanks, Baltimore, MD.

CROM's focus on innovation spans far and wide, as evidenced by the Prestressed Concrete Egg-Shaped Digester tanks in Baltimore, Maryland, which have faithfully provided uninterrupted service since the early 1990s (Fig. 1); the "Wave Wall" which was designed and constructed for the Dr. Phillips Performing Arts Center in Orlando, Florida to provide a soundproof barrier between the lobby and theatre (Figs. 2 and 3); the elongated oxidation tanks, which are known for their outstanding concrete crack control (Figs. 4 and 5); and now the straight wall watertight tank known as CROM^2 (Fig. 7).

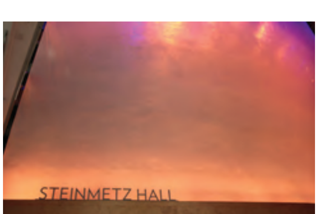


Fig. 2: Wave Wall, Dr. Phillips Performing Arts Center, Orlando, FL.

Fig. 3: Wave Wall, Orlando, FL.

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The Wave Wall, which is over 70 ft (21 m) tall and 100 ft (30 m) long, curving between concave and convex on both axes, and creating a wave-like appearance when viewed from the lobby, won the Architecture | New Construction category for the American Shotcrete Association's Outstanding Project Award in 2022.

While the Wave Wall is an innovation focused on creating one of the world's most acoustically perfect places, the elongated prestressed concrete tank for biological nutrient removal (BNR), also known as an oxidation tank, was created with the intent of processing wastewater more efficiently. The elongated oxidation tank is one of CROM's largest tank offerings.

Fig. 4: Biological Nutrient Removal (BNR) tank, Daytona, FL.

The elongated 16 million gal (60 million l) five-stage prestressed concrete treatment basin in Daytona, Florida is an example of its immense size (Fig. 4); it can fit an entire football field within the tank. In addition, the complexity of this type of tank can consist of a single or multi-channel configuration with a ring, oval, or horseshoe-shaped basin. It is constructed using an AWWA Type II shotcrete core wall with an embedded steel diaphragm. The innovative design and construction means it delivers outstanding watertightness and requires minimal maintenance.

Fig. 5: BNR tank in Southern Alabama.

Fig. 6: Modified digesters in Ottawa, Canada.

CROM has gone even further to offer a full-service experience for its clients by now offering straight-wall, watertight tanks – CROM² – the newest technology in tensioned concrete structures. The addition gives CROM's clients an opportunity to use a single company for much of the construction of water infrastructure.

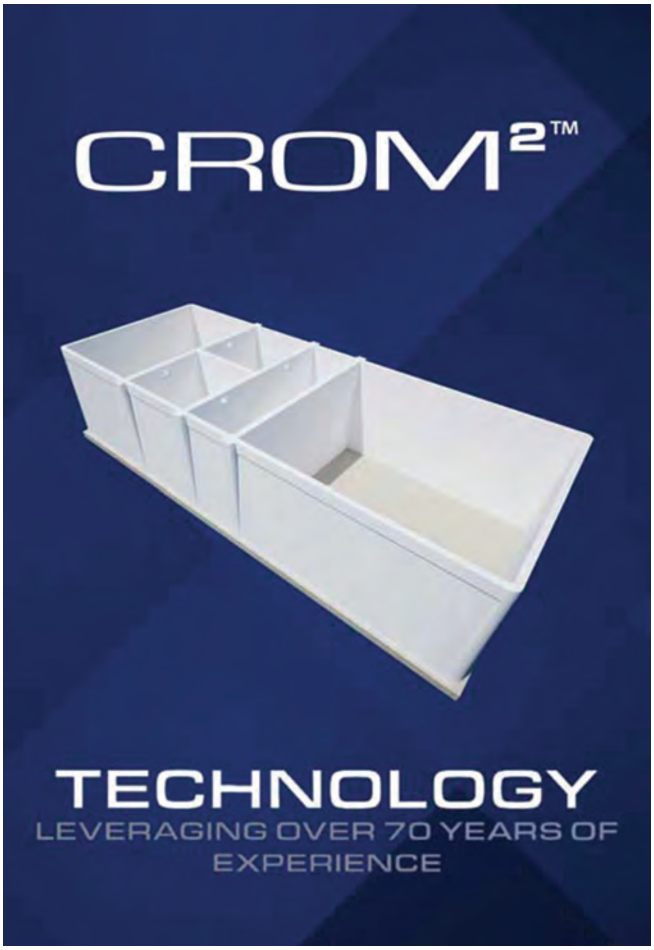

Fig. 7: CROM² straight-wall, watertight tanks.

Beyond the ability to create, CROM's efforts to restore and sustain current American infrastructure has been integral in keeping a foothold in American-made and sustained infrastructure. From repairing and restoring headworks and bridges to polyurethane crack injections, CROM works to save current infrastructure by employing cost-effective restorations.

The constant degradation of concrete, metals, coatings, and equipment by biogenic sulfide corrosion requires restoration of wastewater infrastructure. Restoring current infrastructure has proven to be less time-consuming and more economical than completely replacing a facility. With CROM's design/build approach, repair and restoration allows opportunities to add unparalleled value by creating custom fiberglass diverters and stainless-steel gates, hydrodemolition, replacement of compromised reinforcing steel, crack repair, resurfacing, custom high performance coatings systems, restoration of gates, rehabilitation of connection points to effluent boxes, and removal, rehabilitation, and replacement of weir gates.

Fig. 8: CROM ACI-Certified Nozzleman shooting shotcrete.

CROM's purpose-driven performance, which was built on a foundation of core values, continues to reach for expansion of our current and future portfolio of services.

CROM's goal: to assist the client's efforts to protect water as the world's most precious and invaluable natural resource. With CROM's services, sustainable infrastructure can be attained for future generations.

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2023 Outstanding Architecture | New Construction Project

COST of Wisconsin Blends Art and Engineering to Help Create New Gilder Center at AMNH

By Martin Palicki and Jared Stanwyck

This article originally appeared in InPark Magazine issue #99 (inparkmagazine.com) and is republished with permission and modifications.

Fig. 1: COST of Wisconsin used specialized shotcrete and rebar techniques to construct the interior and exterior walls of the Gilder Center at AMNH. All photos are courtesy of COST of Wisconsin.

It's rare that a building's design can become so immediately iconic – an attraction unto itself. Gaudi's Sagrada Familia in Barcelona comes to mind. It is a visual feast – a sculpture that takes the shape of a building. Many architecture critics are already claiming the same for the newly opened Gilder Center at the American Museum of Natural History (AMNH) in New York City. Officially named the Richard Gilder Center for Science, Education, and Innovation, the addition to AMNH is the icing on a very prestigious cake. AMNH boasted five million visitors in 2019 (the most recent year the TEA/AECOM Theme Index ranked museums). It is the ninth most-visited museum in the world, and in North America, it is second only to the Metropolitan Museum of Art (also in New York City).

Fig. 2: COST also prefabricated GFRC planters and benches for the Davis Family Butterfly Vivarium.

Fig. 3: Flowing, cavernous spaces inside the Gilder Center.

The Gilder Center is a 230,000 ft^2 (21,400 m^2) addition that boasts 33 individual connections spanning four levels to 10 other buildings on the AMNH campus. In addition to helping unify the museum, Gilder houses impressive exhibits, including an insectarium, the Davis Family Butterfly Vivarium, new collection displays, and the immersive Invisible Worlds experience—a projection-mapped environment that takes guests to scientific and natural realms nearly impossible to see under normal circumstances.

Also capturing much attention and fanfare is the building itself. Designed by Studio Gang, the building is curvaceous and flowing, or in architect-speak, it's nonrectilinear. The west-facing exterior features glass windows peeking out from undulating, smooth pink granite forms. The 80-ft-tall (24 m) interior atrium lobby, evocative of a canyon, is made from a material that coats nearly every surface, applied in novel ways. Openings into exhibit spaces and bridges spanning the atrium are amorphous – no shape is repeated in the design. The finish is off-white, and although the primary material is concrete, the effect is organic and almost like looking at bone on a microscopic level with its crevices and tendons stretching across the space.

THE SKILLS TO BUILD

Coming up with a design of this magnitude requires very specific talents, but figuring out how to build it is another skill entirely. Construction manager and general contractor AECOM Tishman turned to contractor COST of Wisconsin to help create the building – and the construction means and methods. They tasked COST's President Mike Schmuhl and VP Greg Marks with a unique, design-assist role. Instead of just taking plans and building them, COST played a critical part in the team determining – or assisting in – how the architect's vision would be achieved.

Based in Jackson, Wisconsin, with offices in Orlando, FL, and Berryville, AR, COST-Inc. has been providing theme and specialty construction services for projects around the world since 1957. Though their work can be seen in everything from commercial to recreational and residential environments, they are perhaps best known for their work in themed attraction spaces. In fact, the company was founded to create realistic animal habitats at the Milwaukee County Zoo at a time when animal enclosures were being reimagined to be less like cages and more like natural environments. COST is known for attention to detail in its fabrication, and recent projects include work on Lost Island Theme Park, Meow Wolf Convergence Station (Denver), and the Cincinnati Zoo: Hippo Cove, home to the world-famous hippo Fiona.

Gilder provided an opportunity for COST to showcase their skills beyond decorative theming, bringing together design, engineering, fabrication, and artistry in new ways. “We were so excited to be part of the team creating this epic project that will be around for generations to come,” said Jeff Sheiber, VP of Sales for COST. “We are thankful that the American Museum of Natural History, AECOM Tishman, and Studio Gang trusted that we had the unique skillsets needed to achieve their vision.”

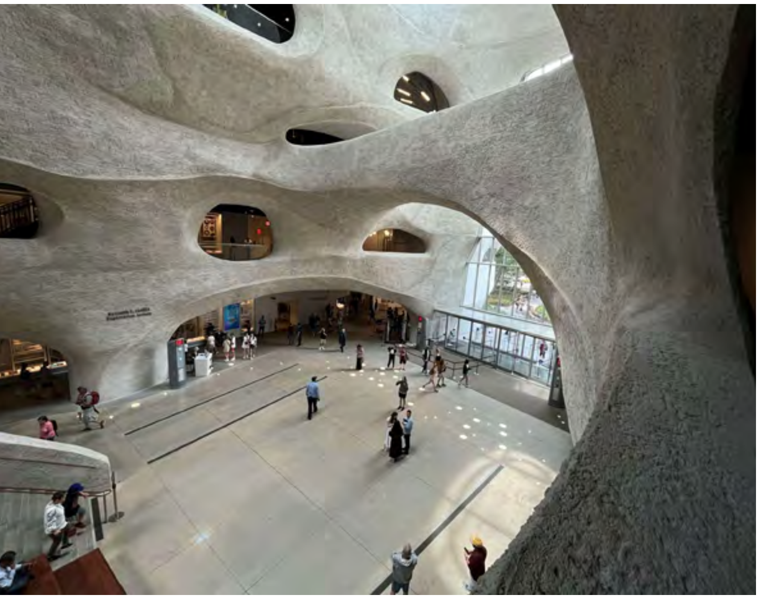


Fig. 4: The Gilder Center is a 230,000 ft^2 addition that boasts 33 individual connections across four levels to 10 other buildings on the AMNH campus.

FABRICATION INNOVATION

The vision and mandate were clear: create a building with minimal straight lines and right angles, and where no shapes are repeated. Oh, and no visible seams either.

“The museum and designers knew the shape of what they wanted for the building, but they weren’t exactly sure how it could be done,” said COST of Wisconsin senior project manager Sergio Castro. “It was a real collaboration of minds between the engineering group, the museum, the construction managers, and us at COST-Inc.”

The design team at COST, led by Design Director Kaleigh Warren with the support of Schmuhl, determined that traditional formwork would not be appropriate for the project. That method typically relies on concrete being poured into plywood forms, which are difficult to make into smooth, rounded shapes. The solution was to use wet-mix

Fig. 5: Final touches on the finish work.

Fig. 6: Space restrictions were a serious issue that required immense planning.

Fig. 7: Average workspace when shooting the structural layer of shotcrete.

shotcrete, a well-established method of spraying a cementitious mixture onto a rebar cage. Shotcrete is commonly used for curved tunnel walls. It's also used for decorative rockwork, such as in theme parks or animal habitats. But the Gilder application had to function as a mix between the two. The shotcrete had to provide the structural support of a tunnel wall as well as the aesthetic style and finish of decorative rockwork. COST's extensive experience with shotcrete was the perfect fit for the project.

As a proof-of-concept, under the leadership of Schmuhl, COST fabricated a sample for the general contractor and Studio Gang to examine. "We created a section of the model at our shop to prove to the team that we were able to execute their vision," said Castro. "And it worked."

"We pride ourselves on being able to find new ways to approach problems and to look at the fabrication process in different ways," said Sheiber. "Gilder shows that with the right approach, you can effectively combine constructability, longevity, and aesthetics into one process."

AN ODYSSEY OF REBAR

To create the unique shapes of the structure, COST designed, fabricated, and installed custom pipe forms and rebar. The pipe formwork acted as a basic guide and mounting point for rebar, which was then sprayed with shotcrete.

Under the leadership of COST Superintendents Bobby Lynch and Randy Ferguson, and supported by Director of Field Operations Corey Rabbitt, construction began on site with conventionally built concrete perimeter columns and floor slabs. Next, over 900 pipe forms were individually designed, fabricated in Wisconsin, identified, and shipped. Due to the existing service yard below, the structural design of the canyon walls required load paths at only six main touchdown points. The installation of these vertical pipe forms was the first major step in bringing the Gilder Center to life.

Each pipe form was meticulously surveyed into place and played a crucial role in the project. They supported every flat plate floor slab (which was held up by dynamic shoring) and also acted as a basic guide and mounting point for the rebar. The standoffs on the pipe forms were color-coded and tagged.

The need for 453 tons of rebar (also fabricated in Wisconsin under the leadership of Jamie Ehlke, Shop Director) was extracted from extensive 3D computer models; the rebar was tagged with identifying numbers that coincided with drawings created by COST's design team. Over 50

Fig. 8: After structural coat was set, shoring could be removed. This allowed for ample room to shoot the finish coat.

Fig. 9: Shoring.

semi-trucks traveled from Wisconsin to Brooklyn, where a staging yard was set up before pieces were brought on site for installation.

"Space on the site in the middle of Manhattan was extremely limited," explained Castro. "The logistics behind bringing components to the site had to be precise. We didn't have room on site to store materials, so items had to be brought from the staging yard in a coordinated fashion."

The pipes were anchored to the slabs, and each individual rebar piece was attached to the pipes. Next, work began on the shotcrete application. Teams worked in sequence; as pipe and rebar sections were completed, shotcrete teams took over, and the process continued.

SHOTCRETE LIKE NEVER BEFORE

COST used two different shotcrete mixes for the Gilder Center. The first was a gray structure coat, which gave the building structural stability. It was applied as the first layer over all the rebar, as required by the engineer. The structure coat was followed by a white finish coat, which also produced additional structural qualities for the building but was not required for the building's engineering.

Application was performed via a shotcrete pump sprayed by COST's ACI-certified nozzlemen Mike Tower and Steve Thomas in a preplanned shooting sequence. This was necessary to create the specific aesthetics of the building as required by Studio Gang. Crews started spraying the gray coat from the base and worked their way up. Due to the amount of dynamic shoring in place, space was extremely limited until the structure coat was finished and able to support the load.

The thickness of the finish coat was checked prior to completion to ensure there was no additional unintended weight on the building. Once the correct thickness was confirmed, COST applied a rough trowel technique to the finish surface to achieve its final look. The white color was achieved through the addition of Type I white cement to the mix. No paint or stains were introduced to the surface.

The exterior of the building was handled a bit differently. There are no perimeter columns for the exterior west-facing wall. Instead, COST fabricated a series of premade rebar panels rather than individual pieces of rebar as was done

Fig. 10: Exterior work - 5 crews working in separate locations.

for the interior. The shotcrete was applied traditionally and can be seen exposed on the inside of the wall. The exterior surface is covered in granite panels and hung onto metal plates that are embedded into the shotcrete.

"The granite panels had an extremely small tolerance for variance. The prefab rebar panels we produced back in Wisconsin gave us more control over the geometry and allowed for easy hanging of the exterior granite by others," explained Castro.

The completed building opened on May 4, 2023, and has already captivated museum guests and architecture aficionados alike.

Fig. 11: Gilder Center—completed exterior.

Fig. 12: The walls have a unique texture and pigmentation. The white cement was sourced locally from Lehigh, New York.

"The finished product shows that COST knows rebar and knows shotcrete, and we are able to do just about anything with them," said Castro. "So often, theme park professionals look at these tools and just think of pretty rockwork – which of course they are great for! But the capabilities far exceed architectural theming and can be used in truly innovative ways to build the impossible."

2023 OUTSTANDING ARCHITECTURE | NEW CONSTRUCTION PROJECT

Project
American Museum of Natural History, Gilder Center

Project Location
New York, NY

Shotcrete Contractor
COST of Wisconsin Inc.

Architect/Engineer
Studio Gang

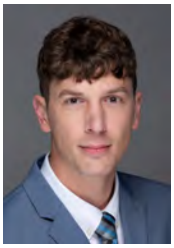
Equipment Manufacturer
REED Shotcrete Equipment

Materials Supplier
Tec-Crete Transit-Mix Corp

General Contractor
AECOM Tishman

Owner
American Museum of Natural History

***Martin Palicki** owns and publishes InPark Magazine. Started in 2004, InPark Magazine covers the themed entertainment industry, from the inside out, with a special focus on technology, storytelling, and the creative skills needed to bring interactive and immersive experiences to life. Martin lives in Milwaukee, Wisconsin and has been featured in Time Magazine, CNN.com, and Folio.*



***Jared Stanwyck** is the Marketing Manager for COST of Wisconsin Inc., a family owned theme and specialty construction company that started in 1957. Known for their work in theme parks, zoos, aquariums, museums, resorts, and other commercial applications, every job COST does is unique and one of a kind. Jared has experience in everything from fabrication, project management, estimating, and operations, along with gunite and cast work in his previous role at Refractory Service Inc. While his educational background is in Mechanical Engineering from Valparaiso University and Operations Management from University of Wisconsin, he loves being able to showcase the beautiful work COST's talented crews perform on a daily basis.*

2023 Outstanding Infrastructure Project

Advancements in Train Bridge and Underpass Construction:

Architectural and Structural Shotcrete over Sheet Piles at Ross Street Underpass in Salmon Arm, BC

By Dan Pitts

Fig. 1: Aerial View of Completed Ross Street Underpass, Salmon Arm, BC, Canada.

INTRODUCTION

Salmon Arm, British Columbia, is witnessing a paradigm shift in train bridge construction with the adoption of innovative techniques such as architectural shotcrete over steel sheet piling. This method not only enhances the structural integrity and durability of the bridges but also contributes to the aesthetic appeal of the infrastructure for the Ross Street Underpass.

SHEET PILES AS FOUNDATION

Sheet piles serve as the foundation for the train bridge in Salmon Arm. These interlocking, vertical steel sheets create a robust barrier against lateral soil forces by stabilizing the ground and providing a secure base for the structure. The choice of sheet piles in this region was influenced by the challenging geological conditions, and their versatility makes them well-suited for projects in areas with varying soil types.

ARCHITECTURAL SHOTCRETE APPLICATION

Architectural shotcrete, a process involving pneumatically spraying concrete at high velocity onto a surface, has gained prominence in bridge construction. In Salmon Arm, this technique was employed to create a protective layer over the sheet piles. The advantages of shotcrete include rapid construction, increased durability, and the ability to conform to complex shapes and designs.

Fig 2. Sheet piles used to stabilize the Ross Street Underpass.

Fig. 3: Architectural rock finish.

Fig. 4: Architectural rock finish—additional view showcasing coloring.

This shotcrete project was a team effort between LRutt Contracting Ltd. And Ocean Rock Art Ltd. The 418 m^3 (547 yd^3) of shotcrete was shot over a 6-day period involving 840 m^2 (9000 ft^2) of architectural rock finish and 2 days of colouring. Every other rib of the sheet pile shoring consisted of approximately a 24 in. (600 mm) thickness in applied shotcrete. The maximum height to the wall was 25 ft (8 m).

Fig. 5: Aerial view during construction.

The vibration of the train passing by had to be taken into consideration as there was a train every 30 minutes. This was shot in conjunction with scheduling the train and shooting areas closest to the tracks when the trains were at a slowdown zone and reducing their speeds.

Fig. 6: Train crossing over the Ross Street Underpass.

Fig. 7: A pedestrian crossing the Ross Street Underpass.

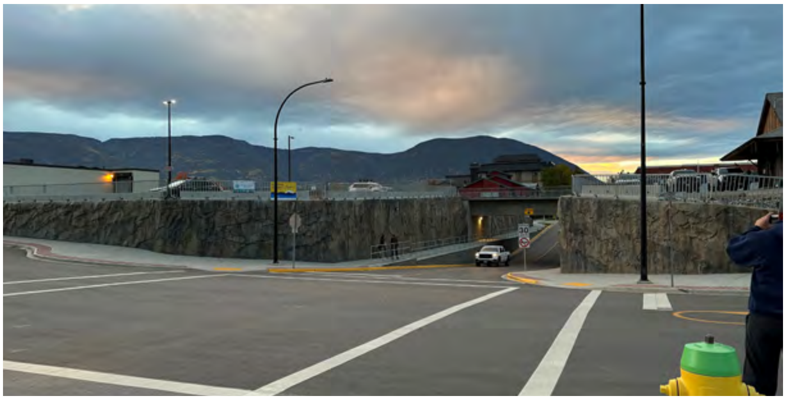


Fig. 8: Mountain view from the Ross Street Underpass.

STRUCTURAL BENEFITS

The combination of sheet piles and shotcrete enhances the overall structural strength and durability of train bridges in Salmon Arm. The shotcrete layer acts as a durable shield, protecting the sheet piles from corrosion, weathering, and abrasion. This synergy ensures a prolonged lifespan for the bridge and underpass by reducing maintenance costs and increasing reliability for the transportation network.

AESTHETIC INTEGRATION

Beyond structural benefits, architectural shotcrete allows for aesthetic integration with the surrounding environment. Salmon Arm's picturesque landscape was seamlessly incorporated into the design; this ensured that the train bridge and underpass will not only serve their functional purpose but will also contribute to the visual harmony of the region. Local rock formation style, colours, and textures were applied to the shotcrete surface, and this created a unique and visually appealing infrastructure.

ENVIRONMENTAL CONSIDERATIONS

The use of architectural shotcrete over sheet piles aligns with sustainable construction practices. The efficiency of the construction process

Fig. 9: Aerial view of the completed Ross Street Underpass.

minimizes environmental impact, and the longevity of the resulting structure reduces the need for frequent maintenance; thus, resource consumption is decreased over time.

Conclusion

Salmon Arm, BC is at the forefront of modernizing train bridge and underpass construction through the strategic use of architectural shotcrete over sheet piles. This innovative approach not only ensured structural resilience but also integrated aesthetics and environmental sustainability into the fabric of the region's infrastructure. As the transportation landscape continues to evolve, such advancements pave the way for safer, more durable, and more visually appealing train bridges and underpasses in the heart of British Columbia.

2023 Outstanding Infrastructure Project

Project
Ross Street Underpass

Project Location
Salmon Arm, BC, Canada

Shotcrete Contractor
Ocean Rock Art Ltd LRutt Contracting Ltd

Architect/Engineer
Binnie Civil Engineering Consultants

Equipment Manufacturer
REED Shotcrete Equipment

Materials Supplier
Salmon Arm Ready Mix

General Contractor
Kingston Construction

Owner
City of Salmon Arm, BC

***Dan Pitts** is President of Ocean Rock Art Ltd. and Partner in Ocean Rock Art US LLC. He is a Certified ACI nozzleman and proudly serves as a corporate member of the American Shotcrete Association. Ocean Rock Art's work has garnered widespread recognition, earning them multiple accolades. Dan Pitts' innovative approach to blending nature with design sets him apart as a true luminary in the field of shotcrete rock art, leaving an enduring mark on the landscape of contemporary architecture.*

2023 Outstanding International Project

Shotcrete as Roadside Slope Protection in Brazil

By André Bezerra de Menezes, Juliana Borella de Menezes, & Lucas Passos Santana

Fig. 1: Completed roadside slope connecting the towns of Marília and Assis in the state of São Paulo, Brazil.

The use of shotcrete has proven to be of paramount importance in the treatment process of the slopes along the margins of SP 333 highway in the interior of the state of São Paulo, Brazil. This application focused on a stretch covering kilometers 337 to 385, connecting the cities of Marília and Assis. The implementation of shotcrete in this challenging location represents not only a technical choice but also a strategic response to the specific challenges presented by the slopes along this section of the highway.

MARÍLIA AND ASSIS CONTEXT

Marília stands out as a bustling hub of the food industry. With a unique combination of abundant agricultural resources and efficient logistical infrastructure, the city has become home to a variety of renowned companies in the sector. From food processors to gourmet product manufacturers, Marília hosts a diverse range of enterprises that contribute significantly to the economy. The prominent presence of the food industry not only strengthens the city's economic base, but it also plays a crucial role in creating

Fig. 2: Aerial view of roadside slope.

Projeto Internacional Destaque 2023

Concreto Projetado como Proteção de Taludes Rodoviários no Brasil

Escrito em português por André Bezerra de Menezes, Juliana Borella de Menezes e Lucas Passos Santana

Fig. 1: Taludes rodoviários concluídos entre as cidade de Marília e Assis, no estado de São Paulo, Brasil.

A utilização do concreto projetado revelou-se de suma importância no processo de tratamento dos taludes ao longo das margens da rodovia SP 333, no interior do estado de São Paulo, Brasil. Essa aplicação concentrou-se em uma extensão que abrange os quilômetros 337 a 385, que conectam as cidades de Marília e Assis. O emprego do concreto projetado nessa localidade representa não apenas uma escolha técnica, mas também uma resposta estratégica aos desafios apresentados pelos taludes ao longo desse trecho da rodovia.

CONTEXTO DE MARÍLIA E ASSIS

Marília destaca-se como um centro da indústria de alimentos. Com uma combinação de recursos agrícolas abundantes e uma infraestrutura logística eficiente, a cidade se tornou lar de uma variedade de empresas renomadas no setor. Desde processadoras de alimentos até fabricantes de produtos gourmet, Marília abriga um leque de empreendimentos que contribuem de maneira expressiva para a economia. A presença da indústria não apenas fortalece a

Fig. 2: Vista aérea dos taludes rodoviários.

employment opportunities for the local community. Furthermore, the synergy between the industry and the agricultural sector fosters an integrated supply chain that drives the development of both agricultural production and industrial activities.

Assis emerges as a crucial economic hub in the region as a result of its diversified industrial and commercial base. The city is known for its robust transportation infrastructure, which represents a strategic link in product distribution. With efficient road networks and railway connections, Assis significantly facilitates the flow of goods, which promotes logistical integration between suppliers, industries, and consumer markets. This logistical advantage not only strengthens the local economy but also elevates Assis to the status of a vital commercial hub in the region and a major contributor to the prosperity of both the city and the surrounding areas.

The synergy between the cities of Marília and Assis establishes a strategic alliance for the efficient distribution of food products on a global scale. While Marília stands out as a pulsating center of the food industry, Assis complements this scenario as a crucial economic hub by offering a solid transportation infrastructure. The logistical integration between these two cities, as facilitated by efficient road networks and railway connections, creates an environment conducive to the rapid and effective flow of goods. This collaboration not only strengthens local economies but also elevates the region to a strategic position in the international food industry landscape which contributes to joint prosperity and expands business horizons.

NEED FOR HIGHWAY EXPANSION

Due to the notable economic importance of the food and transportation sectors in Marília and Assis, the expansion of the highway in this section became an imperative need. This undertaking involved not only duplicating the road but also the complex task of excavating and reprofiling the imposing mountains that defined its margins. The resulting slopes were predominantly composed of rock masses, especially sandstone, and had begun exhibiting some discontinuities, fractures, and surface erosions, all of which raised concerns about their stability.

After thorough geotechnical analyses, it became evident that the proper protection of these slopes was an essential priority. The intrinsic characteristics of rock masses, which were subject to erosion and fractures, demanded a precise technical approach to mitigate potential risks of erosion and landslides.

In the face of this challenging scenario, the choice of applying shotcrete emerged as an effective solution. The technique not only provides a robust protective layer against surface erosion, but it also proves instrumental in the structural consolidation of slopes—this ensures their long-term stability.

PROJECT DETAILS

Unicom Engenharia, recognized for its expertise and pioneering work in the application of wet-mix shotcrete in Brazil, took on the responsibility for shotcrete application, soil nailing, and the installation of surface and deep drains in this remarkable project.

The comprehensive scope of the project covered 10 distinct sections, intervening in 16 slopes, each with varying heights between 10 and 38 m (33 and 125 ft). The slope inclinations varied considerably, ranging between 45° and 70°, and added an additional layer of complexity to the project execution. The total length of the project extended for approximately 2670 m (1.7 mi)—further indication of the scale of the challenge.

Fig. 3: Excavation and slope process for highway expansion.

Fig. 4: Additional view of the excavation and slope process.

base econômica da cidade, mas também desempenha um papel crucial na criação de oportunidades de emprego para a comunidade local. Além disso, a sinergia entre a indústria e o setor agrícola fomenta uma cadeia de abastecimento integrada, impulsionando o desenvolvimento tanto da produção agrícola quanto das atividades industriais.

Assis também se destaca como um importante polo econômico na região, impulsionando o desenvolvimento através de uma diversificada base industrial e comercial. A cidade destaca-se pela infraestrutura de transportes, representando um elo estratégico na distribuição de produtos. Com uma malha viária eficiente, linha férrea, Assis facilita o escoamento de mercadorias, promovendo a integração logística entre fornecedores, indústrias e mercados consumidores. Essa vantagem logística não apenas fortalece a economia local, mas também eleva Assis a um status comercial importante na região, contribuindo para a prosperidade tanto da cidade quanto das áreas circunvizinhas.

A sinergia entre as cidades de Marília e Assis estabelece uma aliança estratégica para a distribuição eficiente de produtos em escala global. A integração logística entre essas duas cidades, facilitada por malhas viárias eficientes e ferrovias, cria um ambiente propício para o escoamento rápido e eficaz de mercadorias. Essa colaboração não só fortalece as economias locais, mas também eleva a região a um patamar estratégico no cenário internacional da indústria de alimentos, contribuindo para a prosperidade conjunta e a expansão dos horizontes comerciais.

NECESSIDADE DE AMPLIAÇÃO DA RODOVIA

Devido à importância econômica da indústria de alimentos e da infraestrutura de transportes de Marília e Assis, a expansão da rodovia nesse trecho tornou-se uma necessidade imperativa. Esse empreendimento envolveu não apenas a duplicação da via, mas também a complexa tarefa de escavação e retaludamento das imponentes montanhas que delineavam suas margens. Os taludes resultantes, predominantemente compostos por maciços rochosos, em especial arenito, exibiam algumas descontinuidades, fraturas e erosões superficiais, trazendo preocupações quanto a sua estabilidade.

Após as análises geotécnicas, tornou-se evidente que a proteção adequada desses taludes era uma prioridade. As características intrínsecas dos maciços rochosos, sujeitos a processos erosivos e fraturas, demandavam uma abordagem técnica para mitigar os riscos potenciais de erosão e deslizamentos.

Diante desse cenário, a opção pela aplicação de concreto projetado emergiu como uma solução eficaz. A técnica oferece não apenas uma camada protetora robusta contra erosão superficial, mas também se revela instrumental na consolidação estrutural dos taludes, promovendo sua estabilidade a longo prazo.

DETALHES DO PROJETO

A Unicom Engenharia, reconhecida por sua expertise e pioneirismo na aplicação de concreto projetado por via úmida no Brasil, assumiu a responsabilidade pela aplicação de concreto projetado, solo grampeado e instalação de drenos superficiais e profundos em um projeto de magnitude notável.

O escopo abrangente do projeto compreendeu 10 trechos distintos, totalizando a intervenção em 16 taludes, cada um apresentando alturas variáveis entre 10 e 38 metros (33 e 125 pés). Os ângulos de inclinação desses taludes variaram consideravelmente, situando-se entre 45° e 70°, acrescentando uma camada adicional de complexidade à execução do projeto. A extensão total do projeto foi de aproximadamente 2.670 metros (1,7 milhas), sinalizando a escala do desafio.

Fig. 3: Processo de escavação e retaludamento para ampliação da rodovia.

Fig. 4: Processo de escavação e retaludamento por outra perspectiva.

Sections (Metric)										
	km 341+800 West	km 341+200 West	km 341+200 East	km 362+000 West	km 363+400 West	km 363+800 West	km 364+000 East	km 364+100 East	km 371+000 West	km 350+000 East
Slope	5	2	4	1	1	1	1	1	2	2
Height	38 m	15 m	25 m	10,5 m	17 m	12 m	18 m	18 m	12 m	10 m
Angle	50°-70°	45°-50°	50°-60°	50°-55°	55°	60°	65°	50°	45°	45°
Lenght	420 m	250 m	630 m	170 m	170 m	170 m	240 m	120 m	300 m	200 m

Sections (Imperial)										
	km 341+800 West	km 341+200 West	km 341+200 East	km 362+000 West	km 363+400 West	km 363+800 West	km 364+000 East	km 364+100 East	km 371+000 West	km 350+000 East
Slope	5	2	4	1	1	1	1	1	2	2
Height	124 ft	49 ft	82 ft	34 ft	55 ft	39 ft	59 ft	59 ft	39 ft	32 ft
Angle	50°-70°	45°-50°	50°-60°	50°-55°	55°	60°	65°	50°	45°	45°
Length	459 yd	273 yd	688 yd	185 yd	184 yd	184 yd	262 yd	131 yd	328 yd	218 yd

Table 1: Slope Sections & Measurements (Metric and Imperial)

KEY CHALLENGES

One of the prominent challenges faced during the execution of this project was the application of shotcrete in hard-to-reach areas, especially in the higher section reaching 38 m in height. The complexity of this task required the mobilization of a crane to overcome access restrictions; this elevated the need for rigorous safety criteria and personnel who were certified to handle this specific operation in challenging conditions.

Certification of safety criteria was essential not only to ensure the protection of the involved workers but also to ensure the structural integrity during the shotcrete application in hard-to-reach areas. The combination of significant heights and remote locations demanded an approach with the highest standards of safety and operational efficiency.

Fig. 5: Application of shotcrete from a man basket using a crane.

Fig. 6: Application of shotcrete using a shotcrete placing robot.

Additionally, efficient time management proved to be another challenging aspect of this project. Unicom adopted a simultaneous approach on three shotcrete fronts by implementing techniques such as rappelling, using an

Trechos (Sistema Métrico)										
	km 341+800 Oeste	km 341+200 Oeste	km 341+200 Leste	km 362+000 Oeste	km 363+400 Oeste	km 363+800 Oeste	km 364+000 Leste	km 364+100 Leste	km 371+000 Oeste	km 350+000 Leste
Taludes	5	2	4	1	1	1	1	1	2	2
Altura	38 m	15 m	25 m	10,5 m	17 m	12 m	18 m	18 m	12 m	10 m
Ângulo	50°-70°	45°-50°	50°-60°	50°-55°	55°	60°	65°	50°	45°	45°
Extensão	420 m	250 m	630 m	170 m	170 m	170 m	240 m	120 m	300 m	200 m

Trechos (Sistema Imperial, aproximado)										
	km 341+800 Oeste	km 341+200 Oeste	km 341+200 Leste	km 362+000 Oeste	km 363+400 Oeste	km 363+800 Oeste	km 364+000 Leste	km 364+100 Leste	km 371+000 Oeste	km 350+000 Leste
Taludes	5	2	4	1	1	1	1	1	2	2
Altura	124 pés	49 pés	82 pés	34 pés	55 pés	39 pés	59 pés	59 pés	39 pés	32 pés
Ângulo	50°-70°	45°-50°	50°-60°	50°-55°	55°	60°	65°	50°	45°	45°
Extensão	459 jardas	273 jardas	688 jardas	185 jardas	184 jardas	184 jardas	262 jardas	131 jardas	328 jardas	218 jardas

Tabela 1: Dados sobre os trechos previstos no projeto. Inclui medidas no sistema imperial.

PRINCIPAIS DESAFIOS

Um dos desafios preeminentes enfrentados durante a execução desse projeto foi a aplicação de concreto projetado em áreas de difícil acesso, especialmente no trecho mais elevado, atingindo 38 metros (125 pés) de altura. A complexidade dessa tarefa exigiu a mobilização de um guindaste para superar as restrições de acesso, elevando a necessidade dos critérios de segurança no trabalho, certificados para lidar com essa operação específica.

A certificação dos critérios de segurança foi essencial não apenas para garantir a proteção dos trabalhadores envolvidos, mas também para assegurar a integridade estrutural durante a aplicação do concreto projetado em áreas de difícil alcance. A combinação de alturas significativas e locais remotos exigiu uma abordagem com os mais elevados padrões de segurança e eficiência operacional.

Fig. 5: Aplicação de concreto projetado com guindaste.

Fig. 6: Aplicação de concreto projetado usando um robô de projeção.

Além disso, a gestão eficiente do tempo revelou-se outra faceta desafiadora deste projeto. A Unicom adotou uma abordagem simultânea em três frentes de concreto projetado, implementando técnicas, como rapel, plataforma

Fig. 7: Application of shotcrete using the rappelling technique.

articulating boom lift, and using a shotcrete placing robot. This multifaceted strategy allowed the team to achieve satisfactory productivity, which was exemplified by the volume of 72 m³ (94 yd³) of shotcrete applied in a single eight-hour working day.

The complexity of the project's height in certain areas required a specific approach to slope recomposition. In certain locations, the team opted for the "Rip Rap" technique, which involved the application of soil and cement bags to reinforce and recompose the slopes.

The compressive strength required for the shotcrete in the project was 25 MPa (3600 psi) at 28 days. As an additional measure to enhance the quality of the shotcrete, synthetic polypropylene microfiber was incorporated into the mix at a ratio of 5 kg/m³ (8.5 lb/yd³) of shotcrete. The fiber aimed to reduce the incidence of cracks caused by shrinkage, and it contributed to the durability and structural integrity of the material.

Furthermore, the presence of emerging water points on the slopes introduced additional challenges. To overcome this specific condition, a setting accelerator additive was incorporated during the shotcrete placement. This measure not only facilitated the efficient application of the material in wet areas but also contributed to the rapid attainment of the required strength; this was necessary to mitigate potential impacts caused by water.

The soil nailing service covered several stages starting with site preparation. The next phase involved rock drilling: a process aimed at creating holes for the installation of anchors. These anchors, which are fundamental components of the soil nailing system, were positioned to optimize the stabilization of the soil mass. The injection of cement grout bonded the anchors to the rock and provided their stabilizing function.

Fig. 8: Application of shotcrete using an articulating boom lift.

Fig. 9: Application of shotcrete using a truck-mounted crane.

Fig. 7: Aplicação de concreto projetado pela técnica de rapel.

articulada e um robô de projeção de concreto. Essa estratégia multifacetada permitiu que a equipe alcançasse uma produtividade considerável, exemplificada pelo volume de 72 m³ (94 yd³, jardas cúbicas) de concreto projetado aplicado em um único dia de trabalho de oito horas de atividade.

A complexidade do projeto se acentuou em determinadas áreas, exigindo uma abordagem específica para a recomposição dos taludes. Em certos locais, a equipe optou pela técnica de "Rip Rap", envolvendo a aplicação de sacos de solo e cimento para reforçar e recompor os taludes.

A resistência à compressão necessária para o concreto projetado no projeto era de 25 MPa (3600 psi, libra-força por polegada quadrada) aos 28 dias. Como uma medida adicional para aprimorar a qualidade do concreto, incorporou-se microfibra sintética de polipropileno ao traço, na proporção de 5 kg/m³ (8.5 lbs/yd³, libras por jarda cúbica) de concreto. Essa adição visa diminuir o índice de fissuras causadas pela retração, contribuindo assim para a durabilidade e integridade estrutural do material.

Além disso, a presença de pontos com água emergente nos taludes introduziu desafios adicionais. Para superar essa condição específica, foi incorporado aditivo acelerador de pega durante a projeção do concreto. Essa medida não apenas facilitou a aplicação eficiente do material em áreas úmidas, mas também contribuiu para a rápida obtenção de resistência necessária, mitigando os impactos potenciais causados pela água.

O serviço de solo grampeado abrangeu uma série de etapas, iniciando-se com a preparação do terreno. A fase

Fig. 8: Aplicação de concreto projetado com plataforma articulada.

Fig. 9: Aplicação de concreto projetado com caminhão Munck.

Fig. 10: Slope after shotcrete application.

Fig. 12: Aerial view of the completed slope.

To ensure the full functionality of the system, the installation of surface drains was implemented, which was an effective mechanism for managing water drainage and preventing potential soil saturation issues. Additionally, deep sub-horizontal drains were installed in areas that required control of the ground water table. The application of steel mesh complemented this process, providing an additional layer of strength and support to the structure. The final stage of this procedure involved the application of shotcrete by consolidating all measures taken to ensure the effectiveness and durability of the system.

The efficiency of the soil nailing system was validated through pull-out tests. These tests are essential to assess the quality of the interaction between the soil and the cement grout; this ensured not only the immediate stability that was necessary but also the long-term durability of the intervention.

RESULTS

Unicom Engenharia carried out the application of 2,866 m³ (3750 yd³) of shotcrete, which covered an area of 31,220 m² (336,000 ft²). Additionally, 310 m² (3340 ft²) of soil nailing was incorporated, which involved rock drilling and the placement of 708 m (2320 ft) of anchors with the injection of 29,800 kg (65,700 lb) of cement in the corresponding grout. This activity was complemented by the installation of 986 m (3230 ft) of surface drains, 674 m (2210 ft) of deep sub-horizontal drains, and the recomposition of 290 m³ (380 yd³) of the slope through soil-cement bags (Rip Rap).

The significant volume of shotcrete applied and the challenges that were overcome during this intervention highlight the growing importance of this technology for infrastructure in Brazil. More than a mere construction solution, shotcrete proves to be a vital element for regional development and the expansion of road networks.

Furthermore, highway expansion, facilitated by the application of shotcrete, plays a strategic role in facilitating the flow of agricultural and food products. This efficient flow contributes to the sustainability of the sectors—food products reach markets quickly and effectively. Thus, reinforced infrastructure not only benefits the regional economy but also plays a global role in feeding thousands of people worldwide.

Fig. 11: Another view of the slope after shotcrete application.

Fig. 13: Another aerial view of the completed slope.

Fig. 10: Inclinação após aplicação de concreto projetado.

Fig. 12: Vista aérea do talude concluído.

seguinte compreendeu a perfuração em rocha, um processo destinado à criação de furos para a instalação dos chumbadores. A injeção de calda de cimento, reforçou a aderência dos chumbadores à rocha, solidificando sua função estabilizadora.

Para assegurar a plena funcionalidade do sistema, implementou-se a instalação de drenos superficiais, um mecanismo eficaz para gerenciar o escoamento de água e prevenir possíveis problemas de saturação do maciço. Além disso, foram instalados drenos sub-horizontais profundos em áreas que demandavam controle do nível freático. A aplicação de tela de aço complementou esse processo, proporcionando uma camada adicional de resistência e suporte à estrutura. O estágio final desse procedimento envolveu a aplicação de concreto projetado, consolidando assim todas as medidas adotadas para garantir a eficácia e a durabilidade do sistema.

A validação da eficiência do sistema de solo grampeado foi realizada por meio de ensaios de arrancamento. Esses testes são fundamentais para avaliar a qualidade da interação do solo com a calda de cimento, garantindo não apenas a estabilidade imediata, mas também a durabilidade a longo prazo da intervenção realizada.

RESULTADOS

A Unicom Engenharia realizou a aplicação de 2866 m³ (3750 yd³, jardas cúbicas) de concreto projetado, abrangendo uma extensão de 31.220,15 m² (336.000 ft², pés quadrados), além de incorporar 310,00 m² (3400 ft², pés quadrados) de solo grampeado, envolvendo perfuração em rocha e a colocação de 708 m (2320 ft, jardas) de chumbadores, com a injeção de 29.800 kg (65.700 lbs, libras) de cimento na calda correspondente. Essa atividade foi complementada pela instalação de 986 m (3230 ft, jardas) de drenos superficiais, 674 m (2210 ft, jardas) de drenos sub-horizontais profundos e a recomposição de 290 m³ (380 yd³, jardas cúbicas) do talude por meio de sacos de solo-cimento (Rip Rap).

O volume significativo de concreto projetado aplicado e os desafios superados durante essa intervenção ressaltam a crescente importância dessa tecnologia para a infraestrutura no Brasil. Mais do que uma simples solução construtiva, o concreto projetado revela-se como um elemento importante para o desenvolvimento regional e a expansão das redes rodoviárias.

Além disso, a expansão das rodovias, facilitada pela aplicação do concreto projetado, desempenha um papel

Fig. 11: Outra vista do talude após a aplicação do concreto projetado.

Fig. 13: Outra vista aérea do talude concluído.

2023 OUTSTANDING INTERNATIONAL PROJECT

Project
Shotcrete as Roadside Slope Protection in Brazil

Project Location
SP 333 Highway, São Paulo, Brazil

Shotcrete Contractor
Unicom Construções e Tecnologias Construtivas LTDA

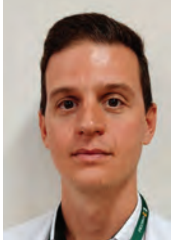
Architect/Engineer
APG Assessoria Projetos Geotecnia

Equipment Manufacturer
Schwing Stetter / Tunelmak

Materials Supplier
MCC Muriam Concreto LTDA

General Contractor
Entrevias Concessionária de Rodovias S.A.

Owner
Entrevias Concessionária de Rodovias S.A.



André Bezerra de Menezes *is a Civil Engineer with a degree from the Universidade Estadual Paulista – UNESP, one of Brazil's top universities. During his undergraduate years, he served as the Chief Executive Officer of Pro Junior – Projetos e Consultoria, showcasing his exceptional leadership skills. Currently, he holds the position of Director of Engineering and Co-Owner at Unicom Engenharia, where he has amassed extensive experience in projects involving shotcrete, soil nailing, anchored curtain walls, and more. Under his leadership, Unicom Engenharia has experienced exponential growth and gained international recognition.*

Juliana Borella de Menezes *is a Civil Engineer, holding a degree from Pontifícia Universidade Católica de Campinas – PUC CAMPINAS. She holds an MBA in Economics and Business Management from Fundação Getúlio Vargas – FGV, one of the most prestigious business schools in Brazil. Juliana serves as the Commercial Manager and Co-Owner of Unicom Engenharia, bringing extensive experience to the commercial leadership of infrastructure projects, including shotcrete, soil nailing, anchored curtain walls, among others. Under her management, Unicom has consistently achieved and surpassed ambitious targets, propelling the company to ever-increasing prominence in the industry.*

Lucas Passos Santana*, a Civil Engineer, earned his degree from Centro Universitário de Itajubá – FEPI, with a portion of his studies completed at Budapest University of Technology and Economics – BME (Hungary/EU). He holds a Master's degree in Infrastructural Engineering from Széchenyi István University (Hungary/EU). Lucas serves as a Geotechnical Engineer and leads the technical team at Unicom Engenharia. His proficiency spans projects involving shotcrete, soil nailing, and anchored curtain walls. Lucas brings a wealth of experience and an international perspective to his role.*

estratégico na facilitação do escoamento de produtos agrícolas e alimentícios. Este fluxo eficiente contribui para a sustentabilidade dos setores, permitindo que os produtos alimentícios cheguem aos mercados de maneira rápida e eficaz. Dessa forma, a infraestrutura reforçada não apenas beneficia a economia regional, mas também desempenha um papel global ao alimentar milhares de pessoas em todo o mundo.

PROJETO INTERNACIONAL DESTAQUE 2023

Projeto
Concreto Projetado como Proteção de Taludes Rodoviários no Brasil

Localização do Projeto
Rodovia SP 333, São Paulo, Brasil

Empresa de Concreto Projetado
Unicom Construções e Tecnologias Construtivas LTDA

Arquiteto/Engenheiro
APG Assessoria Projetos Geotecnia

Fabricante de Equipamentos
Schwing Stetter / Tunelmak

Fornecedor de Materiais
MCC Muriam Concreto LTDA

Empreiteiro Geral
Entrevias Concessionária de Rodovias S.A.

Proprietário
Entrevias Concessionária de Rodovias S.A.

***André Bezerra de Menezes** é Engenheiro Civil formado pela Universidade Estadual Paulista - UNESP, considerada uma das principais universidades do Brasil. Durante sua graduação, atuou como CEO da Pro Junior - Projetos e Consultoria, destacando suas habilidades excepcionais de liderança. Atualmente, ocupa o cargo de Diretor de Engenharia e Co-Proprietário na Unicom Engenharia, onde acumulou ampla experiência em projetos envolvendo concreto projetado, solo grampeado, cortinas atirantadas, entre outros. Sob sua liderança, a Unicom Engenharia experimentou um crescimento exponencial e obteve reconhecimento internacional.*

***Juliana Borella de Menezes** é Engenheira Civil, graduada pela Pontifícia Universidade Católica de Campinas - PUC CAMPINAS. Ela possui MBA em Economia e Gestão de Negócios pela Fundação Getúlio Vargas - FGV, uma das mais prestigiadas escolas de negócios do Brasil. Juliana atua como Gerente Comercial e Co-Proprietária da Unicom Engenharia, trazendo ampla experiência para a liderança comercial de projetos de infraestrutura, incluindo concreto projetado, solo grampeado, cortinas atirantadas, entre outros. Sob sua gestão, a Unicom consistentemente alcançou e superou metas ambiciosas, impulsionando a empresa para uma proeminência cada vez maior no setor.*

***Lucas Passos Santana**, Engenheiro Civil, obteve seu diploma no Centro Universitário de Itajubá - FEPI, com parte de seus estudos realizados na Budapest University of Technology and Economics - BME (Hungria/UE). Ele possui mestrado em Engenharia de Infraestrutura pela Széchenyi István University (Hungria/UE). Lucas atua como Engenheiro Geotécnico e lidera a equipe técnica da Unicom Engenharia. Sua proficiência abrange projetos envolvendo concreto projetado, solo grampeado e cortinas atirantadas. Lucas traz consigo uma riqueza de conhecimento e uma perspectiva internacional para sua função.*

2023 Outstanding Pool and Recreational Project

Shaw Residence

By Andy Duck

Fig. 1: Finished Project—The "Great Wall of Tuckahoe."

How does one provide a backyard transformation that includes a water-in-transit pool, complete with all the outdoor living amenities one could ask for when facing a 75° waterfront sand cliff located on an ever-shifting chain of barrier islands susceptible to a multitude of severe weather patterns?

Through intensive design and engineering consultations, we discovered that to produce a beautiful, resilient, long-lasting investment for our client, this project would include 96 helical pile foundations, 48 tons (910 kg) of steel reinforcement, and 345 yd^3 (264 m^3) of shotcrete placed in 8 yd^3 (6 m^3) loads over a period of 12 months.

This complete backyard transformation includes several concrete retaining walls up to 21 ft (6.4 m) in height, a strategically placed underground storage area, a concrete vault for the watershape equipment and a bathroom, an extension of their livable space through an outdoor kitchen, and a custom concrete swimming pool that features a 19 ft (5.8 m) radial vanishing edge.

In Duck, North Carolina, the "Great Wall of Tuckahoe" stands as a demonstration of the expertise and advanced techniques employed in tackling unique terrain with significant logistical and space demands. This project is engineered not only to withstand hurricane force winds and flooding, but also supports the existing residence above. Permanence was at the forefront of the engineering approach to this project.

The construction process utilized a bottom-up approach to address the project's unique topographical landscape, as well as material access. The stability of the completed structure hinged on the installation of the helical coil piles, which were then connected by concrete grade beams. These grade beams played a crucial role in enhancing stability

Fig. 2: Side view of 19 ft Radial Vanishing Edge.

Fig. 3: Before construction.

Fig. 4: After construction.

and creating space for the essential internal infrastructure necessary to the functionality of the pool. The neighboring property, whose backyard created a valley with their own 70° cliff, was protected with steel sheet pile shoring during construction and was then used as a back form for the shotcrete retaining walls that completed the project.

The concrete supplier's location was 1 to 2 hours away depending on traffic that was highly influenced by the time of year because the site is in a predominantly tourist area (beach town); therefore, this project demanded a stop-and-start approach to the concrete installations. We were limited to the number of trucks we could rely on making it to the jobsite on a daily basis. The decision to use wet-mix shotcrete as the process for concrete delivery and consolidation was quickly made, and the entirety of the project was shot in daily segments of 8 or 16 yd^3 (6 to 8 m^3) increments using certified nozzlemen with a 250 CFM compressor and blow pipe (air lance).

Fig. 5: View of bottom-up approach at ground level.

Fig. 6: The bottom-up approach from above.

Meticulous shotcrete practices on this stop-and-start process allowed us to achieve the type of consolidation and compaction needed to create a monolithic, watertight structure. The monolithic aspects of the shotcrete in this project underwent thorough vetting as a large section of the pool is exposed in one of the underneath storage areas. Despite visible stop-and-start "seams," this exposed area has zero signs of moisture migration, confirming the effectiveness of the shotcrete application.

Fig.7: Backfilling shotcreted walls.

Fig. 8: View of curved forms and rebar for the bottom-up approach.

Aside from construction, we were able to shift our client's perspective on the viability of shotcrete. As the owner of a commercial construction company that specializes in large cast-in-place concrete structures for wastewater tanks and pumping stations, the client now recognizes the potential advantages of properly executed shotcrete in his own ventures.

The challenges and triumphs of the design, engineering, and construction of this project clearly demonstrate the type of ingenuity, skill, and precision that can be achieved when the right team plans and executes a comprehensive vision. By incorporating both aesthetic appeal, functionality, and durability, this project stands as a testament to how a beautiful outdoor space can be achieved using the shotcrete method of concrete placement.

Waterforge Inc. was tapped for the project design and construction documentation. Kitty Hawk Engineering supplied both the civil and structural engineering for this project.

Fig. 9: ACI-Certified Nozzleman shooting wet-mix on the 21 ft retaining wall.

Fig. 10: Finished shotcrete view of the vanishing edge.

Fig. 11: Pallets of stone moved via crane due to site accessibility issues.

Fig. 12: The "Great Wall of Tuckahoe."

Fig. 13: Outdoor kitchen with the retaining-wall-turned-fireplace and a pizza oven.

Fig. 14: Sunset in Duck, NC.

2023 OUTSTANDING POOL & RECREATIONAL PROJECT

Project
Shaw Residence

Project Location
Duck, NC

Shotcrete Contractor
Artisan Pools NC

Architect/Engineer
Waterforge and Kitty Hawk Engineering

Equipment Manufacturer
REED Shotcrete Equipment

Materials Supplier
CnL Concrete

General Contractor
Artisan Pools NC

Owner
Greg and Vicky Shaw

Artisan Pools NC encompasses nearly 25 years of expertise in pool design, construction, and project management. Our mission blends vision, style, robust construction methods, and modern technologies to craft our world class projects. ***Andy Duck****, President, is a registered member of the Society of Watershape Designers, an International Watershapes Professional, and an American Concrete Institute Certified Shotcrete Nozzleman.*

2023 Outstanding Repair & Rehabilitation Project

O'Hare Plaza West Drive and Executive Garage Restoration

By Joshua Freedland

Fig. 1: O'Hare Plaza Entrance. Photo copyright Bob Elmore.

While infrastructure projects such as parking garages are often the last projects to be funded due to their utilitarian nature, they are important to the health of commercial properties since they are often the first impression for tenants and visitors. At O'Hare Plaza, the parking garage serves the 700,000 ft^2 (65,000 m^2) office complex. Construction of the complex began in 1969 and includes five mid-rise office buildings with most parking spaces located on the lower levels. The property's prime location on a major expressway near O'Hare International Airport, as well as its size, provided a rare opportunity for Bulley & Andrews Concrete Restoration (BACR) to complete a large-scale, multi-phased plaza renovation project.

SIGNS OF DETERIORATION

After 50 years of enduring Chicago's often unpredictable and extreme weather, the garage was showing signs of deterioration. Its façade and structural integrity eroded over time. Exposure to deicing salts and freeze-thaw cycling led to cracks and spalls of the concrete as well as corrosion of the embedded steel reinforcing.

Recognizing the deterioration, JLL, the property's on-site management company, hired engineering firm WGI to evaluate, to design repairs, and to perform construction administration services on the three-phased renovation. The project aimed to not only repair the deterioration but also to improve the appearance and performance of the garage. Wright

Fig. 2: Extensive deterioration inside the parking structure.

Fig. 3: Extensive deterioration inside the parking structure showing sunlight through the ceiling.

Heerema Architects served as the architect for Phase 1 and designed the site improvements with WGI. After a competitive bid process, BACR was selected to implement the design to support the office complex and its next generation of tenants.

A MULTI-PHASED OPERATION

Between 2019 and 2022, BACR performed a multi-phased operation to implement the project. The comprehensive plan included repairing the infrastructure of the garage while delivering an updated plaza.

Phase 1 (South Drive Renovation Project) included improvements to the concrete structural slab, beams, and columns. These repairs included partial, underside and full-depth repairs using shotcrete. A new paver system was installed including a waterproofing and a snow-melt system and drains. New concrete curbs and sidewalks were installed, as well as new handrails for staircases. A new skylight was added to provide natural light below grade, while new lighted bollards were installed for site protection. Finally, new electrical, including lighting, was installed throughout the area.

Fig. 4: Demolition of exterior slab.

Fig. 5: Waterproofing membrane on exposed roof slab.

Phase 2 (East Drive and Two-story Garage Restoration) included maintenance to the concrete structural slab, beams, and columns. These repairs included partial, underside, and full-depth repairs using shotcrete. A new paver system was installed, including a waterproofing system and drains. Additionally, concrete curbs and sidewalks were installed, and the basement level of the garage was also repainted.

Phase 3 (Executive West Drive Restoration) included repairs to the concrete structural slab, beams and columns. These repairs included partial, underside, and full depth shotcrete. Phase 3 alone included 11,000 ft^2 (1000 m^2) of underside repairs. A new deck coating was installed in addition to a new paver system, including a waterproofing system and drains. Similar to the repairs in Phase 2, new concrete curbs and sidewalks were also installed, and the basement level of the garage was repainted.

Fig. 6: Overview of roof slab with full depth repair areas apparent.

Fig. 7: Ground view of removed roof.

ACCOMMODATING THE AGGRESSIVE SCHEDULE

BACR leveraged their experience working within occupied buildings to develop a comprehensive project approach to implement the designed repairs. Our team used pull planning—a team-based, production control system for scheduling and planning delivery projects that involves all trade contractors, consultants, and vendors. This helped BACR monitor the schedule and coordinate with trade partners to solicit their buy-in and be held accountable for their production. The removal of the deteriorated concrete was completed using a hydrodemolition trade partner. The hydrodemolition was BACR's critical path activity and

Fig. 8: Replacement roof slab ready to cast.

Fig. 9: Replacement roof slab.

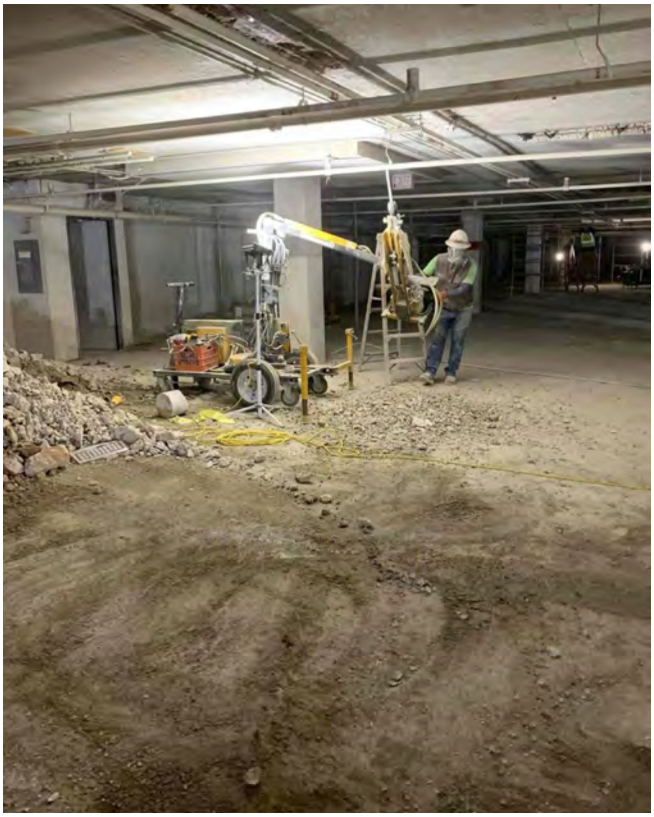


Fig. 10: Mechanically assisted chipping hammer for overhead demolition.

accelerated our schedule so that BACR could successfully meet the project deadlines.

To accommodate the aggressive schedule and to minimize disruption to the building's tenants, BACR worked two shifts to complete the demolition work overnight. Advancements in technology and equipment enabled BACR to focus on sustainability and efficiency. The team used PAM OVE robots for vertical and overhead concrete demolition at locations identified by WGI. The robots reduced the overall load carried and provided increased safety (Fig. 10).

In addition to using PAM OVE robots, hydrodemolition was implemented for all the overhead concrete repairs in the two-story garage and the east lower-level garage. This strategy helped maintain the aggressive schedule. There were two hydrodemolition units onsite during the demolition process: one for overhead demolition and a second for topside, partial-depth demolition which addressed several safety concerns. We could not have any work activity above or below an area while hydrodemolition was being performed because the breakthrough of the concrete would cause serious injury or death to anyone working in proximity of the breach. Another concern was water management. Each unit uses, on average, 50 gallons (190 l) of water per minute, totaling approximately 30,000 gal (114,000 l) of water in a 10-hour workday. All the water used had to be pumped into a special filtration system that removed fine sand particles. The pH and alkaline levels were also tested and adjusted before it was returned to the city water system.

The day crew prepared, coated, and installed the concrete. After removing the unsound concrete, BACR exposed the reinforcing steel. The existing steel was prepared and coated. Where significant section loss was identified, additional supplemental epoxy-coated reinforcing steel was installed. Protective anodes were installed at concrete patch locations to provide long-term protection to the reinforcing from corrosion.

Shotcrete was installed at the vertical and underside partial-depth repairs. The efficiency of shotcrete contributed to completing the project on schedule. The load capacity of the deck forced us to revise our approach during the project to allow for deliveries as well as construction activities. Pump trucks and short-loaded concrete trucks were used to accommodate the weight restrictions. BACR's nozzlemen are ACI certified and have years of experience implementing these repairs. To ensure quality control, each shift and each nozzleman prepared a panel for quality control testing to ensure ideal consolidation of the shotcrete. Two to three nozzlemen were each followed by a crew member who would strike and finish the repairs. After curing, the repairs were coated to improve the appearance of the garage.

Constant coordination with the building team on sequencing minimized the project's impact on the occupied

Fig. 11: Concrete slab with heating piping for melting ice and snow.

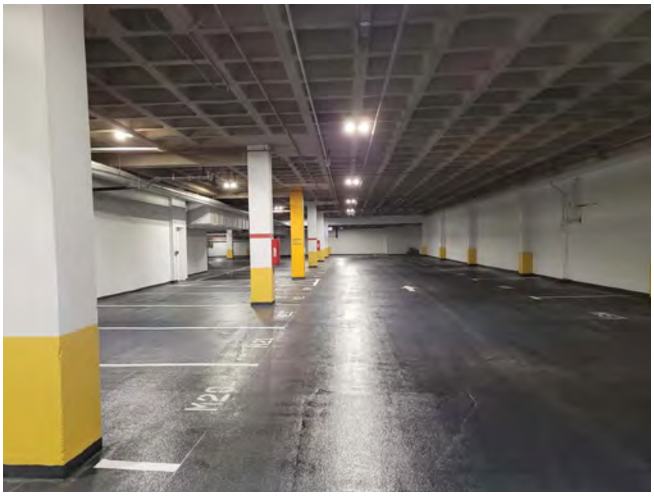


Fig. 12: New top-side coating on repaired slabs.

Fig. 13: Repaved pedestrian walkway.

Fig. 14: Repaved and re-landscaped driveway approach to O'Hare Plaza parking garage.

buildings and their tenants. Maintaining entrances and exits while coordinating two shifts to complete the project was a major challenge. Construction progress required shifting pedestrian paths to keep the occupants safe from the construction activities. Weight load capacities on the existing deck forced BACR to revise their project approach to allow for deliveries as well as construction activities. Pump trucks and short-loaded concrete trucks were used to accommodate the weight restrictions.

Phase 3 was performed during the height of the COVID-19 pandemic. In addition to mitigating the spread of the virus at the jobsite, BACR had to navigate a cement/aggregate shortage due to supply chain issues caused by the pandemic. The approach required weeks of preplanning.

A MODERNIZED UPGRADE

O'Hare Plaza is located adjacent to the Kennedy Expressway and is visible to countless commuters every day. In addition to the structural restoration, the plaza's exterior aesthetic was enhanced by the addition of landscaping. Overall, the project created an opportunity to modernize and upgrade the complex's overall appearance as well as to improve the long-term performance of the parking garage for decades to come.

2023 OUTSTANDING REHABILITATION AND REPAIR PROJECT

Project
O'Hare Plaza West Drive and Executive Garage Restoration

Project Location
Chicago, IL

Shotcrete Contractor
Bulley & Andrews Concrete Restoration

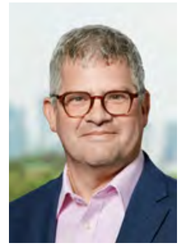
Architect/Engineer
WGI

Equipment Manufacturer
REED Shotcrete Equipment

Materials Supplier
Sika STM/Glenrock

General Contractor
Bulley & Andrews Concrete Restoration

Owner
JLL



Joshua Freedland *is Bulley & Andrews' director of historic preservation. During his 25 year career, his expertise has benefited hundreds of historically significant structures throughout the country including Prudential Plaza and Nickerson Mansion in Chicago; Jackson Lake Lodge in Grand Teton National Park, WY; and the Washington Monument in Washington, D.C. Joshua leverages his exceptional depth of knowledge in materials and construction techniques to preserve historically significant structures across the nation.*

A professional associate of the American Institute of Conservation (AIC) and past chair of the AIC's Architectural Specialty Group, Joshua is an associate editor of the Journal of the American Institute of Conservation. He is also an active member of the Emeritus Board of Landmarks Illinois.

Joshua earned a Master of Arts in comparative history from Brandeis University and a Master of Science in historic preservation from the University of Pennsylvania. His penchant for preservation has extended his professional contributions to include teaching, lecturing, and publishing extensively in academic and professional circles. In his spare time, Joshua enjoys the great outdoors, including fly fishing and kayaking.

2023 Outstanding Underground Project

The Rondout Bypass Tunnel Shafts – Shotcrete Lining

By Paul Madsen, Bade Sozer, Thomas Hennings, & Eileen Test

Fig. 1: Welded wire reinforcement tack welded to the steel pipe.

PROJECT DESCRIPTION

The Rondout-West Branch Tunnel (RWBT), a segment of the Delaware Aqueduct (the Aqueduct), was built from 1937 to 1944 and provides about 50% of New York City's total water supply. The tunnel is concrete lined and has a finished inside diameter of 13.5 ft (4.1 m). It is about 45 mi (72 km) in length and runs in the southeasterly direction from the Rondout to the West Branch Reservoirs. Monitoring during tunnel operations consistently demonstrated that the RWBT is leaking up to 35 million gallons (130 million l) per day, mainly through locations at Roseton and Wawarsing. Leaks at the Wawarsing area will be mitigated through an extensive grouting program of the surrounding rock. The leaks originating from the Roseton area are being mitigated by constructing the Rondout-West Branch Bypass Tunnel (Bypass Tunnel).

The Rondout Bypass Tunnel in New York has two access shafts. The upper sections of the shafts are lined with steel pipe to resist a substantial net internal water head. Initial design included a ¾ in. (19 mm) thick cement mortar lining (CML) for all three components. Because of concerns with CML application on large-diameter pipes, the protective lining was redesigned for shotcrete application.

This paper discusses the design, mock-ups, and construction of the protective lining for the two access shafts of the Bypass Tunnel.

ALTERNATE LINING DESIGN

Bypass Tunnel Access Shafts 5B and 6B are located on the west and east sides of the Hudson River, respectively, and are each over 700 ft (210 m) in depth. Portions of the shafts are lined with steel pipe. The steel lining resists net internal hydrostatic head and external groundwater head during operational and unwatered conditions, respectively. The original design specified a minimum of ¾ in. thick CML for the steel access pipe for protection against corrosion. During early planning stages for the application of CML to the surfaces of the access pipe system, the contractor (Kiewit-Shea Constructors, AJV [KSC]) had concerns about CML maintaining adequate adherence during construction. The specific concern was that crews would be required to work in areas hundreds of feet long beneath the mortar in the later stages of the project.

To save time on the schedule, KSC planned to apply the CML to the access pipe sections prior to shaft installation. To demonstrate the adequacy of CML application and performance through a mock-up, KSC used a section of steel pipe that was a spare from the Bypass Tunnel final lining operation. In April 2021, KSC pneumatically applied CML without any reinforcement to an area of the spare liner pipe in accordance with the design. On a different area of the same pipe, KSC tack welded 4 by 4 in. (100 by 100 mm) welded wire reinforcement (WWR) before applying CML (Fig. 1). KSC planned to pick the mock-up pipe sections with a crane to evaluate the performance of the CML after it underwent any deformation changes during the crane pick. However, this never became necessary as the unreinforced CML fell off the pipe before the crane arrived to do the test pick (Fig. 2). The mortar with the WWR stayed in place and did not show signs of distress following the test pick.

Alternate Design Options

The New York City Department of Environmental Protection (NYC DEP) requested that Delve Underground (the department's tunnel consultant on the Bypass Tunnel Project) design an alternate shaft protective lining. Delve Underground considered reinforced CML, reinforced shotcrete, epoxy, and polyurethane systems. In different lining evaluations, adequate surface preparation to install a suitable anchor profile, anticipated temperature and moisture conditions in the shaft, and the availability of skilled labor necessary for successful application were considered. Epoxy and polyurethane coatings became undesirable options since neither technology would support an extended design life without maintenance. Of the reinforced CML and shotcrete options, reinforced shotcrete was selected because of NYC DEP preference and the historically poor performance of CML when subjected to wetting and drying cycles caused by tunnel unwaterings and restarts.

Fig. 2: Pipe after application of CML.

ALTERNATE DESIGN APPROACH

The primary purpose of the reinforced shotcrete lining is to protect the steel access pipe from corrosion and to optimize the design life. The steel access pipe was designed solely to withstand the full net internal pressure head during operation and the external groundwater pressure head upon unwatering without any load sharing from the surrounding rock. Although the reinforced shotcrete lining serves as a protective barrier and is not required as a structural component, a portion of the loads will inherently be transferred to it during both operating and unwatered loading conditions based on its relative stiffness to the other components of the final system. In addition, gravitational loads needed to be accounted for. To support self-weight of the shotcrete and its reinforcement, headed concrete connectors were required. The headed concrete connectors were welded to the steel components evenly throughout the interior of the steel access pipe to provide locations for the reinforcement cage to be secured during shotcrete application.

DESIGN AND SERVICEABILITY REQUIREMENTS

Design Requirements

The design requirements of the reinforced shotcrete lining included meeting the minimum required shotcrete compressive strength per ACI 318-19. The shotcrete lining was designed conservatively following plain concrete design requirements, including applying a reduction factor of 0.6. Therefore, only nominal reinforcement was required for early-age shrinkage and crack control. Minimum reinforcement requirements were set at 0.25% of the gross cross-sectional area of the shotcrete lining, consistent with project criteria. This minimum reinforcement requirement was set considering a combination of ACI 318-19 and ACI 350-20 requirements. The minimum clear cover requirement for the shotcrete reinforcement and headed concrete connectors was set at 2.5 in. (63 mm), which is also consistent with project criteria.

Serviceability Requirements

Reinforced shotcrete lining serviceability requirements included a smooth trowel finish primarily to achieve a visual similar to a formed finish and to control crack widths. Design for crack control included limiting the stresses in the steel reinforcement following ACI 350 (Eq. 10-4) requirements and considering normal environmental exposures. Following this criterion prevents both early-age shrinkage cracking and cracking due to internal hydrostatic pressures upon Bypass Tunnel operation.

Loading Conditions

Loading conditions include operational (when the Bypass Tunnel is in service) and unwatered (when the Bypass Tunnel hydraulic grade line [HGL] is lowered below the access pipe elevation). Gravitational loads include the shotcrete lining and reinforcement self-weight. The operational and unwatered loading conditions are further defined in the following sections.

Operational Loading

During Bypass Tunnel operation, the access shafts will be filled with Aqueduct water that is pressurized based on the HGL at the shaft locations and the elevation of the shaft pipe system. Because of external groundwater pressures, a net internal hydrostatic pressure (total internal hydrostatic pressures minus external groundwater pressures) will act on the access pipe. The steel access pipe was conservatively designed for the maximum net internal hydrostatic head without any load sharing based on the assumption that gaps could form between the pipe and the refill concrete, preventing any load transfer to the surrounding rock. The shotcrete lining, although not structurally required to support the net internal hydrostatic pressure, will experience load within the access pipe. Steel reinforcement is required to control the width of the cracks.

UNWATERED LOADING

When the HGL is lowered below the bottom of the access pipe, the total net pressure will be acting externally on the access riser pipe; therefore, the external groundwater pressure will be greater than the internal pressure based on the position of the HGL. Upon loading, the access pipe will deform inward against the shotcrete lining, which will absorb a portion of the load based on the relative radial stiffness between the two liner components. About 40% and 30% of the total external hydrostatic load is estimated to be transferred to the shotcrete lining at the Shaft 5B and Shaft 6B locations, respectively.

Shotcrete Design

The tensile hoop stresses in the steel reinforcement during operation and the compressive hoop stresses in the shotcrete lining during unwatering were estimated using Roark's (Budynas and Sadegh, 2020) closed-form solutions for hoop stresses due to uniform loading on a cylindrical shell (Eq. 1). Even though no load sharing was considered for the access pipe design to check reinforcement, and shotcrete stresses for the protective liner, load sharing between the access pipe and shotcrete reinforcement and between the access pipe and shotcrete liner, was considered during Aqueduct operation and unwatering, respectively. The load-sharing distribution as a percentage was estimated based on the relative radial stiffness between the two load-sharing components (Eq. 2).

Hoop stress of a circular pipe due to uniform pressure is as follows:

$$S_h = \frac{P \times R}{t} \qquad \text{Eq. 1}$$

Where, Sh = hoop stress (ksi), P = applied uniform pressure (ksi), R = pipe radius (in.), and t = thickness of pipe (inch).

Load sharing between two shaft lining components resisting hoop stresses is as follows:

$$LS_{1,2} = \frac{\frac{E_{1,2} \times A_{1,2}}{R_{1,2}^{\ 2}}}{\frac{E_1 \times A_1}{R_1^{\ 2}} + \frac{E_2 \times A_2}{R_2^{\ 2}}} \times 100\% \qquad \text{Eq. 2}$$

Where, LS1,2 = load share of components 1 or 2 (%), E1,2 = elastic modulus of components 1 or 2 ksi (7 to 14 MPa), A1,2 = cross-sectional area of components 1 or 2 ($in^{2)}$, and R1,2 = radius of components 1 or 2 in.

The compressive stress in the shotcrete lining was checked against requirements per ACI 318-19. A final minimum comprehensive strength and thickness of the shotcrete lining was determined to be 4,000 psi (28 MPa) and 4.5 in. (114 mm), respectively. A WWR of 4x4 -W4.0xW4.0 (102x102 - MW26xMW26) was selected based on the contractor's means and methods. During aqueduct operation, the tensile stress in the shotcrete reinforcement was confirmed to be less than that required by ACI 350-19 Eq. 10-4 and met crack control requirements.

Headed Concrete Connector Design

The headed concrete connectors were designed to withstand the self-weight of the reinforced shotcrete. The vertical load induced on each shear connector is dependent on the circumferential and vertical spacing of the connectors along the access pipe steel surface. The nominal shear resistance of the connector embedded in the shotcrete liner was determined following AASHTO LRFD Chapter 6.10.10 (2020).

The final required spacing of the headed concrete connectors to support the reinforced shotcrete lining was determined to be 2 ft by 2 ft (0.6 by 0.6 m) along the entire shaft height and circumference. Headed concrete connectors with ½ in (13 mm) diameter and ultimate strength of 61,000 psi (420 MPa) were selected.

SHOTCRETE MOCK-UP

A mock-up was necessary because, although shotcrete is a viable alternative, it requires a high degree of quality control. If not performed correctly, the results could be undesirable. Goals of the mock-up included demonstrating the following:

1. Surface preparation of the steel plate using high pressure water washing is adequate for proper shotcrete application.
2. Welded headed concrete connectors are installed and pass verification testing.

Fig. 3: Mock-up: Shotcrete placement.

3. Circumferential bar reinforcement is adequately secured to the welded headed concrete connectors.
4. WWR is adequately secured to the welded headed concrete connectors/circumferential bar system prior to shotcrete application.
5. Approved shotcrete mixture performs satisfactorily during application, (i.e. bonds well to steel plate, no evidence of sagging through set-up, and no excessive rebound).
6. Shotcrete minimum depth and cover are met and adequately encapsulate the reinforcing steel.
7. Shotcrete as installed over the WWR contains minimal voids, sand pockets, or debonded material.
8. Shotcrete surface finish by troweling is smooth.
9. ACI-certified nozzlemen used to apply mock-up shotcrete are prequalified and subsequently assigned to install shotcrete during the actual work for consistency.
10. Qualified and skilled individuals providing oversight of the mock-up is also present to provide oversight during the actual work.

The mock-up was performed in February 2022 using an available 10 ft (3 m) section of the steel interliner initially procured for the tunnel. The mock-up included all components of the design (pressure washing of the steel pipe, shear connector and WWR installations, and shotcrete) but on a smaller scale. Enough WWR sheets to overlap and form at least three circumferential (vertical) laps, in addition to a longitudinal lap at each circumferential lap location, were installed and shotcreted in the Engineer's presence. This duplicated the worst-case lap of three WWR sheets layered on top of each other and thus could prove the nozzleman's

Fig. 4: Mock-up: Completed.

Fig. 5: Core from mock-up.

ability to properly encase the most dense reinforcing layout. The mock-up quality control included core testing to confirm "very good" steel encasement per ACI 506.6T-17, panel testing to confirm shotcrete mixture strength, and thickness and cover verification. Figures 3 and 4 are from the mock-up. Figure 5 shows a core from a mockup whose quality was "very good."

This mock-up was successful, and the design was finalized and issued for construction.

SHOTCRETE LINING INSTALLATION

Access

The key to a productive operation is good access to the work. Considering that the work was to take place more than 600 ft (180 m) above the bottom of the shafts posed some unique challenges. The project team had extensive knowledge of working throughout the shaft, from placing concrete shaft liner to placing and installing the steel access pipe itself. Two work decks were designed and fabricated to be used at each shaft to allow for concurrent operations.

The access decks were designed to handle loading for all the steps of the operations listed and described in the following sections. To ensure the safety of the workers on the deck, a roof was incorporated into the lifting frame above the deck. The roof was designed to withstand the loading from dropped objects. The lifting frame located above the deck also had lighting installed. Additionally, the open diamond grading of the work deck allowed for air movement up and down the shafts to reduce the concentration of airborne particles from the shotcreting operation.

The decks were suspended from a Favco crane on the 5B side and a Cobelco crane on the 6B side.

As secondary access to the deck, a backup crane with a bullet cage was available.

Work Sequence

There were four major components of work to install the shotcrete lining, all of which were performed in June and July 2022: pressure washing of steel lining; headed concrete connector and wire mesh installation; applying, finishing, and curing shotcrete; and final cleanup.

Pressure Washing of Steel Lining

Total quantity of work was 17,762 ft^2 (1650 m^2) between the two shafts, and the work was completed with a 3000 psi (21 MPa) pressure washer located on the work deck. Design required that any rust scales, grime, oil, and dirt be removed prior to shotcrete application.

Headed Concrete Connector (Nelson Studs) and WWR Installation

Nelson studs were used as headed concrete connectors. KSC rented Nelson stud guns and received training in stud installation from the supplier. A total of 4394 EA studs were installed in the two shafts: a row of 28 EA studs per 2 feet vertically. A #4 (#13M) rebar was bent to the diameter of the inside of the studs every other lift of studs at 4 ft (1.2 m) centers. The purpose of this bar, which is nonstructural, was to provide stiffness to the WWR and prevent it from vibrating during the shotcrete application. Further, it expedited the WWR installation as the wire did not have to be aligned on the mesh exactly with the studs. Figure 6 is a view down the inside of the steel liner from the work deck, showing the #4 bar and stud detail, prior to WWR installation. WWR was inspected during installation to ensure stiffness and correct overlap. See Figure 7.

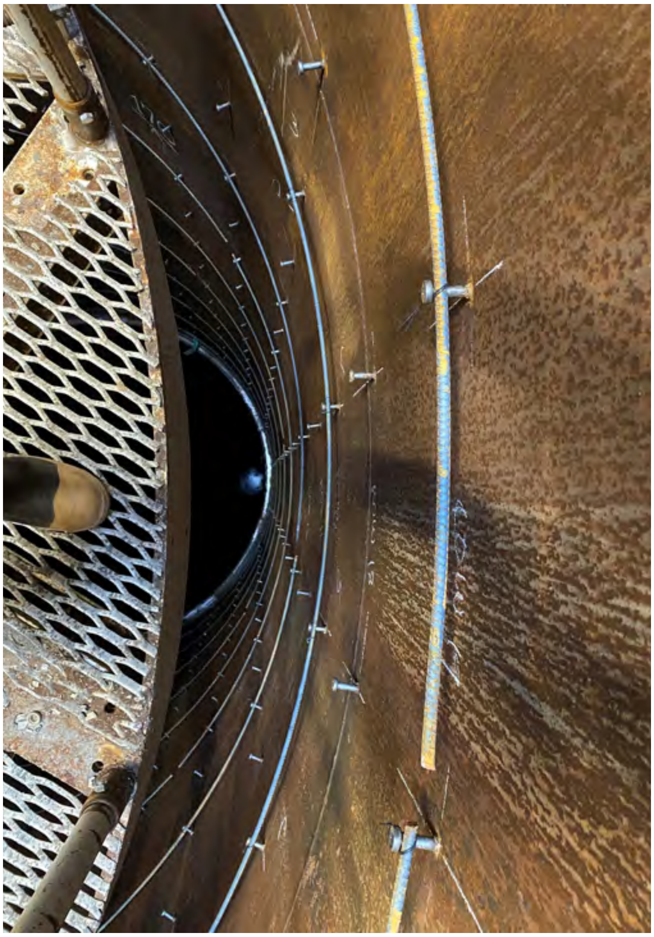


Fig. 6: Detail of #4 bar tied to the studs.

Fig. 7: Inspection to ensure the correct overlap of WWR.

Applying, Finishing, and Curing Shotcrete

The shotcreting operation was performed by a specialty subcontractor on a single shift operation. The shotcrete crew consisted of six personnel on the deck: a bottom lander, a nozzleman, and four finishers. A second shift was used for applying curing compound to the finished shotcrete and to clean up and prepare the work deck for the following day's operation. The total quantity of shotcrete for the work was 17,762 ft^2. At a thickness of 4.5 in., this is 246 yd^3 (188 m^3) in volume of concrete.

Prior to starting the shotcrete operation, the specialty subcontractor tied a horizontal pencil rod to the wire mesh to serve as a screed for the finishers and to ensure the adequate cover of shotcrete over the WWR. The pencil rods were removed on the back shift.

The shotcrete equipment consisted of two high-pressure shotcrete pumps: one main and one spare; a 2 in. (50 mm) steel slick line to the top of the access pipe; and a 2 in. bull hose down to the work deck and the nozzle applicator. Air was delivered to the nozzle from KSC's on-site compressor though a ¾-in. hose. No accelerator was used for the shotcrete. See Figure 8 for a view down the finished 5B Shaft.

Fig. 8: The completed 5B Shaft from above.

Shaft Bottom Cleanup

Despite having placed heavy plastic sheeting on the shaft bottom, the cleanup operation turned out to be more encompassing than anticipated. Lessons were learned from 6B, which was the first shaft to be shotcreted.

First, the quantity of waste shotcrete exceeded the volume anticipated. This was mainly due to the relatively thin lining where a few inches of overspray is a large percentage of the total. One inch of overspray on a 4.5 in. lining is over 20%. Typically, the subcontractor would overspray the pencil rods with 1 in. minimum and then trowel the surface back to the pencil rod to achieve the required smooth trowel finish. Over the depth of the access pipes, this resulted in 50 yd^3 (38 m^3) of shotcrete ending up in the bottom of the shafts.

Second, the shotcrete would "splatter" up the sides of 6B when it hit the shaft bottom following a 600 to 800 ft (180 to 240 m) drop. Therefore, at Shaft 5B, KSC installed sheets of heavy plastic 20 ft (6 m) up the walls and covered the entrances to the Bypass Tunnel, which had received a good amount of "splatter" during the earlier shotcrete installation at Shaft 6B.

The third lesson learned was that the subcontractor would drop the discarded pencil rods down the shaft. These pencil rods would get embedded in the wet concrete and create a hardened concrete porcupine, which was a painful experience to remove.

Conclusion

Mockups are valuable in identifying issues with an initial approach and later to verify a design and application method; this includes an evaluation of the personnel actually performing the work.

This small, but important, piece of work on a large project exemplified the importance of having a collaborative environment between project owner, construction manager, designer, contractor, and specialty subcontractor to tackle a technical and operational challenge in order not to delay the project.

Application and trowel finishing of shotcrete linings require highly skilled and trained personnel. Never underestimate the need for clean up after a shotcrete operation.

For Bypass Tunnel Shafts 5B and 6B, the quality of the shotcrete finish was exceptional and similar to a formed concrete surface.

ACKNOWLEDGMENTS

The authors wish to acknowledge the New York City Department of Environmental Protection for allowing the publication of this work, which was an example of collaboration on the Bypass Tunnel project. Special acknowledgement also goes to Patriot Shotcrete, Jersey City, NJ, for their contributions and hard work.

2023 OUTSTANDING UNDERGROUND PROJECT

Project
Rondout Bypass Tunnel

Project Location
New York, NY

Architect/Engineer
DELVE Underground

Shotcrete Contractor
Patriot Shotcrete

Equipment Manufacturer
Western Shotcrete Equipment

Materials Supplier
Bonded Concrete

General Contractor
Kiewit Shea Constructors, AJV

Owner
New York Department of Environmental Protection

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REFERENCES

American Concrete Institute. 2019. Building Code Requirements for Structural Concrete and Commentary (ACI 318-19). Farmington Hills, MI: American Concrete Institute.

American Concrete Institute. 2021. Code Requirements for Environmental Engineering Concrete Structures and Commentary (ACI 350-20). Farmington Hills, MI: American Concrete Institute.

ACI Committee 506. 2017. Visual Shotcrete Core Quality Evaluation Technote (ACI 506.6T-17). Farmington Hills, MI: American Concrete Institute.

American Association of State and Highway Transportation Officials (AASHTO). 2020. LRFD Bridge Design Specifications, 9th edition. Chapter 6.10.10. Washington, DC: AASHTO.

Budynas R.G. and Sadegh A.M. (2020). Roark's Formulas for Stress and Strain, Ninth Edition. McGraw-Hill.

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2023 Shotcrete Awards: Honorable Mention

The Neville Island Bridge Project

By Ted Sofis

Fig. 1: The river span over the main channel of the Ohio River.

The Neville Island Bridge Rehabilitation project originally came out for bid in 2018. The bridge is located in Allegheny County, PA and within PennDOT's District 11. In the bid package, it was noted that construction could not begin until a nesting pair of Peregrine Falcons had fledged their young, which translated to a late summer start. The construction delays were then compounded with the outbreak of COVID-19 in March of 2020. When the pandemic occurred, the State of Pennsylvania closed down all construction operations, except for emergency repairs, for several months. As an ultimate result, along with necessary prep work, our shotcrete operations did not begin until May of 2021. The Trumbull Corporation's $43 million dollar project included structural steel repairs, full structure painting, deck repairs and overlays, and other items in addition to the substructure repairs.

HISTORY

The Neville Island Bridge, northwest of Pittsburgh, is a tied arch bridge carrying Interstate 79 over the Ohio River and Neville Island. It has 29 spans from the back channel over Neville Island, the river, and the Borough of Glenfield, all with multiple traffic lanes. The adjacent girder spans extend over the low-lying areas on the south end and over areas to the north. Originally opened to traffic in 1976, the bridge provided the last section of the 180-mile Interstate highway to be completed. The bridge's Ohio River span is the 2nd largest span in Allegheny County, which is known for having

Fig. 2: Gunning a pier at the river's edge. When shooting from a man lift, each patch or area must be shot, cut down to grade and finished before moving on to the next.

Fig. 3: Finished pier at the river's edge.

Fig. 4: A pier is prepped and ready for gunning.

the most bridges in the nation. Pittsburgh, "The City of Bridges," and the county seat, has more bridges than any other city in the world.

REHABILITATION

The restoration project included the substructure repairs on the piers of the 29 spans. This repair work extended from Coraopolis, PA on the south end, over the back channel of the Ohio River, the Neville Island community, the main Channel of the Ohio River, and over the Borough of Glenville on the north riverbank. Also included in the project was the rehabilitation of the smaller four-span bridge at Deer Run, just north of the Neville Island Bridge. The substructure concrete repairs were specified for conventional form-and-pour repairs but also allowed for an alternate shotcrete option. Needless to say, we chose to go with the shotcrete option.

The general contractor, Trumbull Corporation, began the demolition and concrete preparation work early in the 2021 construction season. Our shotcrete placement throughout the project was sequenced to follow as each area became available. Coordination was excellent between the owner, PennDOT District 11; the general contractor, Trumbull Corporation; and us as the subcontractor.

DRY-PROCESS SHOTCRETE

As in many repair projects, using dry-mix shotcrete provided us with several advantages. Dry-mix gives the nozzleman greater control to make fine adjustments with the water and air as needed. The repair areas were scattered, which necessitated a stop-and-go sequence; this also lends itself to use of dry-mix shotcrete. With the dry-mix method, the gunning hose is completely discharged when you stop; therefore, there is no material remaining in the hose when shut off. This is both convenient and efficient when performing work of an intermittent nature. Also because of the many locations and varying distances between piers and spans, we often had to break down our equipment "set-up" and move the operation to other locations for placing shotcrete. Access to the work required several moves in each area of the project. Most of our shotcrete work was performed using JLG manlifts. Because we could only fit two men in the basket, each and every repair had to be shot, cut down to grade, and completely finished before moving on to the next area. With this type of repair, it's not possible to gun continuously.

MATERIAL

The material that we used on the project was Shotcrete MS, manufactured by Quikrete. Shotcrete MS is a micro-silica enhanced, pre-packaged concrete repair mortar that is specifically designed for shotcrete applications. For most of the project, we used the pre-packaged material in 3000 lb (1400 kg) bulk bags. In certain areas, like the piers on the

Fig. 5: Shooting a pier on an approach span on the south end of the Neville Island Bridge.

Fig. 6: Dry-mix shotcrete gunning of bridge pier to the right with finished sections to the left side of the pier.

Fig. 7: Pre-packaged material, Quikrete Shotcrete MS, being loaded into a bulk hopper. The concrete repair mortar is then pre-dampened immediately prior to gunning and then water is added at the nozzle.

median of the divided highway under the north end of the bridge, it was more convenient to use 2400 lb. pallets of 50 lb (23 kg) bags.

Using a pre-packaged repair material saves time by eliminating on-site mixing. It also provides the contractor and customer with a level of quality control with a uniform, pre-mixed manufactured product. With kiln-dried, aggregates and dry cement products, it is recommended that the material be pre-dampened with a 4% to 6% moisture content prior to gunning. With dry-mix shotcrete, there are several advantages to pre-dampening. First and foremost, it greatly reduces dust which creates a safer and cleaner work environment for all involved. With pre-dampened material, there is less separation, due to wind, between cement and aggregates in the nozzle stream while shooting. Also, the dampened material more efficiently accepts the rest of the water that is introduced at the nozzle, providing better mixing.

EQUIPMENT

The dry-mix equipment used on the project were continuous-feed rotary bowl type guns, the Airplaco C-10s, in conjunction with an auger-type predampener. Unlike batch-type mixers in pre-dampening, the auger-type are continuous feed, so the shotcrete repair mortar is dampened immediately before being fed into the dry-mix gun. There are no issues with a moistened material sitting and reacting in a holding hopper when delayed. Our gunning equipment was then positioned below a large bulk hopper which could hold five bulk bags of the Shotcrete MS.

For the gunning, it's advisable to use a large air compressor with a minimum of 400 to 600 CFM with dry-mix shotcrete. Additionally, we chose to use a separate, smaller compressor to run our air-powered pre-dampener. This was done so there would be no other draw of air that could cause fluctuations in air pressure while gunning. For the rotary guns, we used a minimum of 425 CFM to 825 CFM depending on the area or distance involved.

Fig. 8: Holding hopper being loaded with a 3,000 lb bag of pre-mixed material. The hopper holds 5 bulk bags of the Shotcrete repair mortar.

Fig. 9: Shotcrete being gunned in place on a riverbank pier. Dry-mix shotcrete works well with the stop and go nature of concrete repair applications.

PERFORMANCE

The surface preparation work was performed by the general contractor, Trumbull Corporation. We were fortunate to have an excellent GC to work with. Because the prep work took longer than the shotcrete placement, we needed several mobilizations during the two years we were on the job. As mentioned earlier, our gunning operations began in May of 2021 on the south approach pier spans. Initially after starting, we were only able to gun for a short time due to flooding conditions and rising river levels.

Our work around the piers near the railroad tracks had to be performed on Saturdays, which required back-tracking and some additional moving and relocation activities. When working near and around railroad tracks, special precautions needed to be taken with the railroad company, including suspending the work when oncoming trains were approaching.

On a job that covers the distance and number of exits that the Neville Island bridge has, conditions can vary greatly from one section of the project to another. In the main river channel of the Ohio River, it was necessary to work from a barge.

Consequently, when flooding occurred, our work had to be suspended temporarily. In February of 2022, there were a few overhead sections where the underside of the bridge delaminated and needed to be addressed immediately. Precautions were taken for winter conditions and the overhead shotcrete repairs were quickly undertaken and completed. We hold fast to guidelines regarding acceptable

Fig. 10: Installing Shotcrete from a barge in the main channel of the Ohio River. Note the prepared area on the left face of the river pier.

Fig. 11: The cutting-down and finishing work has to be done in a timely manner. Working out of man lifts necessitates a stop and go procedure.

Fig. 12: A close-up picture of a bridge pier with the newly installed shotcrete adjacent to the existing concrete.

Fig. 13: Four gunned and completely finished piers in the Glenfield Borough section of the project.

temperatures being 40 °F (4 °C) and above before gunning, or we provide adequate tenting and heating to achieve that.

Conclusion

After 47 years of performing shotcrete work as an owner of Sofis Company, I recently retired from the business. The completion of this project was bittersweet for me. I began working as a laborer during the summers in the early 1970s after high school. After graduating from college, I worked in the local steel mills as a nozzleman and gun operator shooting refractory for lining steel teeming ladles, Treadwell "submarine" ladles, and blast furnace troughs. Much of

2023 HONORABLE MENTION

Project
The Neville Island Bridge

Project Location
Coraopolis, PA

Shotcrete Contractor
Sofis Company Inc.

General Contractor Superintendent
Rob Opel

Engineer
SAI Consulting Engineers

Project Manager
Ted Sofis

Superintendent
Rob Svihla

Equipment Manufacturer
Gunite Supply & Equipment Co.

Materials Supplier
The Quikrete Companies

General Contractor
Trumbull Corporation

Owner
Pennsylvania Department of Transportation

my work involved shotcrete refractory installations, re-lining ash hoppers, and servicing coal-fired power plants. Over the years we, as a company, have performed shotcrete work in power plants, steel mills, dams, tunnel spillways, culverts, slope protection, and in many other shotcrete-related applications. Some of the notable shotcrete projects that we've performed over the years include the Baltimore Harbor Tunnel, the 41st Bridge in Baltimore, Union Station in Washington, DC, the McKees Rocks Bridge, the Noblestown Road Bridge, and the Neville Island Bridge in western Pennsylvania.

Ted W. Sofis *is an ACI Shotcrete Nozzleman Examiner and has served on the ASA Executive Board of Directors, on the ASA Board, and as the Chair of ASA Publications Committee (11 years); he has also served as a member on several other ASA 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.*

2023 Shotcrete Awards: Honorable Mention

Moyie Dam Repair: Back to the Future

By Mike Newcomb and Leo Waddell

Fig. 1: Prep Training at Moyie Dam, 1981.

GOING BACK TO MOVE FORWARD

Moyie Dam at Bonner's Ferry in northern Idaho started initial construction just before WWII. They shut down construction during the war. After the war was over, the dam went into service in the late 1950s.

The dam is hydroelectric, and the dam's surplus electricity is purchased by Seattle Light—Washington's electric company. After running high-velocity water down the spillway for decades, by 1980, the concrete was significantly deteriorated and needed to be rehabilitated.

In 1981, Leo Waddell won a bid to resurface the first half of the spillway with an epoxy grout. Leo bid on the job based on the Engineer's requirements. Leo then got together with the Engineer and showed him that the epoxy specified had major bonding problems – it was de-bonding. Leo demonstrated that by tapping the epoxy with a hammer, there were many hollow, delaminated spots. Leo convinced the Engineer that shotcrete was the best solution for the spillway rehab. They did a mockup test with a gunite (dry-mix shotcrete) machine and showed the Engineer that with shotcrete, there were no hollow spots—it was 100% bonded. After that, a change order was processed to switch from epoxy to shotcrete. Because there were only about two or three months a year that the dam's spillway was without water, the project needed to be split into two separate "dry seasons." Leo got the contract to do them both: the first half in 1981 and the second half in 1982.

As a consultant on the Moyie Dam Rehabilitation in 2021-22, this project recently took Leo back to the future!

In 1981, Leo and his crew used a REED LOVA model dry-mix shotcrete machine to spray the material. The mixture was extremely simple by today's standards – just four parts sand and one part Type II cement. The mixture was batched on the job site with a continuous-feed mixer with a vane feeder that Leo built. Leo used a 750 CFM Gardner Denver air compressor to blow this material through a 2 in. (50 mm) gunite hose to get to a REED 2 in. liner style, Hamm nozzle. Leo used an air-driven water booster pump to get approximately 100 psi (0.7 MPa) of water pressure. They also used the high-water pressure water to wash the rebound down the slope and right into the river. Consulting on the job in 2021, Leo acknowledged that, "you can't do that no more."

On the original resurfacing job in 1981, Leo built his own scaffold; it had skids on it, it was about 10 ft (3 m) wide, and there was a winch down at the bottom of the dam to help move the scaffold. They had an 8 in. (200 mm) diameter pipe up on top of the dam that gravity-fed the mixed material down to the bottom of the dam. They shot everything from the bottom to the top, which was roughly 100 ft (30 m) up the spillway. The spillway and the three training walls between were the only parts of the dam that needed to be rehabilitated because it is the force of the fast-flowing water that deteriorates the spillway surfaces.

Fig. 2: Prep at Moyie Dam, 1981.

Fig. 3: Moyie Dam completion, 1982.

Fig. 4: Right spillway at Moyie Dam showing old shotcrete, 2021.

Fig. 5: Left spillway at Moyie Dam showing old shotcrete, 2021.

FAST FORWARD TO THE FUTURE

Nearly 40 years have passed since that original rehabilitation project, and Leo got a unique chance to go back and work on it again. In 2021, the very same spillway was once again in need of repair. So, the project was put out to bid. Leo got a copy of the plans on the bid. Once again, they wanted to use epoxy. Leo met with the Engineer and once again insisted that the bonding agents must be removed from the bid. Leo said, "On shotcrete, we don't use bonding agents—no epoxies. With shotcrete, ASA and ACI have shown that bonding agents are not only unnecessary, but they also cause failures."

S & L Underground, out of Bonners Ferry, ID, was awarded a new contract for 2021 and 2022. Leo was hired as a consultant by S & L on the new project, and he found about 70% of the previously placed shotcrete on the spillway was still in good shape. Both dry-mix and wet-mix shotcrete were considered for the new repair. Part of the reason for selecting dry-mix was the excellent performance of the previous shotcrete. Most of the new deterioration was found to result not from the shotcrete but from the low strength in the original 1940s and 1950s concrete. In the 1980s repair, they used chipping hammers to locate and tear off any concrete that was loose, sandblasted it, and then shot new the shotcrete.

In 2021, S & L Underground used hydro demolition to prepare the surface. They found, when they tried to hydro demo much of the 1980 shotcrete repairs, it was so hard that they left portions of it in place because the hydro blaster was taking too much time to remove the structurally sound concrete.

The material and logistical situation in the 2021 rehabilitation was quite a bit different than the 1981 repair except for one thing. Just like in 1981, in 2021 a REED LOVA model dry-mix shotcrete machine with 2 in. hose and nozzle and a 15-pocket standard bowl was used. This time, instead of Leo's handmade mixer, the contractor bought a new Canusa model PDM-1 continuous pre-dampener/mixer with an integrated tote bag holder for the 3000 lb (1400 kg) super sacks of dry concrete material. The PDM-1 uses an electric motor powered by a diesel generator.

The dry-mix material used on this job was significantly more sophisticated than the rehabilitation in the 1980s. The material was pre-batched by Oldcastle in Spokane, WA. Leo worked with Oldcastle to design the mixture. The mixture was 41.5% coarse sand, 26.5% fine sand, 22.8% Type II

Fig. 6: Hydro demolition at Moyie Dam, 2021.

Fig. 7: Bulk bag hanger at Moyie Dam, 2021.

cement, 7.6% pea gravel, 1.7% silica fume, 0.02% Master Builders M100 fibers, and an air-entraining agent. When field tested, the mixture as-shot had 5% air content. Overall, this mixture was much better than the 1980s mixture with higher strength and entrained air for freeze-thaw durability.

They used 3000 lb super sacks. Each sack contained the following:

- Ash Grove cement 685 lb (311 kg)
- 1244 lb (564 kg) coarse sand
- 792 lb (359 kg) fine sand
- 239 lb (108 kg) pea gravel
- 50 lb (23 kg) silica fume
- 0.5 lb (0.23 kg) of fibers
- 27 to 34 oz (0.77 to 0.96 kg) of powdered air entraining admixture

In 2021, the contractor had the predampener and dry-mix shotcrete machines set at the top of the spillway. They used a crane on site to move the scaffolding, the hydroblaster, and super sacks of dry-mix material. During the second phase of the project (2022), they put the dry-mix machine down at the bottom of the spillway just as Leo had done in the 1980s.

Other than the fancier mix design and much more expensive on-site equipment, Leo said that biggest difference from the 1981 rehab to the 2021 rehab is that in 1981, Leo put on a layer of shotcrete that was between 2 to 6 in. (50 to 150 mm) thick. For the new 2021 rehab, the contractor added #4 (#13M) reinforcing bars spaced at 10 in. (250 mm) on center and applied shotcrete from 6 to 12 in. (150 to 300 mm) thick. Leo thinks with the addition of the reinforcing bars, the thickness of the shotcrete, and the more sophisticated dry-mix material used, the spillway's strength should easily still be good the next time he visits the dam in another 40 years.

Leo Waddell's legacy in shotcrete spans over 60 years, and the work he has done with the Moyie Dam has bridged an impressive gap of 40 years. This project is a celebration of not only his career-spanning commitment to shotcrete as a placement method, but to his present-day commitment to the industry and to the next generation of its leaders.

Fig. 8: View of equipment staging at Moyie Dam, 2021.

Fig. 9: Nozzlemen placing and finishing new shotcrete at Moyie Dam, 2021.

Fig. 10: Continuation of shotcrete placement at Moyie Dam, 2021.

Fig. 11: 86 years young—Leo shooting a pool wearing his signature cowboy-style hard hat.

2023 HONORABLE MENTION

Project
Moyie Dam Repair

Project Location
Bonner's Ferry, ID

Shotcrete Contractor
S & L Underground

Shotcrete Consultant
Leo Waddell, Shotcrete Consulting

Architect/Engineer
JUB Engineering

Equipment Manufacturer
REED Shotcrete Equipment

Materials Supplier
Oldcastle Precast
REED Concrete Pumps

General Contractor
S & L Underground

Project Owner
City of Bonner's Ferry, ID

***Leo Waddell** is a legend in the shotcrete world. Leo's now 86, and he has been around wet-mix and dry-mix shotcrete for most of those years. In 1960, Leo was hired as a finisher to work with a crew and shot two pools in one day with an Allentown Double Chamber Gun at the Grand Cooley Dam.*

In 1964, Leo shot a pool for the State of Nevada–a girl's school operated by the State. It was about this time that Leo met Frank Reed, inventor of the bowl-type dry-mix (gunite) machine. Mr. Reed showed Leo a prototype for an automated, double-chamber pressure vessel with valves to operate it that he had had never moved forward with.

One of the more unique shotcrete projects that Leo came across was in the U.S. Military's Pregondola 1 project in 1966 and 1967. Dry-mix was used to build seven underground structures in Montana as a way to test the idea of using nuclear explosives to "dig" a new Panama Canal wide enough to sail aircraft carriers though. In the test in Montana, they used alcohol to simulate a nuclear explosion. Later, an actual nuclear explosion was performed in the Aleutian Islands near Alaska, but because the military identified a major problem in the nuclear fallout, the military's "nuclear digging" plan was scrapped.

Even at 86, Leo is still getting his hands dirty. As a consultant, Leo still flies out to help people set up job sites, to suggest materials and equipment, and to train nozzlemen.

***Mike Newcomb** is the Sales and Marketing Manager at REED Shotcrete Equipment. Mike holds a B.A. from UCLA and an M.B.A. from Cal State Fullerton. Mike started at REED in 1997 and enjoys working with REED's dealers and customers. REED is a privately held, American-owned company that has been manufacturing concrete placing equipment in California since 1957 when Frank Reed invented the bowl-type "Guncrete" Gunite Machine. REED has a worldwide network of well-qualified Official Dealers who are experts in shotcrete equipment and are responsible for all on-site startups, after-sales service assistance, and parts assistance.*

2023 Shotcrete Awards: Honorable Mention

Water's Edge

By Bill Drakeley

Fig. 1: Vanishing edge slot perimeter overflow with multiple edge elevations.

The Water's Edge pool project was a contracted water feature that drew its contemporary design from the architecture of the new house addition. The house is a modern version of the old coastal mansions once built and adorned by the Rockefellers, Morgans, and Vanderbilts. The house, with its surrounding architecture and landscape architecture, incorporates a contemporary, strict linear version of the old-world construction. The house and all its features, including the pool, blend into the modernist property connecting directly to the ocean. This pool is a reflection of the house. It's a 3-tiered pool, spa, and vanishing edge slot overflow with a Moses edge detail. All water spills over the edges into a shotcrete-constructed runnel system that leads to a lower shotcrete basin and surge tank.

CONSTRUCTION PHASING

Construction phasing started with forming and reinforcing bar installation. Unlike the cast concrete substructure, our forms were one-sided, rough-sawed lumber that was 2x4x1.5 in. (50x100x40 mm) thick as well as 3/4 in. (19 mm) sheets of plywood. The entire pool installation was out of ground, and some intricate forming was required. The steel reinforcement was Grade 60, #4 and #5 bars (Grade 420M, #13M and #16M), including 12 and 6 in. (300 and 150 mm) on centers, in double and triple cages. All reinforcing steel was installed with a high degree of rigidity and free of oil and contaminants that could affect performance. Total steel installed was 12 tons (11,000 kg).

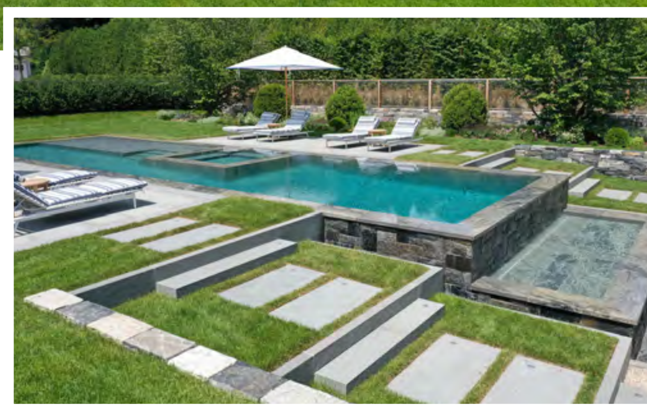

Fig. 2: Multiple edge/water-in-transit.

SHOTCRETE PROCESS

The shotcrete process was completed over a three-day period. The first two days were for the bulk of the main pool shooting and some of the thicker wall to floor areas, which included full thickness bench shooting on seats, benches, and shelves. The last day was focused on the detail of the vanishing edge and all of the spillway lower pools.

Fig. 3: Rigid forming, plumbing, and reinforcing steel installation.

Fig. 4: Form removal—quality concrete example of the sprayed pneumatic wet shotcrete process.

Fig. 5: Water-in-transit changes in elevations and edge designs.

Fig. 6: Plan view of in-pool features and shapes within and on top of the pool structure.

The most challenging part of the shotcrete process was the installation of the Moses detail. The spa shotcrete common wall has a slot built into the shotcrete itself (see Figs. 1 and 6). With tight tolerances established by the shotcrete crews, the spa overflow stones are essentially equal with the stainless steel gutter system that surrounds the pool and is hidden on top of the shotcrete atmospheric perimeter gutter. This set up shows the water surface to be clean and without any part of the structure protruding up and above the clean glass looking pool surface. This architectural look was a high priority for the clients. Our shotcrete engineering had to devise a way to use this under-surface water spa independently from the pool, based on client's usage.

With surface elevations the same and automatic valving at the filter system, we installed a system where the client can hit a spa button and have the surface of the water evacuate through our Moses detailed shotcrete slot in the spa wall. This gives the visual effect of the water "parting" to allow for the spa and pool to "separate." Elapsed time to do this takes approximately 20 seconds. Having this feature flow through our watertight shotcrete channel allows the pool user to heat and circulate just the spa water, providing sustainable use of fuel for the pool heaters and sustainable power used by the pumps.

Even though the dimensions of the pool are not that large, the detail work of the tolerance was critical. After the concrete installation via wet-mix process, the concrete was water-cured to ensure not only strength gain but to also give a sense of watertightness. Compressive values after 28-day wet cure were between 6000 and 7500 psi (41 and 52 MPa).

Completion of the pool included the following finish materials:

- Native stone veneer matching existing house foundational colors
- Pennsylvania Select Bluestone treads and caps
- Italian marble stone
- Stainless (316L) steel slot perimeter overflow earth support
- Pool plaster, aggregate finish

SIGNIFICANCE OF SHOTCRETE

The significance of the shotcrete work, especially to the pool industry, is a successful installation and watertight connection of two connected water retaining structures. Using a hidden channel in the spa for the Moses effect—incorporating shotcrete's strengths for water retention, ability to connect, bond, and function as one monolithic structural vessel—pushes our existing norms to a new level. This water feature is proof positive that shotcrete placement not only creates a watertight bond to support vastly different surfaces, but it can be used in conjunction with leading architecture and design that satisfies and recreates world-renowned architectural works.

SHOTCRETE SEGMENT OF THE PROJECT

The shotcrete segment of this project was one week's worth of shotcrete on the pre-formed reinforcing steel caging for three interconnecting water-in-transit pools. Although the shotcrete took three days to complete, due to shotcrete placement's inherent properties, there were no cold joints, and all interconnecting pools were monolithic and watertight. There was no expansion joint or bonding agent used between concrete connections. All next day shooting and connecting joints were prepped to an SSD condition with a three-dimensional bond plane before shotcrete placement.

MIX DESIGN

- Cement (ASTM C150 Type I/II) – 750 lb (340 kg)
- Fly Ash (ASTM C618 Class C) – 50 lb (23 kg)
- Sand (ASTM C-33) SSD – 2020 lb (920 kg)
- ASTM No. 8 (3/8") – 600 lb (270 kg)
- Water – 358 lb (162 kg)
- Air Mix 250 (air entraining admixture) – 1.0 to 2.0 oz (28 to 57 g)
- Water reducing admixture – 2.0 oz
- Entrained air content before placement – 8%-10%
- Slump – 1 to 3 in. (25 to 75 mm)
- w/cm Ratio – 0.44

Total yardage: 165 yd^3 (126 m^3)

Equipment: Schwing BP500 Wet Mix Shotcrete Pump and Ingersoll Rand 375 Air Compressor

SUSTAINABLE BENEFITS REALIZED ON THE PROJECT RESULTING FROM SHOTCRETE

Sustainability benefits on this project were as follows:

- Approximately 50% labor and material savings over conventional form work.
- Our form work did not need to be designed for internal pressures and thus only needed one-sided forming.
- The speed of labor increased by almost 50% because of the reduced need for overall forms in relationship to reinforcement.
- The restricted work area and its elevated accessibility could not have been completed economically or timely by any other means besides the shotcrete process.
- The cost savings with materials and manpower is evident when placed in comparison with the formed foundation on this same job.

CONCLUSIONS

Building water features or swimming pools with multiple layers of water-in-transit edges and elevations requires quality shotcrete installations. Tight tolerances, material bond ability to a structure, and clean water flow at a minimum energy usage all rely on quality shotcrete. Durability and serviceability of a swimming pool is contingent on how well the structure was built. The top criteria of a well-built swimming pool is the quality of the shotcrete placement. Clearly, this water's edge placement of watertight concrete with wet-mix shotcrete is entirely reliant on not only the concrete materials but how that material was shot into place. This project was installed correctly.

2023 HONORABLE MENTION

Project
Water's Edge

Project Location
Greenwich, CT

Shotcrete Contractor
Drakeley Pool Company

Architect/Engineer
James Doyle Design Associates

Equipment Manufacturer
Schwing America

Materials Supplier
O&G Industries

General Contractor
Drakeley Pool Company

Owner
Nordic Custom Builders

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.*

Bekaert Underground

With over four decades of experience in the world's most challenging ground support applications in metro, highway, rail, water, and mining, Bekaert Underground Solutions not only has the in-depth expertise and know-how to ensure the safety of these projects, but we also offer fiber concrete reinforcement solutions which guarantee a cost-effective, more durable, and more sustainable shotcrete structure when compared to conventional form-and-pour structures. Replacing conventional rebar and mesh with fibers is our expertise.

We have a wide portfolio of fiber concrete reinforcement solutions and offer a high-quality fiber for reinforcing wet-mix or dry-mix shotcrete applications. With our global expertise, we provide state-of-the-art, fiber-reinforced shotcrete solutions for ground support in mining and in primary and final sprayed concrete linings in civil tunnels, shafts, and caverns. Our fiber-reinforced shotcrete solutions have been used in numerous tunnels and mines around the world. Bekaert is the modern-day pioneer in the development of Dramix® steel fibers in the 1970s. Now, our newest lines of high-performance fibers have proven themselves just as revolutionary in enabling structural shotcrete single-shell linings of tunnels and underground stations. Saving time, saving material, and providing a low carbon solution at a significant cost savings is in the mix!

At Bekaert, we continuously strive to minimize our environmental impact by integrating sustainability at every level of our business. The Bekaert R&D team, together with universities, continues to investigate recyclability. In January 2023, Dramix® manufactured at our USA production plant was granted an Environmental Product Declaration (EPD) Stee certificate.

MINING APPLICATIONS

The role of a thin shotcrete lining is not to support the original ground pressures. The role of the shotcrete is to stabilize the deformations required to mobilize the ground's inherent strength. Most underground excavations do not have a smooth, uniform rock surface. Wire mesh reinforcement cannot conform to the uneven excavation surface, but steel-fiber reinforced shotcrete can easily adapt to nearly any surface profile.

PRACTICAL BENEFITS OF STEEL-FIBER REINFORCED SHOTCRETE

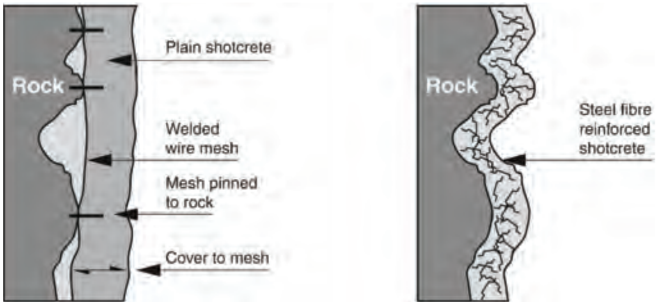

Figure 1: Rebar vs. SFRC Reinforcement.

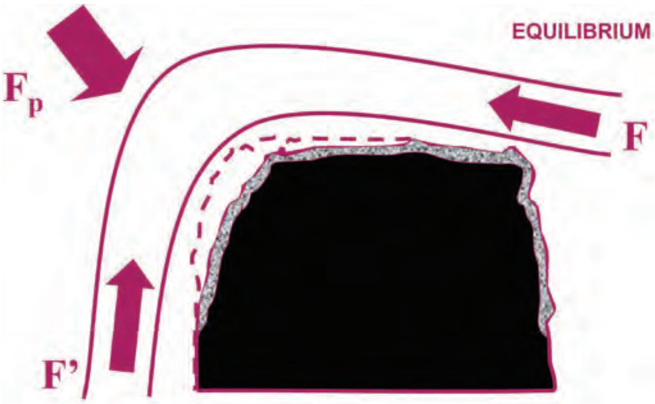

Figure 2: Tunnelling Stresses.

CIVIL APPLICATIONS FOR STEEL-FIBER REINFORCED SHOTCRETE

- Fast and efficient method of tunnel lining (wet-mix).
- Replaces wire mesh in most cases.
- Increases safety.
- Sprayed manually or with a remotely manipulated nozzle (robotic).
- Available for use on either wet-mix or dry-mix shotcrete.
- Suitable for repairs and small works in dry-mix.

Traditionally, conventional excavated tunnels consist of a "double shell" type lining. The initial shell is a FRSC (Fiber-Reinforced Sprayed Concrete) "temporary" lining that stabilizes the opening after excavation and contains short- to medium-term loads. Following installation of a waterproofing membrane, a traditionally reinforced final cast in-place concrete lining is installed to contain long-term loads and provide durability. Thanks to advancements in shotcrete and steel fiber technology, a SFRPSCL (Steel Fiber-Reinforced Permanent Spray Concrete Lining) system that is a "single shell" of sprayed concrete is attainable.

> "You can count on Bekaert for support along each step of your project – from concept design to on-site quality support."

The advantages expected from the development of SFRPSCL as a permanent lining are many:

- Environmental Impact: Reduction of CO_2 by reducing the steel weight vs. rebar.
- Reduction of CO_2: A thinner lining uses less concrete; plus a more durable lining means a longer service life.
- Cost Reduction / Performance: Reduction in weight of steel required plus no separate installation cost.
- No Formwork Required: Less labor, less forming materials, and a quicker build time.
- Quality and Safety: Achieved using the right product for the right use, specifying clear performance requirements and appropriate testing methods.

You can count on Bekaert for support along each step of your project—from concept design to on-site quality support. Our services include recommendations on design, construction detailing, concrete optimization, and automatic total quality control procedures. We are also happy to share our knowledge with you and your team. Feel free to request a workshop or training on the topic of steel fiber reinforcement for your offices.

CONTACT INFORMATION:

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Fig. 3: Edouard Montpetit (EMP) Station Cavern. Photo courtesy of AECOM.

Fig. 4: Edouard Montpetit (EMP) Station. Photo courtesy of AECOM.

PROJECT PROFILE: ÉDOUARD-MONTPETIT STATION (EMP) – MONTREAL, QC, CANADA

Once completed at the end of 2024, the Réseau Express Métropolitain (REM) will be the 4th largest automated transportation system in the world! The project includes 3 underground stations in downtown Montreal. One of the underground stations, Edouard Montpetit (EMP) Station, will be the deepest station in Canada when complete. The EMP Station is built within the existing double track Mont Royal Tunnel (MRT). The side platforms are built by enlarging the existing tunnel. Using the NATM method of excavation, the EMP Station utilizes permanent rock bolts and shotcrete reinforced with steel fibers for both the initial and the final linings of the station structures (tunnels, shafts, caverns, etc.). First, a 2 in. (50 mm) layer of steel-fiber shotcrete is applied as initial support and safety; then, rock bolts are installed, followed by a sprayed-applied waterproofing membrane, and then another 2 in. (50 mm) of steel-fiber-reinforced shotcrete is applied. The liner is designed for a 125-year service life.

SHINE A LIGHT ON YOUR BUSINESS! ADVERTISE IN *SHOTCRETE* MAGAZINE

Are you seeking a powerful strategy to boost the growth of your business? Consider channeling your marketing budget into advertising within ASA's *Shotcrete* magazine. Distinguished as the sole global publication entirely dedicated to the shotcrete industry, *Shotcrete* magazine is your gateway to a vast and diverse audience. Our magazine comprehensively explores every facet of the shotcrete market, showcasing the latest advances and achievements in this dynamic field. We take pride in recognizing remarkable projects, delivering in-depth reports on cutting-edge shotcrete research, and presenting enlightening articles that epitomize the pinnacle of shotcrete placement practices. With each issue, *Shotcrete* magazine reaches an extensive readership, encompassing over 17,000 subscribers spanning across more than 100 countries. Elevate your business by connecting with a global audience of industry professionals through our magazine today.

Themes for the remainder of 2024 include:

- Q2 2024 – Infrastructure
- Q3 2024 – Tunnels/Mining
- Q4 2024 – Why Shotcrete?

Look for the 2024 *Shotcrete* magazine media kit online at **www.shotcrete.org/mediakit**. For more information, rates, and deadlines, contact Tosha Holden, ASA Member Engagement and Marketing Manager, at tosha.holden@shotcrete.org or 248.983.1712.

SUBMIT A NOMINATION FOR "SHOTCRETER SPOTLIGHT"

Shotcrete magazine has a new column, "Shotcreter Spotlight," where we want you to sing the praises of the people within your organization who are making a difference. We have three categories for you to nominate someone in:

- **Nozzlemen & Field Crews**—nozzlemen, field teams, and crews.
- **Support Staff**—office staff, mechanics, shop employees, etc.
- **Women in Shotcrete**—a woman who is making her mark on the shotcrete industry in big or small ways.

Use this Google form to nominate someone: **https://forms.gle/bBrNY8xJfyPqQiyq5**

Read more about the new "Shotcreter Spotlight" in the Q4 2023 issue of *Shotcrete* magazine, linked on page 54.

Please reach out to Cindy Spires, Managing Editor, at cindy.spires@shotcrete.org if you have any questions.

SHOTCRETE CALENDAR

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

MARCH 11 - 13, 2024	**Shotcrete Nozzleman Certification** Concrete Pumping Association of Australia | Melbourne, Australia
MARCH 18, 2024	**Recognizing Quality Shotcrete** ACI Mid-Atlantic Resource Center | Columbia, MD
MARCH 24 - 28, 2024	**ACI 2024 Concrete Convention** Hyatt Regency New Orleans | New Orleans, LA
MARCH 28, 2024	**Quality Shotcrete for Pools – Know It When You See It** Western Pool and Spa Show | Long Beach, CA
APRIL 10 - 12, 2024	**ACI Shotcrete Nozzleman Certification (Wet & Dry-Mix)** Minova | Millstadt, IL
APRIL 17, 2024	**Recognizing Quality Shotcrete** ACI SoCal Resource Center | San Bernardino, CA
APRIL 22 - 24, 2024	**2024 ICRI Spring Convention** The Westin Copley Place, Boston | Boston, MA
MAY 3 - 5, 2024	**ACI Shotcrete Nozzleman Certification (Wet & Dry-Mix)** Applied Shotcrete | Sebastopol, CA
JUNE 9, 2024	**ASTM Workshop on Next Generation Cements and SCMs: Towards Specification** Philadelphia Marriott Downtown | Philadelphia, PA
JUNE 9 - 12, 2024	**ASTM Committee Meetings – C09 Concrete and Concrete Aggregates** Philadelphia Marriott Downtown | Philadelphia, PA
JUNE 23 - 26, 2024	**North American Tunneling Conference (NAT 2024)** Nashville, TN
SEPTEMBER 23, 2024	**Recognizing Quality Shotcrete** ACI Mid-Atlantic Resource Center | Columbia, MD
OCTOBER 3, 2024	**Recognizing Quality Shotcrete** ACI SoCal Resource Center | San Bernardino, CA
OCTOBER 24, 2024	**Recognizing Quality Shotcrete** ACI MidWest Resource Center | Elk Grove Village, IL
NOVEMBER 2, 2024	**ASA 2024 Fall Committee Meetings** Location TBD | Philadelphia, PA
NOVEMBER 3 - 7, 2024	**ACI 2024 Fall Concrete Convention** Philadelphia Marriott Downtown | Philadelphia, PA
NOVEMBER 1 2 - 14, 2024	**International Pool | Spa | Patio Expo 2024** Kay Bailey Hutchison Convention Center | Dallas, TX
DECEMBER 8 - 11, 2024	**ASTM Committee Meetings – C09 Concrete and Concrete Aggregates** Philadelphia Marriott Downtown | Philadelphia, PA
JANUARY 21 - 23, 2025	**2025 World of Concrete** Las Vegas Convention Center | Las Vegas, NV
MARCH 9 - 11, 2025	**2025 Shotcrete Convention & Technology Conference** The DeSoto | Savannah, GA
MORE INFORMATION	To see a full list, current updates, and active links to each event, visit www.shotcrete.org/calendar.

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