shotcrete MAGAZINE

A quarterly publication of the
American Shotcrete Association

VOLUME 26, NUMBER 3 • 3RD QUARTER | 2024

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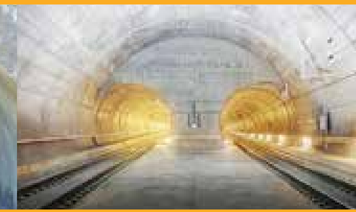

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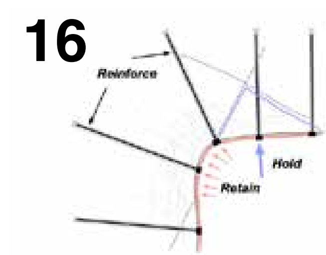
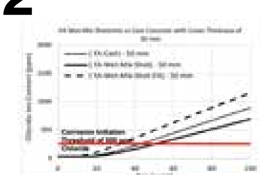
Volume 26, Number 3 • 3rd Quarter | 2024

FEATURES





DEPARTMENTS

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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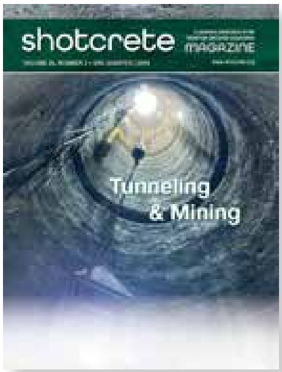

Ventilation shaft from the excavation pit of a long road tunnel in the southern German Alps with an 18 ft (5.5 m) diameter and 279 ft (85 m) depth. Noted in "The Application of Shotcrete in Shafts", Pg. 10.

Hey

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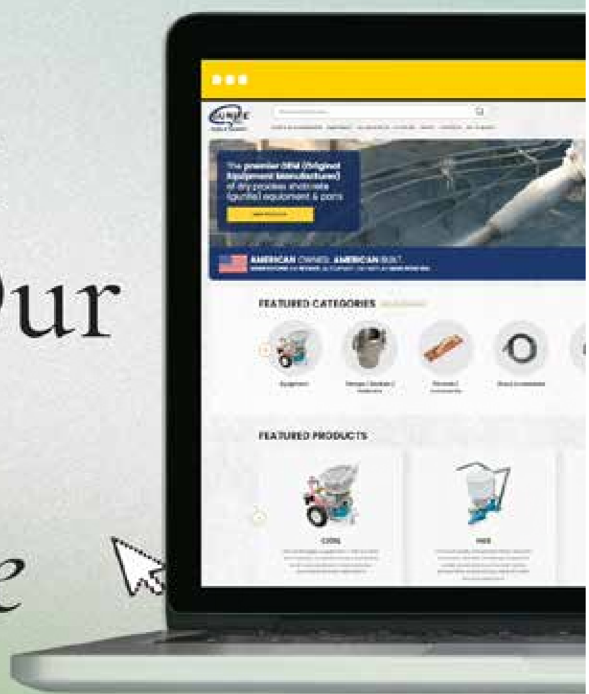

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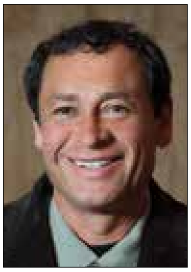
An Open Letter to the Future Leaders of the ASA

By Oscar Duckworth, F.ACI



Like many of you, I began my career within a timeframe when shotcrete was practically unknown. Shotcrete, and my business model, were disruptive innovations to the established methodology for concrete construction in my region.

And if you look at history, disruptors never have an easy path.

Shotcrete was not the established method in the concrete industry. Specifiers wanted cast concrete, not some new and unknown material — so every job had to be built upon human relationships. We looked them in the eyes, promoting shotcrete to those who didn't believe it could work. We made commitments. Shook hands. Pressed flesh. Gave away valuable time. And occasionally failed.

It was a time when the shotcrete process needed credibility and had none.

And it is the American Shotcrete Association (ASA) and its past leaders who have forever changed that.

The Association's early leaders shared a common thread. Like you and I, they were disruptors. They faced the challenge of promoting and using a process that was different from the established methodology, and like many of us, they were a passionate group of contributing members striving for one common goal: To establish the disruptive innovation of shotcrete as a worthy competitor for form-and-pour concrete.

Their tireless work achieved the credibility for the shotcrete process that we all benefit from today — *and I cannot adequately describe the impact that my involvement with the ASA has had on me.*

My initial expectations upon joining the Association were nothing compared to the incredible level of personal and financial growth that I have experienced. I have met and interacted with so many like-minded people with common goals and similar life experiences, witnessing what is possible when a like-minded group encourages each other toward excellence through small but constant steps.

It has been an honor to have my name added to that list of leaders who came before me — those who believed what was possible with shotcrete and put forth the effort necessary to enact change. Leaders who took a moment to see potential in me, and encouraged me to press on and choose to step into that fray. It is a special honor that in this issue, we take a moment to chat with one of those leaders, Merlyn Isaak. You'll find his story on page 40.

It's said that concrete is the world's most important construction commodity, and that how we use concrete can be identified as the component that separates the industrialized world from the third world. Because of the ASA and the efforts of the disruptive leaders who came before me, the shotcrete process now plays a significant part in this most essential Industry.

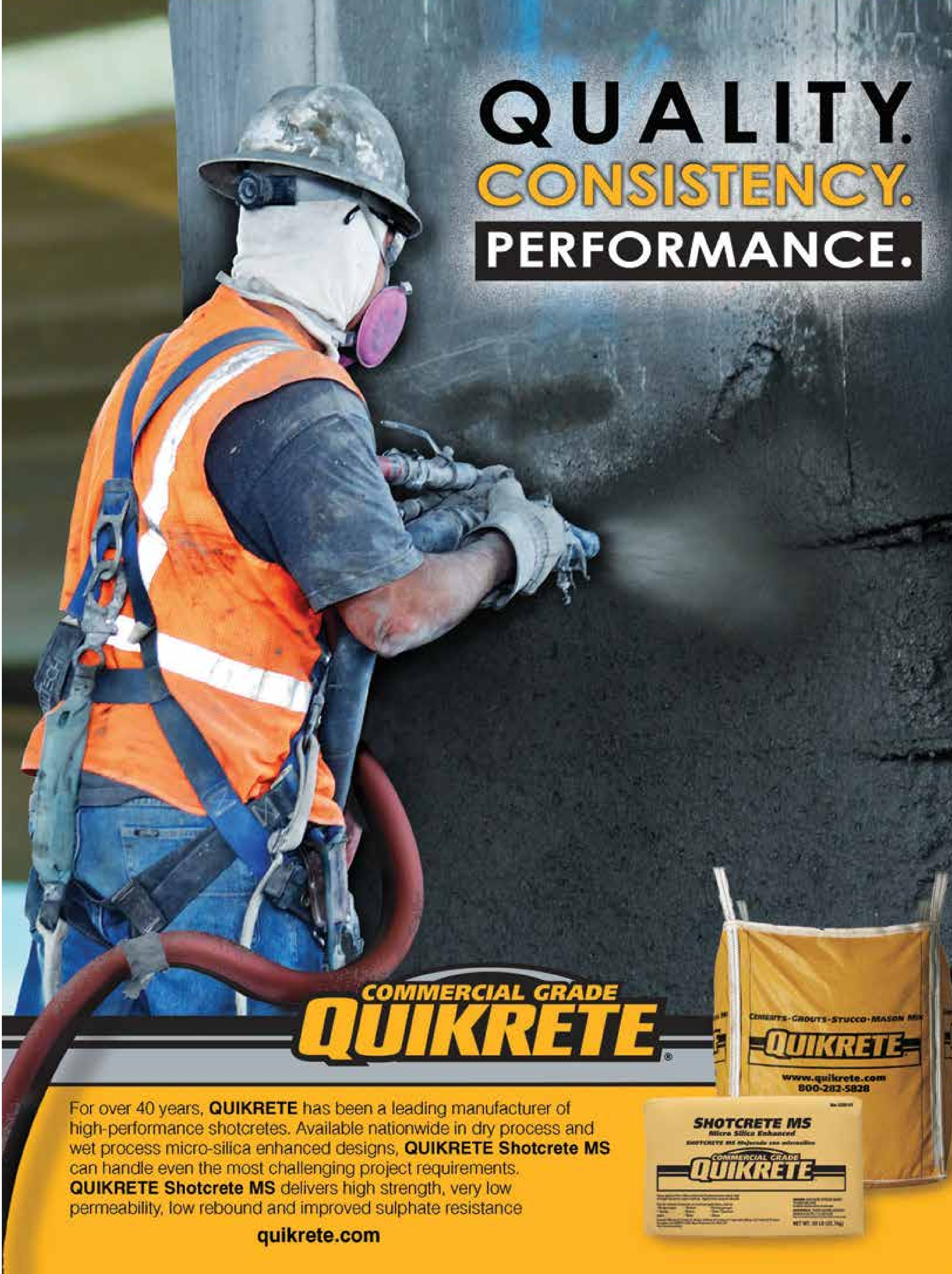
Disruptive innovation plays a leading role in who will, and will not, be the next players in any industry — and the future changes of this industry will bring great personal and financial growth to those leaders who can adapt to change and master the craft's many variables. The future will introduce us to the Association's next disruptive leaders.

You know who you are. You are disruptors. You are displacing established market leaders and alliances. Every job is built upon human relationships; by looking people in the eyes and promoting shotcrete to those who don't believe it could work. Make commitments. Shake hands. Press flesh. Give away valuable time. And occasionally, fail.

To you, the new and future leaders of the ASA: Step up. It is your turn to be added to that list of disruptors who put forth the effort necessary to enact change.

Change is hard. Change is a god that is ever working, never stopping, and affects everyone and everything — and it has been an intense pleasure to be a part of it. Pass on the torch!

Disruptive innovation:
An innovation that creates a new market and value network and eventually disrupts an existing market and value network, displacing established market leaders and alliances. This term was defined — and phenomenon analyzed — by Clayton M. Christensen beginning in 1995.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Underground, But Not Dormant!

By Christoph Goss, PhD, PE, PMP, F.ASCE

The mining and tunneling industry was an early adopter of shotcrete placement because the concrete could stick overhead, adapt to the shape of the excavation, and keep small rock blocks or sheared material from falling out. As you can see from the articles, the underground industry continues to use shotcrete as primary — and sometimes permanent — ground support. ASA's Underground Committee is actively working to produce position papers and address concerns that challenge shotcrete placement in this market sector. Here's a taste of what's in the works.

Since underground shotcrete is used for ground control (i.e., to keep the tunnel from caving in), making it gain strength quickly and knowing what that strength is are both critically important. Hence, the ASA Underground Committee is developing Position Statement #5: "Very Early Strength Shotcrete Testing in Underground Construction". This statement will be an update of the excellent paper "Early-Age Test Methods for Fiber Reinforced Shotcrete" by Stefan Bernard, published in the Spring 2005 issue of Shotcrete Magazine, and will consider strength requirements for entry after shooting shotcrete. It will also evaluate the popularity and appropriate use of specific testing methods, including the soil penetrometer, Schmidt hammer, Meynadier or Meyco Needle Penetrometer, end beam tester, old and new Hilti Gun, and temperature sensors. If you have experience (good or bad) with any of these methods and would like to share your thoughts, please contact me at **cgoss@schnabel-eng.com**.

Associated with this interest in early strength gain and testing is the sudden dominance of portland limestone (Type 1L) cement in the market. One of the main ways it differs from regular portland cement is that it contains 5-15% inert limestone powder. This variability of the limestone filler has caused problems underground, as a 5% limestone mixture will require a different accelerator dosage and will have a different strength gain than a 15% limestone mixture. On some projects, the mixtures vary daily or weekly, making it difficult to get consistent results. When the question you are trying to answer is "Can I safely enter?", inconsistency is not just irritating but outright dangerous.

Given the need to apply shotcrete overhead in a safe and effective manner, the committee is also addressing remotely manipulated nozzle placement. In fact, that is the topic of ASA Position Paper #4. The biggest news there is that ACI is in the process of approving a remotely manipulated shotcreter certification similar to the popular ACI Shotcreter Certification program for predominantly hand nozzling. The Job Task Analysis has been submitted to ACI's Certification Programs Committee (CPC) for approval. Hopefully this certification will launch soon.

If any of these topics sound interesting to you, please contact me or **info@shotcrete.org** to get involved with the ASA Underground Committee. We would love to have you join us.

UNDERGROUND COMMITTEE

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Jake Wiseman, Secretary | Wiseman Shotcrete

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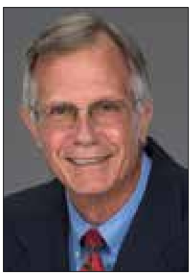
Frank Townsend | Patriot Shotcrete & Constructors
Marcus von der Hofen | Coastal Gunite Construction Company

Welcome to the Shotcrete Portal!

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



An important aspect of our updated strategic plan included significant updates to **shotcrete.org**. Despite the wealth of content on our old site, it was challenging to find information easily. Often one had to click down through multiple levels to get to the information.

In mid-2023, we contracted with our association management firm, Virtual Inc., to develop a totally new website. We not only wanted a modern, clean-looking, image heavy website, but needed it to be mobile friendly. After many months with our ASA staff working closely with the web development team, we finally had a final product in mid-2024.

One fundamental concept was to have our information accessible in segments or portals. These portals would compartmentalize the shotcrete resources and minimize the "clicks" to get to relevant information: You have direct access to each portal using the sub-domains listed after the portals named below.

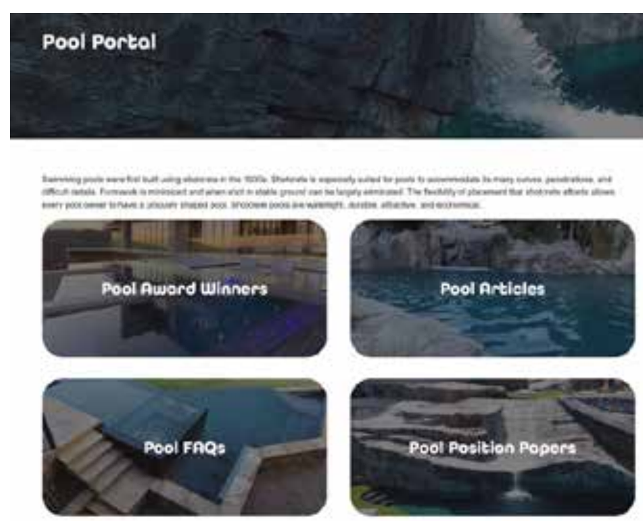
THE PORTALS INCLUDED THESE APPLICATION AREAS:

- Pools (**pools.shotcrete.org**)
- Repair (**repair.shotcrete.org**)
- Architectural (**architectural.shotcrete.org**)
- Underground (**underground.shotcrete.org**)
- Structural (**structural.shotcrete.org**)
- International (**international.shotcrete.org**)
- Recreational (**recreational.shotcrete.org**)

WE ALSO HAVE PORTALS FOR OUR PROGRAMS:

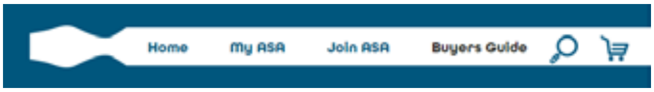
- Certification and Qualification (**certification.shotcrete.org**)
- Awards (**awards.shotcrete.org**)
- ASA Conventions (**shotcrete.org/conventions**)
- World of Concrete (**shotcrete.org/asa-at-world-of-concrete**)

Clicking on an application portal will show buttons for Award Winners, Articles, FAQs and Position Statements that are filtered to that application. For example, here's a look at the Pool Portal.



The program portals similarly give you information on those specific programs or events. Here's an example of the Certification & Qualification subpage.

BUT THERE'S EVEN MORE! EVERY PAGE HAS THE SAME TOP BAR, INCLUDING:



- **My ASA:** A direct link for members to sign into our communities
- **Join ASA:** An informational page about membership with an online application and list of sustaining corporate members
- **Buyers Guide:** Opens our Buyers Guide page with a search field to show a detailed listing of the products and services offered by our Corporate Members
- **Search:** Searches the entire website for keywords matching your query
- **Shopping Cart:** For access to the shopping cart after using our bookstore

UNDER THE TOP BAR WE HAVE A PERSISTENT MENU BAR, INCLUDING THE FOLLOWING:

ABOUT SHOTCRETE

- **Awards:** Link to the Awards portal
- **FAQs:** Opens our FAQ search; all technical inquiries from past Shotcrete magazines can be searched by keyword and application type
- **Resources:** A variety of shotcrete resources including ASA position statements, specification guidance, web sessions, conference proceedings, corporate member website resources, industry resources
- **Bookstore:** ASA shotcrete brochures, ACI documents, ASA safety guidelines — even hard hat stickers and baseball caps
- **Submit Your Project for Bid:** An online form for companies or agencies to submit an upcoming shotcrete project. The information is reviewed and then sent to all corporate members.

CERTIFICATION & QUALIFICATION

- **Shotcreter:** Information for our shotcreter (formerly called nozzleman) certification sessions
- **Shotcrete Inspector:** Information for our shotcrete inspector educational programs
- **Contractor Qualification:** Information about our ASA Qualified Shotcrete Contractor program

EVENTS & EDUCATION

- **Calendar:** With calendar and list layout options
- **News:** A link to current and past What's in the Mix eNewsletters
- **ASA at World of Concrete:** A link to our World of Concrete portal
- **Upcoming Conventions:** A link to the ASA Conventions portal

SHOTCRETE MAGAZINE

- **Current Issue:** With a link to download the full magazine PDF
- **Past Issues:** Listed by year and with a keyword search, all with links to full magazine PDFs
- **Advertise:** Info for advertising in Shotcrete magazine
- **Articles Search:** A search box to find past individual articles by keyword
- **Become an Author:** Info for those wanting to write articles for Shotcrete magazine

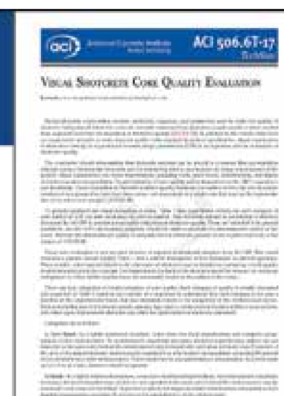
ASA

- **ASA Committees:** Listing of all committees and their current chairs
- **Strategic Plan:** A PDF with our current strategic plan
- **About ASA:** A brief overview of who we are
- **Contact Us:** Staff listing with contact emails and phone, plus an Inquiry Form

APPLICATION PORTALS

- Shortcuts to the individual application portals available on the home page

Whew! That's a lot of information about our website. Feel free to recommend **Shotcrete.org** to anyone who asks you for shotcrete information. Further, if you want to send someone to an application portal, just remember you can use our shortcuts like pools.shotcrete.org or repair.shotcrete.org. These shortcuts are easy to drop into a social media or forum post and send the reader directly to the information they need. Take the site for a spin! We appreciate any feedback you may have: Feel free to email me at Charles.Hanskat@Shotcrete.org.



The Application of Shotcrete in Shafts

WORK PREPARATION AND CONSTRUCTION BASED ON VARIOUS PROJECTS IN CENTRAL EUROPE

By Paul von der Hoeh, Norbert Fuegenschuh, Richard Gradnik

The construction of all kinds of shotcrete shafts is recently very popular in Central Europe. Shafts are needed in combination with infrastructure projects, power plants, and energy and water distribution and treatment. A few of the specific uses of shafts include: ventilation, emergency evacuation, surge chambers, water transport, and pipe jacking or drop shafts in waste water handling.

Shotcrete placement in shafts requires precise work preparation and a well thought-through choice of spraying method to ensure an optimized construction process. This process and the final execution are illustrated below through several different case studies.

SHOTCRETE PLACEMENT

Depending on diameter and depth of the shaft, shotcrete gets applied either manually or by remotely manipulated nozzling equipment. Three different types of shotcreting methods are commonly used to support the excavated rock or soil surface: Dry-mix, semi-dry, and wet-mix shotcrete. Each of these methods has certain characteristics and needs to be selected based on the specific circumstances and conditions of the project at hand.

DRY-MIX SHOTCRETE

One decisive advantage of dry-mix shotcrete is the small equipment footprint on the construction site compared to the other methods. Particularly in densely populated urban areas and steep mountainous locations, storage of oven-dry shotcrete material in tower silos can avoid the constant traveling of concrete delivery vehicles and can be filled in large batches.

The process is particularly advantageous for narrow shafts and, in general, projects where only small and unpredictable quantities are used or where the use of ready-mix delivered concrete is not economical. Normally, spraying rates of up to 5 yd^3/hr (4 m^3/hr) are achieved. To reduce dust formation and rebound, it is absolutely necessary to use a pre-dampening unit.

SEMI-DRY SHOTCRETE

Semi-dry shotcrete is a variant that is rarely used today, although it has some significant advantages. The concrete itself has a similar composition to wet sprayed concrete, but the concrete materials are only partially wetted (similar to moisture levels we would see in our aggregate sources of 3 to 5%) and has water added at the nozzle during the spraying process. Essentially, this also makes sense for narrower shafts, as high spraying rates cannot be achieved here either (up to 8 yd^3 /hr or 6 m^3/hr) — depending on the size of the pump). Two of the major advantages over dry-mix shotcrete are the lower rebound factor and the significantly lower dust generation. Further, it is particularly suitable for use if a mixing plant is available on site, as it can be easily produced.

WET-MIX SHOTCRETE

In contrast to the previous variants, wet-mix shotcrete is mainly sprayed by a mechanical system of nozzle manipulation, and significantly higher spraying rates (up to 33 yd^3/hr or 25 m^3/hr) can be achieved. Dust formation and rebound can also be significantly reduced when compared to the dry processes. Due to the working space of the spraying manipulator and the cost-effectiveness of larger volumes of concrete, the use of this method usually only makes sense for larger shaft diameters.

CASE HISTORIES

18 FT (5.5 M) DIAMETER AND 279 FT (85 M) DEPTH

PROJECT DESCRIPTION

A good example of the use of shotcrete in deep and narrow shafts is the ventilation shaft of a 2.2 mi (3.6 km) long road tunnel in the southern German Alps. The single-tube road tunnel with a parallel rescue tunnel is ventilated via a false ceiling and a connected ventilation cavern. The exhaust air is then extracted out of the cavern into the open air via the ventilation shaft. The shaft itself was sunk from the surface to a depth of 279 ft (85 m) using an excavator and blasting with an excavation diameter of 18 ft (5.5 m). The site staging area for the shaft was located about 328 ft (100 m) higher than the north portal of the main tunnel on the mountainside and could be reached via a 1,640 ft (500 m) long temporary access road. Depending on the geological conditions, between 6 and 12 in. (150 to 300 mm) of shotcrete support with mostly single-layer welded wire fabric (WWF) reinforcement was applied. This is equivalent to an area of almost 16,000 ft^2 (1,500 m^2).

SELECTION OF THE SPRAYING METHOD

Due to the very cramped location, the decision was made to apply a semi-dry shotcrete manually. This was mainly due to the small quantities required for the individual work steps (usually less than 4 yd^3 [3 m^3]), which meant that the concrete mixer's delivery of about 9 yd^3 (7 m^3) could be produced over several hours. Another decisive factor was the possibility of having shotcrete on site ready-for-use while the excavation was going on. The difficult and potentially quickly changing ground and groundwater conditions required shotcreters to be able to apply shotcrete on short notice.

CONSTRUCTION WORKS

Work began in mid-2020 with the construction of a 20 ft (6 m) deep pre-cut with soil nail supported shotcrete and the site staging area. The uppermost 184 ft (56 m) were excavated with advance support using metal sheet piles, while the section below 184 ft (56 m) was completely

Fig.1: ventilation shaft from the excavation pit

excavated by drill and blast. Therefore, a 3.5-ton mini-excavator was selected which could be equipped with a drill attachment and hydraulic hammer. Due to the required rope length and flexibility, a 130-ton (118 tonnes) telescopic crawler crane (manufactured by Sennebogen) was used for the vertical lifts in and out of the shaft.

The concrete was produced in the site's mixing plant, located at the portal of the main tunnel, approximately 1.2 mi (2 km) from the shaft site, and temporarily stored on the site in a concrete handling hopper. An Aliva 262 rotary dry-mix shotcrete gun was used as the spraying device, which was supplied with compressed air from an Atlas Copco GA75 compressor.

To transport the concrete, a steel pipe (2 in. (50 mm) diameter) was attached to the wall. Particular attention was paid to adequate fastening, as the heavy weight of concrete and pipe over 279 ft (85 m) posed a serious risk to personnel. The supply lines were extended at regular intervals, usually every 16.5 ft (5 m).

The shotcrete was delivered by the electric rotary gun positioned at the surface with compressed air through the steel pipe to the nozzle. Water and accelerator were then added by the shotcreter in the shaft. The rate at which the accelerator was added was approximately 5-8% to achieve the required early strength development curve of J3 (see Austrian Guideline for shotcrete [1] and European Standard [2]). Warm water was used to kick-start the hydration process during the cold winter weather.

Fig.2: Feeding the Alivia-Pump with shotcrete

The use of semi-dry shotcrete also offered occupational safety and economic advantages, since the amount of dust and rebound is significantly reduced compared to dry-mix shotcrete. Employees were equipped with powered air purifying respirators and a ventilation concept was designed to suit the conditions. The mandatory communication between gunman and shotcreter was ensured by radio.

The average spraying rates achieved were 2 to 2.6 yd^3 (1.5 to 2 m^3) per hour (incl. set-up time).

Fig.3: Shotcrete application inside the shaft

THICKNESS CONTROL

A comparison of the delivered and installed shotcrete quantities was carried out as part of the post-construction evaluation process of the shaft excavation. The quantities delivered were evaluated with the help of the batch plant delivery slips. The installed quantities were established using laser scanner images. Determining the difference between the scan of the finished shotcrete surface and the scan of the excavated ground confirmed that approximately 30% of additional shotcrete was needed to fill overexcavation. This in addition to approximately 20% of rebound.

16.4 FT (8.8 M) DIAMETER AND 98 FT (30 M) DEPTH

PROJECT DESCRIPTION

The rescue shaft of the Füllbach tunnel, a single-track railroad tunnel near Coburg in Germany, has a depth of 100 ft (30 m) and serves as an escape route from the 0.7 mi (1.1 km) long main tunnel. With an excavation diameter of just under 30 ft (9 m), the available space allowed the use of more powerful machines. The excavation here was carried out entirely by drill and blast with subsequent shotcrete support. The primary lining consisted of a two-layer shotcrete shell with a thickness of 7.9 in. (200 mm) and a double-layer of WWF reinforcement. The total shotcrete surface area was approximately 9,000 ft^2 (815 m^2).

SELECTION OF THE SPRAYING METHOD

This meant that 18 yd^3 (14 m^3) of shotcrete were required per excavation round of 4.5 ft (1.3 m), which was batched by the site's on-site batch plant and delivered to the shaft location by regular concrete delivery trucks. Due to the high quantity required per excavation round and the relatively large shaft diameter, the decision was made to use remotely manipulated nozzles for shotcrete placement.

CONSTRUCTION WORKS

Once the site staging area was set up and the shaft head ring constructed, the shaft sinking could begin. A single-boom drilling rig was used for the necessary drilling work. The rig and muck boxes were lifted in and out with the help of a 60-ton (54 tonne) mobile crane. The loosened material was excavated using an 8-ton (7 tonne) compact excavator. For the shotcrete application, a Normet AL-503 spraying manipulator was used, which is characterized by its compact design and long reach of up to 26 ft (8 m). The concrete was supplied using a Sika-PM702 concrete pump. The rapid-set accelerator and compressed air were added at the nozzle. With the system used, spraying rates of up to 20 yd^3 (15 m^3) per hour could be achieved.

Fig.4: Normet spraying manipulator in action

42 SHAFTS WITH 11.2 FT (3.4 M) DIAMETER

PROJECT DESCRIPTION

Due to ongoing problems with wastewater drainage during heavy rainfall events, a new collector sewer is currently being driven under the city of Vienna, Austria. The existing sewer, which is too small, discharges wastewater into the Wien River during storm induced overflows, causing serious environmental problems in Austria's capital. The construction of the new Wiental collector sewer has a total length of 5.4 mi (8.6 km) with a diameter of 11.8 ft (3.60 m) and will be excavated entirely by a tunnel boring machine (TBM). To connect the adjacent existing sewers and provide access and rescue options, a total of 52 shafts will be constructed along the course of the sewer. 42 of these shafts will be excavated using sequential excavation method (SEM) type shaft construction in soft ground with shotcrete support. Depending on the geological conditions, soil improvement is carried out at some shaft locations using jet grouting. The shafts themselves have a very small excavation diameter of just under 11.5 ft (3.5 m) and are up to 69 ft (21 m) deep. The primary lining is carried out with a shotcrete shell up to 12 in. (300 mm) thick and one to two layers of WWF reinforcement. A total of 75,000 ft^2 (7,000 m^2) of shotcrete will be installed. After completion, each shaft will have a 12-in-thick (300 mm) final lining and the respective interior installations such as sewer connection pipes and access ladders.

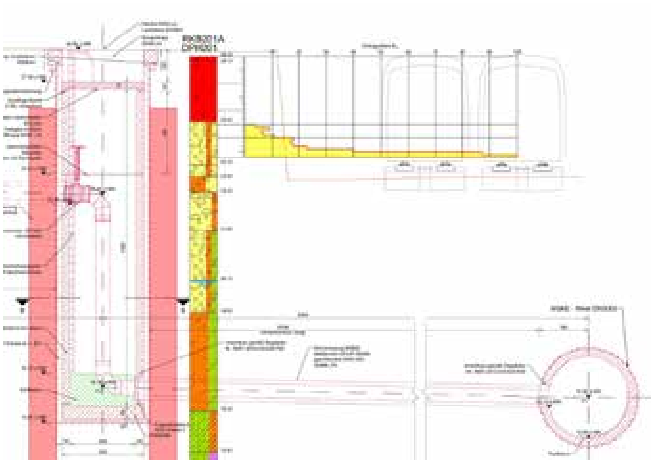


Fig.5: Section through the transfer shaft with connection to the collector sewer

CURRENT STATUS OF WORK PREPARATION

With construction starting in April 2024, work is currently concentrating on the construction of the TBM launch pit and work preparation for the construction project. Initial considerations have already been made regarding the excavation of the shafts. Excavation is planned to be carried out using an excavator positioned at the surface equipped with a telescopic boom and hydraulic grab bucket. Corrective excavation works at the bottom of the shaft will be done using a mini excavator. A mobile crane will be used for logistics and to lift equipment in and out. For schedule purposes, a total of three equipment sets will be necessary to be able to work at several shafts concurrently. Starting with one shaft at a time in the initial phase, it is planned to construct three shafts simultaneously during later stages.

SELECTION OF THE SPRAYING METHOD

What is both interesting and challenging about this project is the large number of similar shafts with very small excavation diameters. Furthermore, the size of the individual site staging areas is very limited due to the inner-city location and little room to maneuver. With a required shotcrete quantity of less than 4 yd^3 (3 m^3) per excavation round and the difficult access situations, there is still discussion as to whether dry-mix or wet-mix shotcrete will be used.

Due to the nearby residential buildings and busy roads, one of the biggest concerns is the potentially large amount of dust generated during dry-mix shotcreting. On the other hand, wet shotcreting is not the most economical solution due to the small quantities required and the limited space available. Furthermore, wet-mix shotcrete has to be delivered by a ready-mix delivery vehicle every time, whereas oven-dry shotcrete materials can be stored in large silos on site and is available at all times. The final decision will be made as part of the spraying tests at the first shaft. During this time, the machine concept will also be further optimized.

Special attention will be paid to the relocation of the construction site equipment, as a lot of working time can be saved here due to the numerous relocation processes from one excavated shaft to the next.

Due to the very cramped working conditions in the shaft with only 12 ft (3.6 m) diameter, the shotcrete will be applied manually. Therefore an electric Aliva rotary gun (e.g. Aliva 262) will likely be used, which transports the shotcrete through the delivery hose pneumatically. The advantage of this system is that it can be used for both dry and wet shotcreting.

CONCLUSION

Shotcrete shafts often present unique challenges for construction projects. In many cases the construction method is different from the one used in the main tunnel (often using a TBM), presenting challenges recruiting experienced and certified personnel for the shaft works. Surface conditions at shaft locations are often tight, presenting challenges not only for material supply, muck discharge, and equipment movements, but also with regard to environmental issues like dust and noise control. Project representatives need to pay particular attention to these special circumstances early on, to be able to cope with these challenges.

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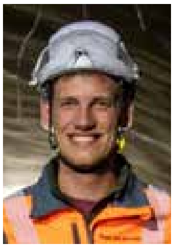

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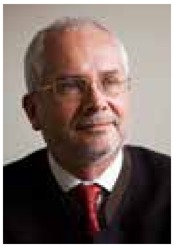

Norbert Fuegenschuh *holds a masters degree in Civil Engineering, University of Technology in Graz, Austria (1989).*

He started working for BEMO Tunnelling in Innsbruck, Austria in February of 1990, is still employed by BEMO and gathered 34+ years of experience in SEM/ NATM tunneling.

After work in the estimation department he started his on-site career filling different positions on construction sites in Germany, among others on the subway system in Munich, two SEM high speed railway tunnels between Frankfurt and Cologne and the Egge-Tunnel near Kassel in the North of Germany.

In 2001 he became the Tunnel Manager on the Russia Wharf Tunnel in Boston, MA (MBTA Silverline subway between South Station and World Trade Center) and spent the time between 2004 and 2011 in Sweden as BeMo`s Area Manager for Scandinavia. Major projects there were Tunnel Troeingeberg, a 1,100 m long high speed railway tunnel in Falkenberg, Sweden and an 8,000 m long sewer tunnel from Lerum to Partille, Sweden – both are drill and blast tunnels with extensive hard rock pre-grouting.

After his move back to the US in 2011 he started working as BEMO`s Area Manager North America and got involved in several high-ranking SEM projects, among others:

- *MUNI China Town Station, Central Subway San Francisco*
- *Cross over cavern on Regional Connector, Metro Los Angeles*
- *Quarters LRT Tunnel in Edmonton, Alberta*
- *John Hart Hydro Power Station in Campbell River, Vancouver Island, BC*
- *Plymouth Tunnel as part of the Purple Line in Silver Spring, Maryland (excavation and shotcrete final lining)*
- *Cross Passages on Purple Line extension Westside 1, Metro Los Angeles*
- *Frozen Ground Adits at 4th Street and Florida Avenue on the North East Boundary CSO Tunnel in Washington, D.C.*
- *McGill South Tunnel rehabilitation, REM in Montréal, Quebec (excavation and shotcrete final lining)*
- *Grand Central/ 42nd Street passageway circulation improvement Tunnel in New York City (excavation and shotcrete final lining)*

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Richard is working with BEMO since August 2016 – as a senior project manager being involved in different projects (Kramertunnel, Herrschaftsbucktunnel, ….) From 2016-2020 he was taking care for the success of BeMo Tunnelling in Germany – in project management for several tunnelling projects as well as in the acquisition process.

Since 2020 Richard has been responsible for the cost estimation and acquisition of tunnelling projects in the D-A-CH region (Germany – D Austria A – Switzerland CH).

The responsibilities are the acquisition of new projects, integration of young engineers in our company; to stay into contact with all stakeholders inside and outside our small tunnelling world. Private: Married, 2 boys (18&17) – interests in enjoying life, travelling and spending time with the family.

Summary of *'Guideline on the Applicability of Fiber-Reinforced Shotcrete for Ground Support in Mines'*

By Rym Msatef and Marc Jolin

Since the early days of industrial mining, one of the biggest challenges has been to reliably support the underground excavations to allow safe access for workers and efficient production. Engineers design support systems based on the surrounding ground conditions, service-life, and the most significant loads. Fiber-reinforced shotcrete (FRS) is an important tool needed to achieve the desired performance. However, ground support engineers often face challenges with properly integrating the properties of shotcreted concrete into the design or navigating the different testing methods and their associated specifications.

This paper is a summary of the *Guideline on the Applicability of Fiber-Reinforced Shotcrete for Ground Support in Mines (see citation at the end of this article)*, which is intended to provide guidance to unlock the full potential of this composite material. The section below presents some of the key points addressed in the guideline.

The use of shotcrete as underground support became common with the introduction of the New Austrian Tunneling Method (NATM) in the 60s[1]. Subsequently, steel fibers were introduced in shotcrete in the early 70s, and their potential in underground support was rapidly identified (Parker, 1974 and Poad et al. 1975 –in ACI PRC-506.1-21)[2].

FIBER-REINFORCED SHOTCRETE

There are many different types of fibers available, each with different properties. Most fibers can be categorized as either macrofibers or microfibers depending on their diameter, and steel fibers or synthetic/polymer fibers. It's important to choose the right type based on the design's need for the surrounding ground: For example, the tensile strength of a steel fiber can go from 350 to 2500 MPa (51,000 to 360,000 psi) and the tensile strength of a macrosynthetic fiber can go from 350 to 650 MPa (51,000 to 94,000 psi).

Their role is to improve the properties of concrete after cracking by (1) controlling the opening of the cracks, (2) absorbing or dissipating energy at the crack location or (3) a combination of both. Simply put, when a crack forms, there is a transfer of the tensile forces from the concrete matrix to the fibers. To have an *efficient load transfer*, three conditions must be satisfied:

1. There must be sufficient transfer surfaces (number, length and diameter of fibers).
2. The nature of the interface between the fiber and the cement matrix must allow for proper load transfer.
3. The properties of the fiber (Young's Modulus, Poisson's ratio, tensile strength, and anchorage mechanism) must allow for force transfer without breakage or excessive deformation.

The *adhesion* and *friction* between the cement matrix and the fibers are important factors for achieving an effective post-cracking response and energy absorption mechanism.

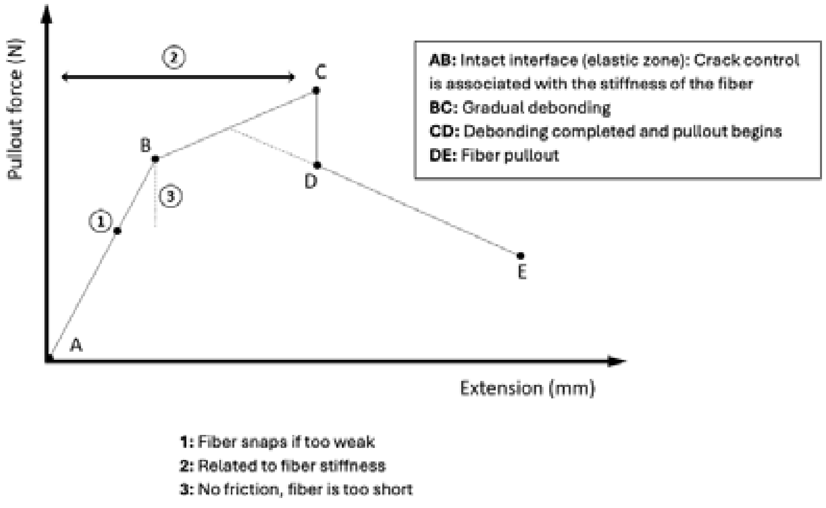

Fig. 1: Ideal pull-out curve of a single fiber (adapted from [3]).

The shape and the texture of the fibers can maximize these effects, but the strength of the cement matrix also has an impact: The *pull-out behavior* of a single fiber is intimately related to the properties of the cement paste around it. A matrix that is too weak may not allow the fibers to reach their full capacity and potential. However, if a matrix is (relatively) too strong and provides too much adhesion and friction, it could cause the fibers to break, which is an undesirable behavior. In fact, it is often better to have a fiber that pulls from the shotcrete rather than one that breaks. Fig. 1 illustrates the idealized pull-out curve of a single fiber.

MINING AND GROUND SUPPORT

The objective of mining operations is to extract and process ore in a profitable and safe manner. Ensuring the safety of workers and equipment is essential, as it is constantly at risk from the instability of the rocks surrounding the underground excavations. Ground support assures this safety, and fiber-reinforced shotcrete often plays a significant role in it.

Several approaches exist for underground excavation and ground support. Thompson, Villaescusa, and Windsor[4] define ground support as a combination of *reinforcement* and *support* systems. A reinforcement system refers to anything integrated into the material surrounding an excavation, such as rock bolts. A support system, on the other hand, refers to anything that is in contact with an excavation face. FRS is classified among the areal support systems, as it is generally used to retain broken rock, similar to wire mesh, and can also be used to hold fractured block.

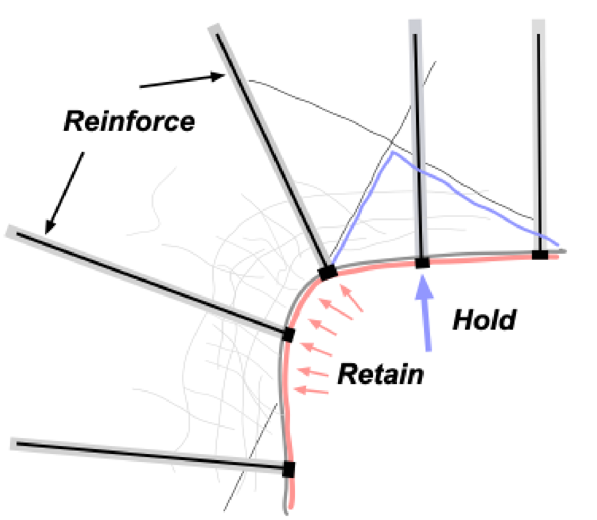

Fig. 2: Visualization of a ground support approach (adapted from Kaiser [5]).

The exact loads and stresses transferred to the FRS are often difficult to exactly predict. It is often a complex combination of stresses, where one area can be in flexure, the next one in shear, or compression, or tension, or a combination!

FRS FOR GROUND SUPPORT

There are several testing methods used in the industry to evaluate the behavior of fiber-reinforced shotcrete. Some methods are better suited for design, while others are more appropriate for quality control. Similar to the choice of fibers, the selection of a test method must be made carefully — the engineer must consider the objectives of the test (design, QA, QC, R&D, etc.) and identify an appropriate test method that will provide meaningful results.

Because the average distance between fibers is usually much smaller than that of reinforcing bars, fibers are mobilized earlier in the cracking process and will greatly influence the crack pattern and its evolution under load. Indeed, fiber reinforcement can change the post-crack response of concrete from brittle to ductile. The biggest improvements are in the tensile strength of concrete. However, testing *post-cracking behavior in pure tension* is experimentally very challenging, which is why most of the test methods presented below focus on evaluating improvements in flexural performance. The stress vs. crack width curves are the most relevant characteristics of FRS in flexural design. These curves represent the true behavior of the material, regardless of the size of the structural member or the loading conditions. Nevertheless, it is crucial to understand that the failure mechanism of FRS is not always purely flexural, as shear and compressive loads are also present.

Multiple tests are presented in the original guideline, their key elements are briefly introduced in Table 1. To gain further insight, the section below explains two of the most commonly used tests in more detail.

ASTM C1550 - STANDARD TEST METHOD FOR FLEXURAL TOUGHNESS OF FIBER REINFORCED CONCRETE (USING CENTRALLY LOADED ROUND PANEL) – A.K.A. "RDP TEST"

The ASTM C1550 test method is an ASTM standard that is used to evaluate the flexural toughness (or energy absorption) of fiber-reinforced concrete (FRC) and particularly FRS[6]. Because the crack pattern is *determinate* (three cracks or the test is deemed invalid), it is possible to determine the post-cracking moment capacity, flexural strength, and therefore the stress-crack width relationship of FRS using yield-line theory[7][8]. The results can be used in several ways; in design regardless of the specific loading conditions, the energy absorption in the Q-system design method[8], and in quality control of FRS.

EXECUTION AND RESULTS

In this test, an FRS round panel specimen is loaded in its center with a rounded steel head and supported on three articulated points placed 120° apart on the perimeter (Fig. 3). The central deflection is measured to produce a load-deflection curve (Fig. 4) that represents the post-cracking flexural behavior. The values of energy absorption are typically reported at central deflections of 5, 10, 20, and 40 mm (0.2, 0.4, 0.8 and 1.6 in.). Depending on the type of application (for ex.: slab vs. deep mining tunnel face), the order of magnitude for the energy absorption at 40 mm deflection is typically ranges between 300-1000 Joules.

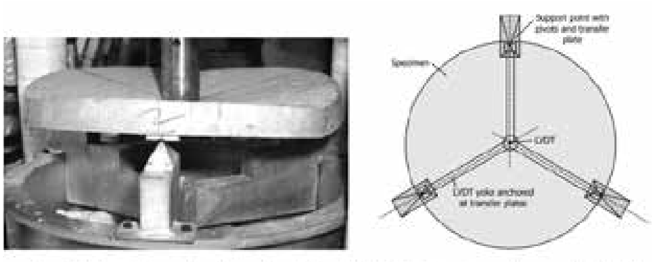

Fig. 3: Illustration and schematics of the ASTM C1550 test specimen under load (from [6]).

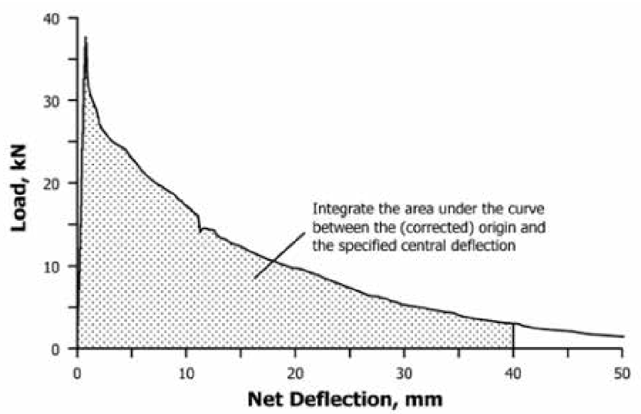

Fig. 4: Example of a Load-Deflection curve in an ASTM C1550 test; the area under the curve — or energy absorption — at 40 mm central deflection is represented by the shaded area (from [6]).

ENGINEERING VALUE

It is possible to calculate the stress-crack width relationship in an inverse analysis from this test method. These parameters can eventually be used to determine the bearing capacity and energy absorption of the deformed lining. The maximum crack width in this test is somewhat closer to what can be observed in mines compared to other tests. Indeed, on a 1.5 m (5 ft) span between rock bolts, the equivalent out of plane displacement could be almost 140 mm (5.5 in.) for the same approximated crack rotation. This test has the advantage of giving a lower variability in the results and the material behavior can easily be analysed from the results.

EN 14488-5 TESTING SPRAYED CONCRETE – PART 5: DETERMINATION OF ENERGY ABSORPTION CAPACITY OF FIBER REINFORCED SLAB SPECIMENS – A.K.A. "EUROPEAN PLATE TEST"

The EN 14488-5 test method is a European standard meant for the determination of the energy absorption capacity of FRS[10]. This test is used in the ground support design method Q-system[11] and for quality control of FRS.

This test allows for stress/load redistribution in the panel. Therefore, the number of cracks and their pattern can vary from one test to another. While this makes the strict interpretation of the results difficult, it also enables the FRS to better express its true behavior. Indeed, it has been shown that a specimen will evolve from a pure shear failure to a combined shear/flexural failure as the fiber content increases[12].

EXECUTION

In this procedure, a FRS square slab specimen is loaded in its center with a square steel head and continuously supported by a rigid steel frame on its entire perimeter (Fig. 5). The slab is loaded and the central deflection measured to produce a load-deflection curve (Fig. 6a), which is analysed and converted into an energy absorption-deflection curve (Fig. 6b).

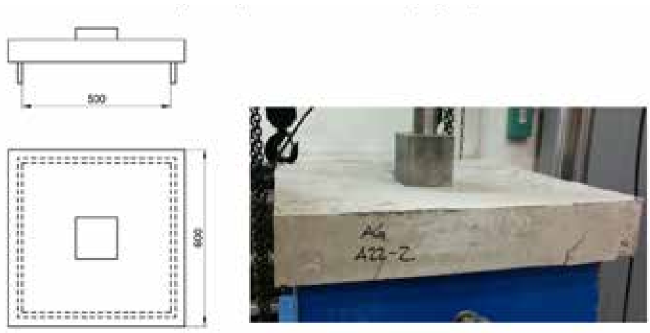

Fig. 5: Schematics of the EN 14488-5 test specimen under load (from [10])

RESULTS

This standard gives a load-deflection curve and an energy absorption-deflection curve that represent the behavior of FRS under a combination of flexural load and punching shear load. The most relevant values that are retrieved are the maximum load and the energy absorption at a 25 mm (1 in.) deflection. The order of magnitude for the energy absorption is hundreds and thousands of Joules and typically ranges between 500-3000 MPa (72,000 to 434,000 psi).

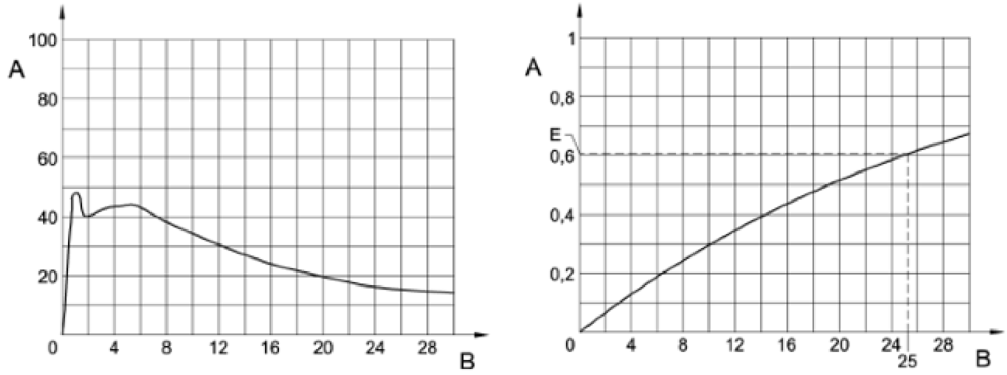

Figure 6a and b: Example of (a) a Load-Deflection curve and (b) an Energy-Deflection curve in an EN 14488-5 test (from [10])

ENGINEERING VALUE

This test method is probably the closest to the actual loading conditions found in a ground support scheme with rock bolting. It is a *statically indeterminate* setup allowing for load redistribution, and creates both flexural and punching shear stresses, leading to more realistic, albeit complex, failure modes. The complex failure modes and the variable crack pattern make it more difficult to understand how the material performs when analyzing the results. Also, the maximum deflection (25 mm) at which the test is performed is relatively small in a mining support context. However, since the span is also relatively small, the actual crack rotation is closer to what can result underground. For example, if we consider a span of 1.5 m between rock bolts, the equivalent out of plane displacement would be 75 mm (3 in.) for the same approximated crack rotation.

Test Method	Information	Typical Results	Main Advantages	Main Disadvantages	Comments
EN 14651	Flexural tensile strength on a notched beam	Load-CMOD curve Limit of Proportionality Residual strengths	Results can be used in fib Model Code	Necessity to saw and notch beams Small crack opening	Performed under closed-loop control
ASTM C1609	Flexural performance on a beam	Load-deflection curve Peak strength Residual strengths Toughness (J)	Results can be used in ACI 318 design code No need to notch beam	Necessity to saw beams Small crack opening	Performed under closed-loop control
ASTM C1399	Average residual flexural strength on a beam	Residual strengths Average residual strength	No need for closed-loop control	Necessity to saw beams Incomplete loading curve Small crack opening	Almost disappeared from specification
EN 14488-5	Energy absorption capacity on a square panel	Energy absorption-deflection curve Maximum load Energy absorption at 25 mm deflection (J)	Structural test Multi-cracking No need to saw specimen Larger crack openings	Difficulty in using results for design	Flexural as well as punching shear stresses are induced
Norwegian Round Panel	Energy absorption capacity on a round panel	Energy absorption-deflection curve Maximum load Energy absorption at 25 mm deflection (J)	Structural test Multi-cracking No need to saw specimen Larger crack openings	Difficulty in using results for design	Flexural as well as punching shear stresses are induced
ASTM C1550	Flexural toughness on a round panel	Load-deflection curve Peak load Energy absorptions at 5, 10, 20, and 40 mm central deflection (J)	Lower variability No need to saw specimen Larger crack openings	Difficulty in using results for design	Very common test in FRS
EN 14488-3	Flexural tensile strength on a notched square panel	Load-CMOD curve Limit of Proportionality Residual strengths	Larger panel with a notch allows for a longer crack monitoring	Only saw notch on underside	*New test not included in the original table*

Table 1: Overview of the different test methods for FRS

CONCLUSION

The original guideline document explores fiber-reinforced shotcrete and offers guidelines on testing in the context of ground support. It provides insights to help owners, engineers, material suppliers, and key players in making the most out of FRS in their ground support programs. The performances of FRS vary with the type of fiber and their dosage, and with the properties of the concrete they are added to. This guide examines and provides a description of the common testing methods used for FRS and how to interpret the information generated. The choice of a test method is a crucial step: Engineers must reflect on the objective(s) of the test and identify a test method that will allow you to truly discriminate successful or meaningful results.

This complete *Guideline on the Applicability of Fiber-reinforced Shotcrete for Ground Support in Mines-MIG III-WP24* was originally published in 2019 by the *Rock Tech Center (RTC)* based in Sweden. The original authors and collaborators of the guidelines are: Antoine Gagnon, Marc Jolin, Pascal Turcotte, Robert Harris, Nicolas Ginouse, Daniel Sandström and Benoit de Rivaz.

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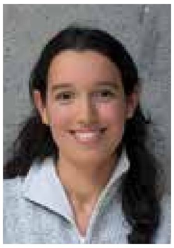
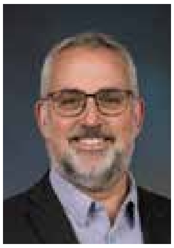
to view the full guidelines



Rym Msatef *is a civil engineering student in Université Laval, Canada where she is working as an intern in the Shotcrete Lab. Rym is interested in and wants to learn more about design and materials in fields like fibre-reinforced shotcrete and sustainable practices in civil engineering. She is also a member of the Laval's Concrete Canoe Team, which ranked 2nd in North America in 2024 during the ASCE competition, where she worked on multiple aspects of the project such as the structural design and analysis, the finances and the construction.*



Marc Jolin, Ph.D., ENG., F.ACI*, is a Full Professor in the Department of Civil and Water Engineering at Université Laval. He received his Ph.D. from the University of British Columbia, Vancouver, BC, Canada, in 1999. An active member of Centre de Recherche sur les Infrastructures en Béton (CRIB), he is involved in projects on service life, reinforcement encasement quality, fibers, admixtures and rheology of shotcrete. He is Past Chair of the ACI Comittee 506 Shotcreting, and secretary of ACI Subcommitee C61, Shotcrete Inspector, and is a member and Past Chair of ACI committee C660, Shotcreter Certification.*

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Modelling the Service Life of Structures with Cast-in-Place Concrete vs. Wet-Mix Shotcrete

By Lihe Zhang, Dudley R. Morgan, Sidney Mindess

While shotcrete is increasingly being used as a construction and repair method for many structural elements, one question is frequently asked regarding the use of shotcrete vs. cast-in-place concrete: Do they achieve similar service life?

Two different scenarios were studied and modelled for 9 different mixtures, including cast-in-place concrete and wet-mix shotcrete, with and without accelerators. Modelled results show that shotcrete can achieve similar or better service life in comparison to cast-in-place concrete.

WHAT IS SHOTCRETE?

> ***Shotcreting:*** *The process of pneumatically conveying concrete materials at high velocity to a receiving surface to achieve compaction.*

First developed by Carl Akeley in 1907, shotcrete has been used for a wide variety of applications, including structural shotcrete, seismic retrofit, architectural shotcrete, ground support for tunnels and mines, canal lining, slope stabilization, pools and infrastructure rehabilitation. It has experienced over a century of technological advancements[2][3] in the years since, and because of the efficiencies and economies they can bring to a project, structural shotcrete applications are increasingly being used in structures all around the world.

More and more civil concrete structure constructors are realizing the benefits of using shotcrete in lieu of cast-in-place concrete, primarily due to the reduction or elimination of formwork and the consequent reductions in materials and labour costs. In addition, the shotcrete process is versatile and can be effectively adapted to many challenging construction requirements, such as curvilinear structures like domes, skateboard parks, and luge tracks.

Sophisticated concrete structures with complicated reinforcement details are now routinely being constructed with shotcrete. This can be seen in underground structures in the New York and the Toronto Metro system where thick, heavily reinforced structural walls and other elements are being constructed using shotcrete. Shotcrete is now included in the ACI 318-19 Building Code Requirements for Structural Concrete, and future trends show shotcrete being used for more of these types of structures[4].

Shotcrete technology involves special mixture designs, application equipment, and shotcreter application procedures. The quality of the final product is dependent on both materials and processes, i.e., the wet-mix and dry-mix shotcrete processes.

- The wet-mix shotcrete process is similar to pumped ready-mix concrete, except that compressed air is added at the nozzle at the end of the pump hose to convey the material to the receiving surface at a high impacting velocity.
- The dry-mix shotcrete process conveys the material down the hose with compressed air and requires water to be added at the nozzle, therefore requiring the shotcreter to control the water content of the mixture.

With the increasing use of shotcrete, questions have been raised about its long-term performance and durability. In particular, how does the durability of shotcrete compare to that of cast-in-place concrete?

DURABILITY OF SHOTCRETE VS. CAST-IN-PLACE CONCRETE

This study examines the service life of cast-in-place concretes compared to wet-mix shotcretes with similar water-cementitious materials ratios (w/cm). Relatively little has been published about the service life of shotcrete. Information on this topic is important, since shotcrete is increasingly being used in a wide variety of new concrete construction and repair applications. Recent research results on transport properties of concrete and shotcrete has demonstrated that properly constructed shotcrete structures can provide equal or better transport properties than conventional cast-in-place concrete[1]. The transport properties evaluated included:

- **Absorption:** Liquid uptake in a porous medium
- **Diffusion:** Liquid, gas, or ion movement under a concentration gradient
- **Permeability:** Resistance to flow of a liquid under a pressure gradient

- **Sorptivity:** Absorption of a liquid by capillarity
- **Wicking:** Capillary transport through a porous medium to a drying surface

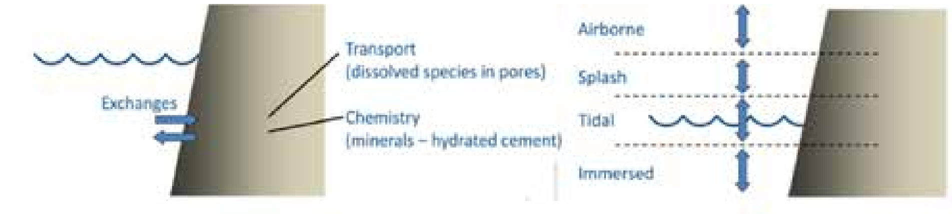

Fig. 1-a) Exchanges of chemical species through the transport process; 1-b) Exposure conditions for marine structures

Using the test results from the previous transport properties study[1], the service life of shotcrete structures was modelled using the STADIUM® model. This model inputs the transport properties for various ionic species generated in a reliable testing environment. STADIUM® is based on the most recent developments in ionic transport modelling and numerical solutions. Service life is calculated based on a finite element model, taking into account nonlinear activity effects, that models the ingress of chloride and other ionic species under different types of environmental conditions (temperature, moisture, chloride ion exposure, etc.).

These transport properties data were input into the STADIUM® modelling program to model the service life of two different shotcrete structures with different exposure conditions.

EXPERIMENTAL PROGRAM

A plain portland cement concrete, fly ash modified concrete, and silica fume modified concrete were cast and tested. In addition, a plain portland cement shotcrete, fly ash modified shotcrete, and silica fume modified shotcrete were shot and tested. The shotcrete tests were also completed on mixtures with rapid-set accelerator added at the nozzle. The cast concrete and wet-mix shotcrete mixtures designs used are provided in Table 1.

Test results indicate that the wet-mix shotcrete exhibits low porosity, low permeability, and reduced coefficients of diffusion[1]. Test results for ASTM C642 Boiled Absorption and Volume of Permeable Voids, ASTM C1792 Drying test, and the ionic migration tests to US Navy Spec UFGS 03 31 29-3[1] were input into the STADIUM® model for service life prediction.

MODELLING PROGRAM

The STADIUM® modelling program requires input of:

- Mixture design and chemical composition of the cementitious materials
- Test results for volume of permeable voids
- Permeability based on a drying test
- Coefficient of diffusion from an ionic migration test.

To initiate a process of ionic migration, details regarding the structural component design, location of the structure, and exposure conditions are required.

STADIUM® models the transport of chemical species in cementitious materials resulting from exchanges at the material-environment interface. For example, Fig. 1a and 1b show the chemical species exchange between the environment and structure for exposure conditions in a marine structure.

Mix. No.	Mix Description	Placement Method	Mix I.D.	As-Batched Mixture Proportions for 1.0 m3										
				Cement (Type GU) (kg)	Fly Ash (kg)	Silica Fume (kg)	Coarse Aggregate (10-5 mm, SSD) (kg)	Fine Aggregate, SSD (kg)	Water (L)	High Range Water Reducing Admixture (L)	Total Mass (kg)	w/cm ratio	Air content, % (As batched)	Air content, % (as-shot)
A1	Portland Cement	Cast Concrete	C-Cast	415	0	0	1027	691	168	0	2329	0.40	5.50%	Not Applicable
A3	Portland Cement	Shot Wet-Mix	C-Wet-Mix-Shot	445	0	0	425	1273	179	0.533	2322	0.40	4.50%	3.20%
A4	Portland Cement	Shot Wet-Mix 5% Accelerator	C-Wet-Mix-Shot-5%	443	0	0	423	1267	179	0.530	2313	0.40	5.90%	3.60%
B1	Fly Ash Modified	Cast Concrete	FA-Cast	334	79	0	1023	688	166	0	2319	0.40	5.30%	Not Applicable
B3	Fly Ash Modified	Shot Wet-Mix	FA-Wet-Mix-Shot	351	86	0	418	1252	176	0	2284	0.40	5.40%	3.50%
B4	Fly Ash Modified	Shot Wet-Mix 5% Accelerator	FA-Wet-Mix-Shot-5%	349	86	0	416	1246	176	0.633	2274	0.40	5.60%	3.90%
C1	Silica Fume Modified	Cast Concrete	SF-Cast	379	0	34	1005	676	166	0.585	2263	0.40	7.20%	Not Applicable
C3	Silica Fume Modified	Shot Wet-Mix	SF-Wet-Mix-Shot	404	0	39	422	1265	178	1.285	2310	0.40	5.10%	3.40%
C4	Silica Fume Modified	Shot Wet-Mix 5% Accelerator	SF-Wet-Mix-Shot-5%	400	0	38	418	1253	177	2.036	2287	0.40	6.60%	4.00%

Table 1: Mixture designs for cast concrete and wet-mix shotcretes

The modelling was conducted to conform with requirements for exposure conditions in ACI, CSA and AASHTO codes and standards. STADIUM® models different types of structures, including bridges, marine structures and parking structures. After applicable structures and exposure conditions were selected, different concrete mixtures were input to compare the chloride initiation, penetration, and migration over time. Parameters obtained from the testing and calculations were entered into the STADIUM® model, including:

Mixture Design: Binder (cement + supplementary cementing materials) Content, Water:Binder ratio, Total Aggregates, Cement Chemistry, Boiled Absorption and Volume of Permeable Voids, Porosity, Coefficient of Diffusion, Age of First Exposure and Age of Laboratory Testing.

The modelling considered requirements for durability in the ACI, CSA and AASHTO codes and standards.

MODELLING METHODOLOGY

The service life was modelled for ages ranging up to 100 years.

Two different structures were selected for modelling. Structures were modelled with each representing a particular structure in a specific location with the most severe environmental exposure condition as detailed below:

- **Bridge Structure in Chicago, IL:** In this structure, exposure to de-icing salt was selected as the corrosion inducing mechanism.
- **Caisson Structure in Tampa, FL:** In this structure, seawater exposure in the tidal zone was selected as this is the most severe condition that will cause corrosion.

All 9 mixtures were modelled for each structure, therefore, a total of 9 mixtures x 2 structures = 18 scenarios were modelled. Results were analyzed and compared for the reference mixture, cementitious materials, and addition of alkali-free rapid-set accelerator, if used.

Uncoated black steel was selected as the reinforcement as it's the most commonly used type of reinforcing steel and is made of unfinished tempered steel which is susceptible to corrosion. No corrosion inhibiting admixture, coating or any other type of steel, including MMFX and stainless steel, were selected in this modelling. This paper compares the effect of chloride ion penetration and corrosion initiation in black steel over time for structures constructed or repaired with shotcrete and cast-in-place concrete for the selected structures.

The Federal Highway Administration[2] suggests a chloride threshold value of 0.30% of the cement by mass of binder, a conservative value, since it is in the lower range of values reported in the literature. Based on this FHWA value for a concrete having a cement content around 690 lb/yd³ (410 kg/m³) and a bulk dry density around 141 lb/ft³ (2,250 kg/m³), the chloride threshold is around 0.05% by mass of concrete (500 ppm). In STADIUM®, the user can modify the threshold value using the Preference tab[3].

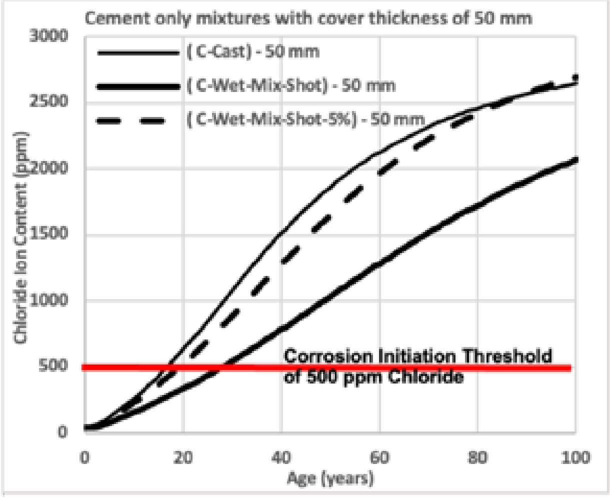

Fig. 2a) Chicago Bridge Structure chloride ion content development with time for cement only mixtures with cover thickness of 50 mm .

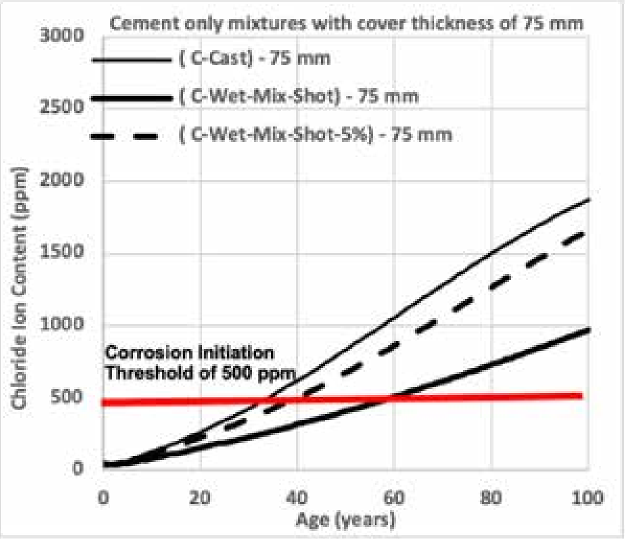

Fig. 2b) Chicago Bridge Structure chloride ion content development with time for cement only mixtures with cover thickness of 75 mm.

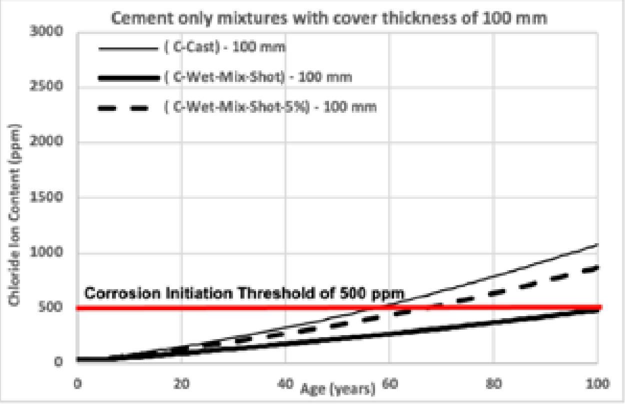

Fig. 2c) Chicago Bridge Structure chloride ion content development with time for cement only mixtures with cover thickness of 100 mm.

SCENARIO #1: MODELLING A CHICAGO BRIDGE STRUCTURE

The Chicago Bridge structure modeled represents a typical concrete structure in an urban area that is exposed to corrosion caused by de-icing salts (Fig. 2). This type of structure is representative of most bridge structures that are exposed to the long winter conditions which prevail in most of the northern, central, and eastern US states and most of Canada. Table 2 shows the exposure conditions that were input into the STADIUM® model for this structure.

Type	Average	Amplitude	Period	Period Offset	Duration
Relative humidity	62.50%	0.0%	365 days	0.0 days	
Air Temperature	9.0 C	14.0 C	365 days	0.0 days	
De-icing Salt	0.0 mmol/L	0.0 mmol/L	1.0 days	0.0 days	246.5 days
	0.0 mmol/L	300.0 mmol/L	110.0 days	246.5 days	55.0 days
	0.0 mmol/L	0.0 mmol/L	1.0 days	0.0 days	63.5 days

Table 2. Exposure Conditions for Chicago Bridge Structures

Figs. 2a), b), and c) show the total chloride ion content for cast concrete and wet-mix shotcrete mixtures with cement only, with cover thicknesses of 50 mm (2 in.), 75 mm (3 in.), and 100 mm (4 in.) respectively.

For the cement-only mixtures, at each cover thickness, the time for the chloride ion content to reach the corrosion initiation threshold of 500 ppm occurs more rapidly in cast concrete compared to wet-mix shotcrete.

Figs. 2a), b), and c) also show that the time to reach corrosion initiation increases by increasing the cover thickness from 50 mm to 75 mm, and to 100 mm. In particular, the time for wet-mix shotcrete with 100 mm cover thickness to reach the corrosion initiation threshold of 500 ppm chloride is about 100 years. This shows that shotcrete with appropriate cover thickness can achieve excellent service life in a de-icing salt exposure environment.

It should be noted that when accelerator is added at 5% by mass of cement, the rate of penetration of chloride ion increased from wet-mix shotcrete without accelerator to wet-mix shotcrete with accelerator. This shows that when accelerator is added, it will accelerate the time for corrosion initiation. However, the time to corrosion initiation for wet-mix shotcrete with 5% accelerator is still longer than that for cast concrete.

Figs. 3a), b), and c) show the total chloride ion content for cast concrete and wet-mix shotcrete mixtures with fly ash with 50 mm, 75 mm, and 100 mm cover thickness.

The rate of penetration of chloride ion for wet-mix shotcrete is slower than for cast concrete. When accelerator is added at 5% by mass of cement, the chloride ion content in the mix with fly ash increased at the fastest rate and is higher than in cast concrete. This shows that the addition of accelerator does increase the rate of chloride ion content penetration in wet-mix shotcrete with fly ash, and reduces the time for corrosion initiation.

Mix Type	**Cement ONLY**								
Placement Method	Cast			Shot Wet-Mix			Shot Wet-Mix with 5% Accelerator		
Mix Designation	A1	A1	A1	A3	A3	A3	A4	A4	A4
Concrete Cover (mm)	50	75	100	50	75	100	50	75	100
Time (years)	18	28	56	29	59	100	20	33	65
Mix Type	**Fly Ash modified**								
Placement Method	Cast			Shot Wet-Mix			Shot Wet-Mix with 5% Accelerator		
Mix Designation	B1	B1	B1	B3	B3	B3	B4	B4	B4
Concrete Cover (mm)	50	75	100	50	75	100	50	75	100
Time (years)	63	>100	>100	78	>100	>100	50	>100	>100
Mix Type	**Silica Fume modified**								
Placement Method	Cast			Shot Wet-Mix			Shot Wet-Mix with 5% Accelerator		
Mix Designation	C1	C1	C1	C3	C3	C3	C4	C4	C4
Concrete Cover (mm)	50	75	100	50	75	100	50	75	100
Time (years)	64	>100	>100	52	>100	>100	52	>100	>100

Table 3: Chicago Bridge with Wet-Mix Shotcrete & Cast in Place Concrete: Time to Reach 500 ppm Corrosion Threshold Limit (years)

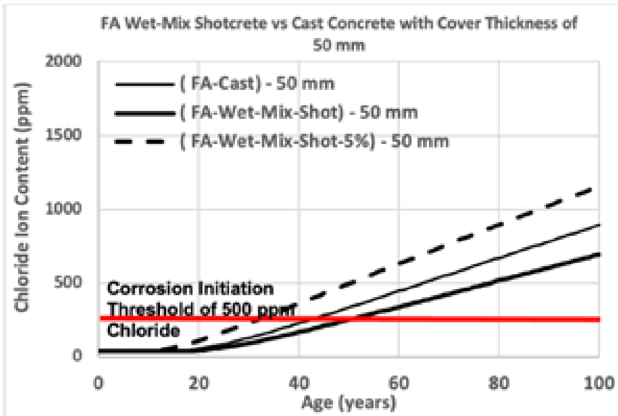

Fig. 3a) Chicago bridge structure chloride ion content development with time for fly ash mixtures with cover thickness of 50 mm

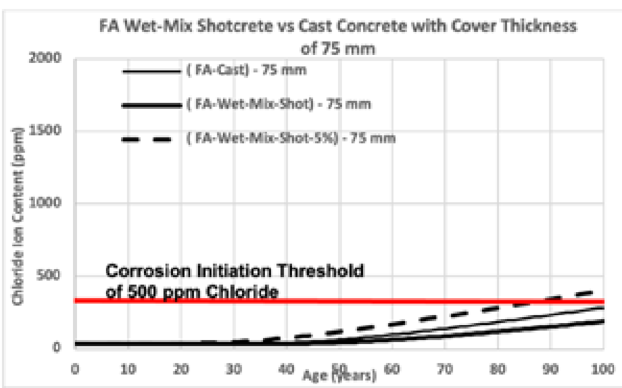

Fig. 3b) Chicago bridge structure chloride ion content development with time for fly ash mixtures with cover thickness of 75 mm

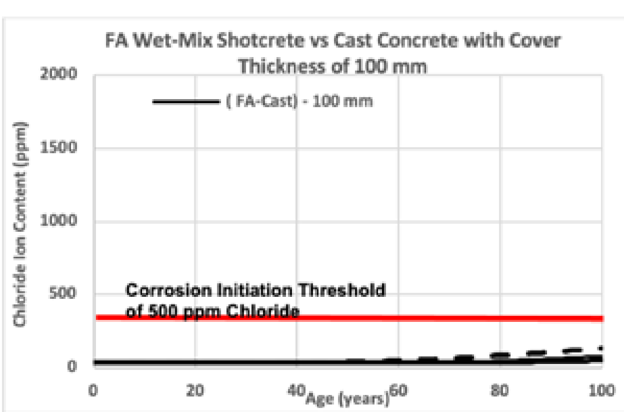

Fig. 3c) Chicago bridge structure chloride ion content development with time for fly ash mixtures with cover thickness of 100 mm

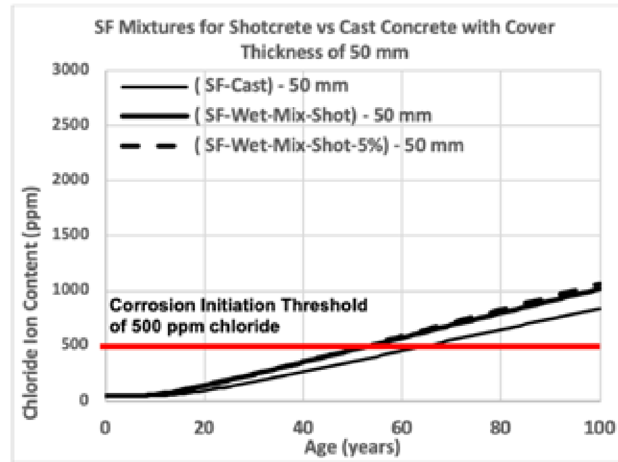

Fig. 4a) Chicago bridge structure chloride ion content development with time for silica fume mixtures with cover thickness of 50 mm

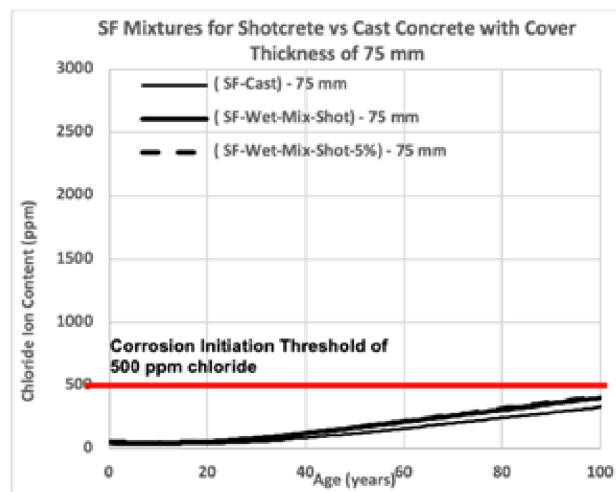

Fig. 4b) Chicago bridge structure chloride ion content development with time for silica fume mixtures with cover thickness of 75 mm

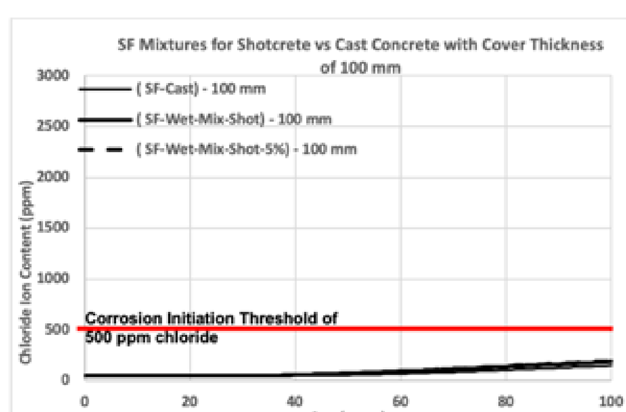

Fig. 4c) Chicago bridge structure chloride ion content development with time for silica fume mixtures with cover thickness of 100 mm

Note, however, that the shotcrete mixtures with fly ash have much greater times to initiation of corrosion than comparable cement-only mixtures.

Figs. 4a), b), and c) show the total chloride ion content for wet-mix shotcrete mixtures with silica fume with cover thickness of 50 mm, 75 mm, and 100 mm respectively.

Fig. 4a) shows that with a cover thickness of 50 mm, the time to corrosion initiation is about 52 years for both shotcrete and shotcrete with 5% accelerator, while it is about 63 years for cast concrete. The longer time to corrosion initiation is caused by the fact that silica fume wet-mix shotcrete has a higher coefficient of diffusion and effective coefficient of diffusion, than cast concrete with silica fume[1], which results in the reduced time to corrosion initiation in the shotcrete mixtures. Figs. 5b) and 5c) show that with cover thicknesses of 75 mm and 100 mm, the chloride ion content does not reach the threshold of 500 ppm at 100 years. This means that the time to corrosion initiation is longer than 100 years for cover thickness of 75 mm and above for all the silica fume mixtures.

SHOTCRETE VS. CAST-IN-PLACE CONCRETE

Figures 2a, b, c, 3a, b, c, and 4a, b, c and Table 2 show the development for total chloride ion profiles for cast concrete vs. wet-mix shotcrete for mixtures with cement only, fly ash, and silica fume respectively. These curves show that the chloride ion content for cast concrete mixtures develops more rapidly with time compared to shot wet-mix shotcrete without accelerator for mixtures with cement only and fly ash (Figs. 2a, b, c and Figs. 3a, b, c). When silica fume is used (Figs. 4a, b, and c), the cast concrete shows slightly better performance than shotcrete at 50 mm cover, and almost the same level of lower than 500 ppm at 100 years at both 75 mm and 100 mm cover. These figures clearly show that the shotcrete process can reduce the rate of migration of chloride ion penetration at cover thickness of 50 mm and above, and therefore delay the time for chloride to reach the threshold to cause corrosion initiation in cement only and fly ash mixtures.

CEMENT VS. FLY ASH VS. SILICA FUME

When comparing Figs. 2a, b, and c, 3a, b, and c, and Figs. 4a, b, and c, the effects of fly ash and silica fume on the time to corrosion initiation are significant. Results for reaching the threshold of 500 ppm are summarized in Table 3. These figures and table show that cast concrete and shotcrete mixtures with cement only have the highest total chloride ion content at 100 years while mixtures with fly ash and silica fume have substantially lower chloride ion contents. These results are consistent with the known reduction in permeability and subsequent improvement in durability when using fly ash and silica fume in the concrete industry.

MODEL SCENARIO #2: CAISSON STRUCTURE IN TAMPA, FL, EXPOSED TO SEA WATER IN THE TIDAL ZONE

The model of a caisson structure in Tampa, FL exposed to seawater in the tidal zone represents one of the most severe chloride exposure conditions for a reinforced concrete structure. The modelling analysis was conducted with concrete cover thicknesses of 50 mm, 75 mm, and 100 mm at ages up to 100 years. Fig. 5 shows the exposure conditions that were input into the STADIUM® model for this structure.

The salinity is about 35 ppt, which is about 35,000 ppm. Figs. 6a), b), and c) model results for total chloride ion content at cover thickness of 50 mm, 75 mm, and 100 mm are presented and discussed below.

The shotcrete mixture (without accelerator) shows the longest time to initiation of corrosion, followed by the cast concrete mixture, and then the shotcrete mixture with accelerator.

Figs. 7a), b), and c) show the chloride ion development with time of fly ash mixtures with cover thicknesses of 50 mm, 75 mm and 100 mm respectively.

The fly ash shotcrete mixture (without accelerator) has similar time to initiation of corrosion as the cast concrete mixture. The shotcrete with accelerator has the shortest time to initiation of corrosion. Comparing these results with the cement only mixtures shows that addition of fly ash prolongs chloride migration and therefore delays the time to initiation of corrosion. The effect of accelerator is discussed later in this paper.

Figs 8a), b), and c) show the chloride development with time of silica fume mixtures with cover thicknesses of 50 mm, 75 mm, and 100 mm respectively.

These figures show that for the silica fume modified mixtures the cast concrete has the longest time to initiation of corrosion, followed by the shotcrete mixtures with and without accelerator, which have similar times to initiation of corrosion. It was only in the silica fume modified mixtures where the cast concrete mix showed a longer time to initiation of corrosion than a shotcrete mixture.

The time to corrosion initiation for all the caisson

Type	Average	Amplitude	Period	Period Offset
Relative humidity	73.00%	0.0%	365 days	0.0 days
Air Temperature	22.0 C	6.0 C	365 days	0.0 days
Salinity	35.0 ppt (‰)	0.0 ppt (‰)	365 days	0.0 days

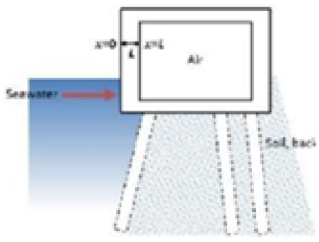

Fig. 5 Exposure Conditions of Caisson in Tampa, FL

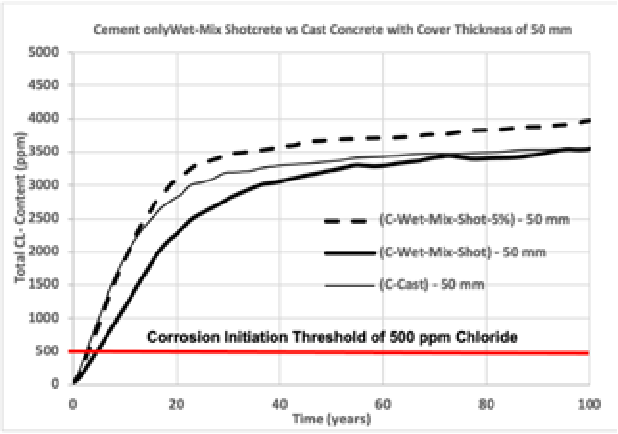

Fig. 6a) Tampa caisson structure chloride ion content development with time for cement only mixtures with cover thickness of 50 mm

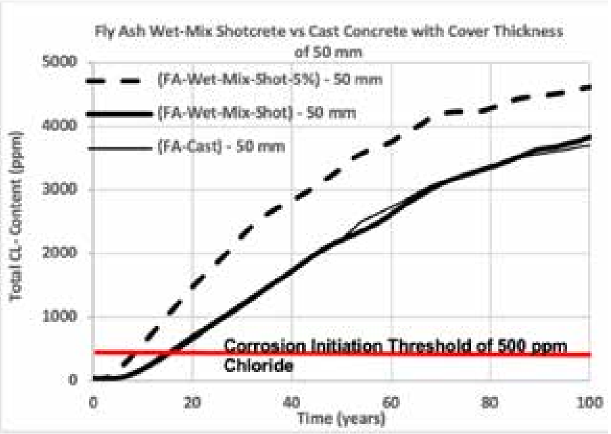

Fig. 7a) Tampa caisson structure chloride ion content development with time for fly ash mixtures with cover thickness of 50 mm

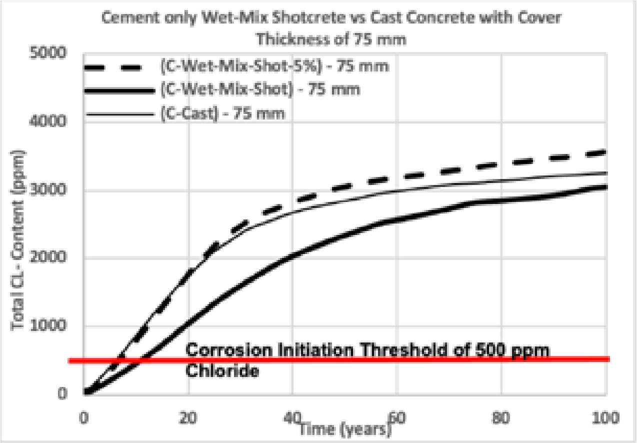

Fig. 6b) Tampa caisson structure chloride ion content development with time for cement only mixtures with cover thickness of 75 mm

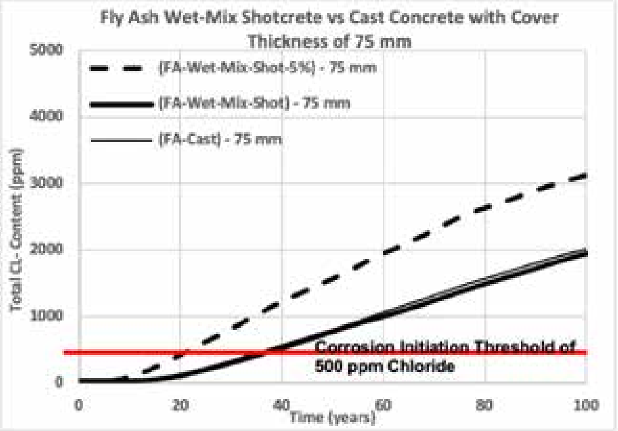

Fig. 7b) Tampa caisson structure chloride ion content development with time for fly ash mixtures with cover thickness of 75 mm

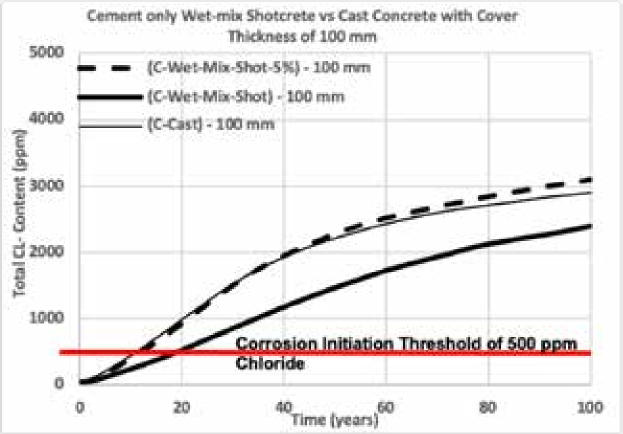

Fig. 6c) Tampa caisson structure chloride ion content development with time for cement only mixtures with cover thickness of 100 mm

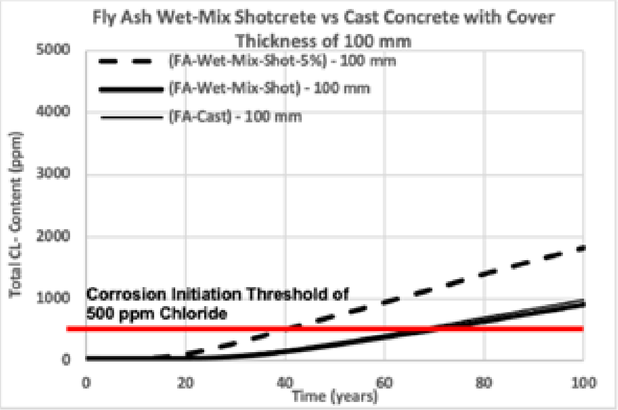

Fig. 7c) Tampa caisson structure chloride ion content development with time for fly ash mixtures with cover thickness of 100 mm

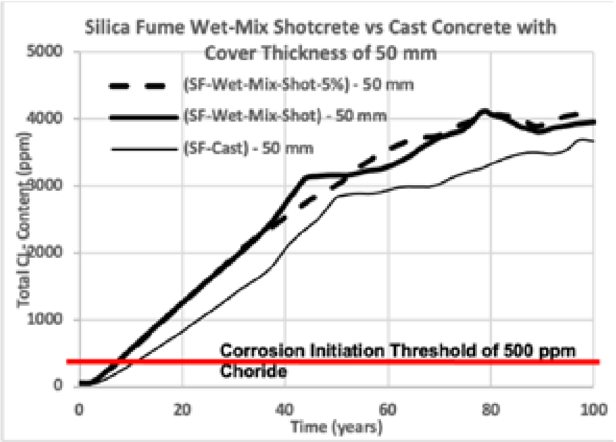

Fig. 8a) Tampa caisson structure chloride ion content development with time for silica fume mixtures with cover thickness of 50 mm

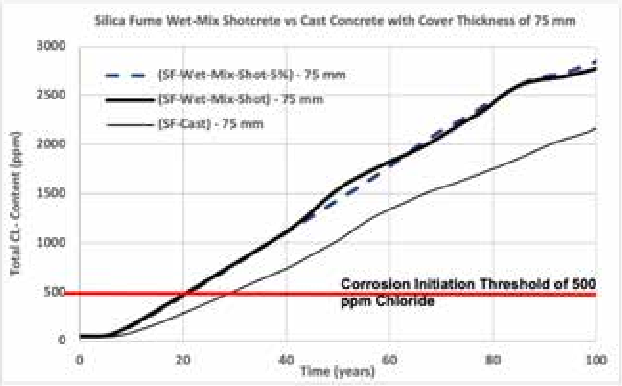

Fig. 8b) Tampa caisson structure chloride ion content development with time for silica fume mixtures with cover thickness of 75 mm

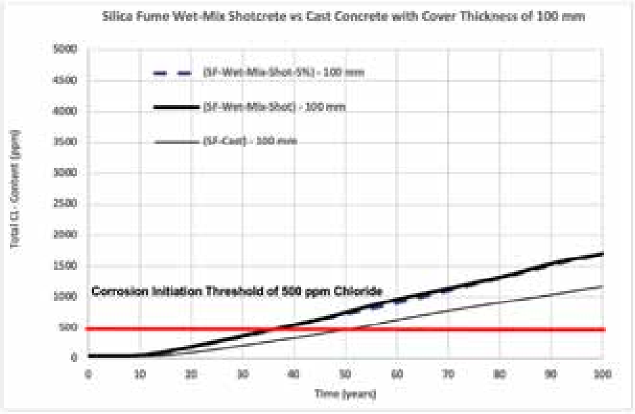

Fig. 8c) Tampa caisson structure chloride ion content development with time for silica fume mixtures with cover thickness of 100 mm

mixtures tested is summarized in Table 4.

SHOTCRETE VS. CAST CONCRETE

Table 4 shows the relationship between cover thickness and the time to initiation of corrosion in all the shotcrete and cast concrete mixtures. It shows that for cement only mixtures the shotcrete mixture without accelerator outperforms the cast concrete mix, while the shotcrete mixture with accelerator has similar performance to the cast concrete mix. In the fly ash mixtures the shotcrete (without accelerator) has similar performance to the cast concrete mixtures, but the shotcrete with accelerator has a lower time to initiation of corrosion. In the silica fume modified mixtures the cast concrete has the longest time to initiation of corrosion, followed by the shotcrete mixtures.

Best overall performance in this marine environment was provided by the fly ash mixtures. Fig. 9 shows the time to initiation of corrosion of the shotcrete (without accelerator) and cast concrete mixtures at different thicknesses of cover for the fly ash mixtures.

EFFECT OF RAPID-SET ALKALI-FREE ACCELERATOR

One should note that these types of accelerator are only useable with shotcrete placement. This opens up many marine applications with tidal changes in water level or underground projects that require a quick set and early strength gain. When accelerator is added to the shotcrete at the nozzle, chloride ion penetration develops at a faster rate with time. This occurs with the cement-only, fly ash and silica fume mixtures at cover thicknesses ranging from 50 mm to 100 mm. This is attributed to the fact that when accelerator is added, shotcrete experiences an accelerated hydration process, which results in a faster production of ettringite and less densified calcium silicate hydrate (CSH) microstructure. This results in an increased permeability and coefficient of diffusion[Ref. 1], allowing a faster rate of chloride ion migration into the concrete.

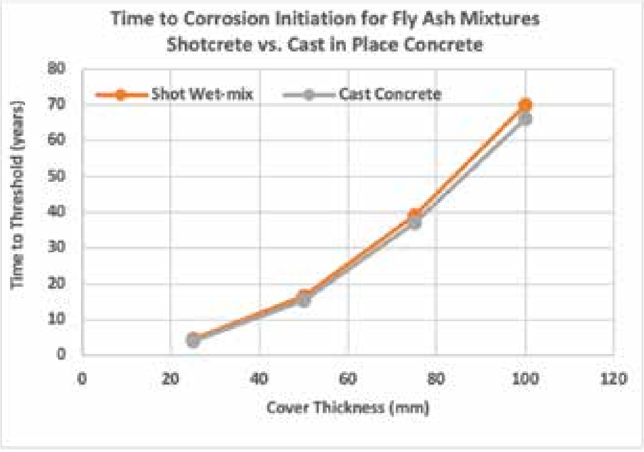

Fig. 9 Time to reach corrosion threshold of 500 ppm with increasing cover thickness in fly ash mixtures.

Mix Type	Cement ONLY								
Placement Method	Cast			Shot Wet-Mix			Shot Wet-Mix with 3% Accelerator		
Mix Designation	A1	A1	A1	A3	A3	A3	A5	A5	A5
Concrete Cover (mm)	50	75	100	50	75	100	50	75	100
Time (years)	4	8	11	6	11	20	4	8	11
Mix Type	**Fly Ash modified**								
Placement Method	Cast			Shot Wet-Mix			Shot Wet-Mix with 3% Accelerator		
Mix Designation	A1	A1	A1	A3	A3	A3	A5	A5	A5
Concrete Cover (mm)	50	75	100	50	75	100	50	75	100
Time (years)	15	38	68	15	38	70	8	21	40
Mix Type	**Silica Fume modified**								
Placement Method	Cast			Shot Wet-Mix			Shot Wet-Mix with 3% Accelerator		
Mix Designation	A1	A1	A1	A3	A3	A3	A5	A5	A5
Concrete Cover (mm)	50	75	100	50	75	100	50	75	100
Time (years)	14	30	50	9	21	35	9	21	35

Table 4: Tampa Caisson with Wet-Mix Shotcrete & Cast in Place Concrete: Time to Reach 500 ppm Corrosion Threshold Limit (years)

Conclusions

Modelling results for the bridge structure in Chicago, which is exposed to the de-icing salts, and the caisson structure in Tampa, which is exposed to the tidal salt water, show that these two structures have the following features in common:

- With a single exception (silica fume shotcrete in caisson structures), cast structural concrete produces the shortest time to reach the chloride threshold of 500 ppm, beyond which corrosion initiation starts. When wet-mix shotcrete (without accelerator) was used, the time to reach the threshold of corrosion initiation increased compared to cast concrete for mixtures with cement as the only binder. In fly ash modified mixtures the performance was similar between cast concrete and shotcrete mixtures. This shows that the shotcrete process delays the time for the chloride ion content to reach the limit for corrosion initiation. This also shows that properly applied shotcrete will extend the service life of the structures in de-icing salt and marine exposure in the tidal zone.
- Time to corrosion initiation increases with cover thickness from 25 mm to 100 mm in a non-linear relationship. This is as expected.
- There are different mechanisms causing corrosion initiation. These involve permeability, porosity, diffusion, and chloride ion penetration resistance. Changing mixture designs, including using fly ash or silica fume and using shotcrete vs. cast concrete, affects these mechanisms differently when subjected to different exposure conditions. The time to corrosion initiation will vary from exposure in a bridge environment with deicing salt and a marine structure. The effects of these mechanisms on the time to initiation of corrosion needs to be evaluated by laboratory testing, modelling, and field tests to validate service life prediction models.

In Summary

When properly designed and applied, wet-mix shotcrete provides equal or increased service life for reinforced concrete structures compared to cast concrete. The addition of supplementary cementitious materials (such as fly ash and silica fume) is recommended, as it further extends the service life. Cement-only cast concrete and shotcrete mixtures have lower resistance to chloride ion penetration and reduced service life and are thus not recommended in chloride exposure environments.

The modelled results provide a comprehensive database for the expected performance of different types of cast and shotcreted mixtures for different exposure conditions.

Recommendations for Future Development

Much more complex reinforced concrete structures are now being built or repaired with shotcrete[4][5][6]. Shotcrete is a technology which involves both materials and application processes. Understanding the service life of shotcrete is critical. This paper provides a basic framework, based on which a guide for service life prediction for structures built or repaired with shotcrete can be developed. In the future, the authors are planning to develop a basic guideline for shotcrete service life prediction for a range of different exposure environments.

A proposed outline for the basic guideline includes:

a. Design suitable mixtures for the selected exposure environment and conduct trial shooting with proper preparation of test samples This process also requires appropriate equipment selection (wet-mix or dry-mix process) and shooting test panels by qualified shotcreters (minimum ACI certified shotcreter).
b. Conduct laboratory testing to obtain the necessary shotcrete transport properties data required for input into the service life model. The minimum required tests to be conducted include compressive strength to ASTM C39, ASTM C642, ASTM C1792, and ionic migration tests.[1] These tests should be conducted at least at 28 and 56 days age.
c. Model the service life with the test results. The modelling process requires input on structure locations, environmental exposure conditions, required service life, details of reinforcement (including concrete cover) and some other required information. Although there are some other service life prediction models available, it is recommended that the STADIUM® model be used.

For structures where service life modelling and prediction is not critical, but designers/engineers would like to know the service life potential when using shotcrete, a simplified method could be used. This would involve conducting shotcrete trials with test panels, extracting cores and conducting tests for at least, compressive strength, boiled absorption and ionic migration, and referring to the service life prediction data presented in this research paper (and additional data to be presented in a future paper). Comparing the results of this data to the data in this paper should provide an approximate indication of the potential service life for the selected structure and exposure conditions.

Tested and modelled results should be able to show that for most environmental exposure scenarios, shotcrete, when properly deigned and applied, is able to provide equivalent or extended service life compared to cast-in-place concrete. Cost analysis based on service life analysis can be conducted to estimate the life cycle costs of a project.

ACKNOWLEDGMENTS

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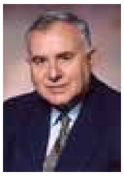

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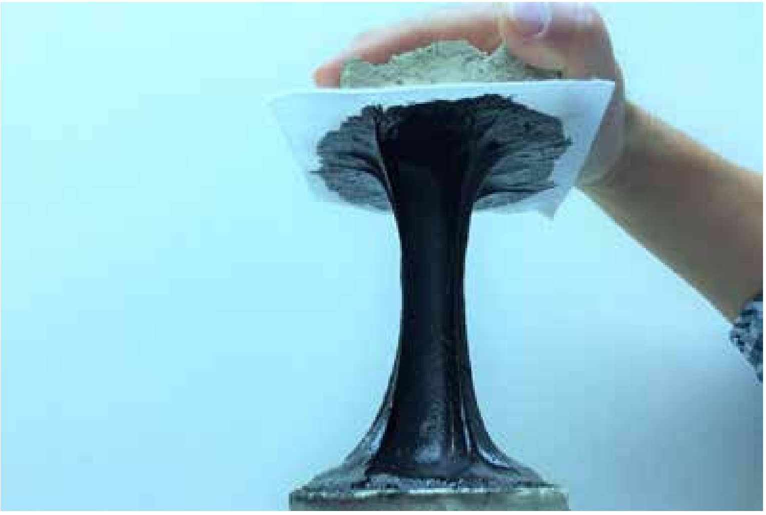
Polymer Rubber Gel Technology: High-Performance Waterproofing for Shotcrete and Blind-Side Applications

By John H. Huh



Using an innovative polymer rubber gel system (GTS) as provided by GelTechSystems for waterproofing underground structures is an effective solution that meets the unique challenges of underground construction. Key characteristics of the GTS waterproofing system includes adhesion to the substrate, responsiveness to substrate movement, non-curing, self-healing, chemical resistance, and environmental friendliness. This versatile technology, combined with a durable, flexible, fleece-reinforced HDPE laminate, creates a dynamically responsive composite waterproofing assembly that exhibits excellent waterproofing effectiveness for both shotcrete and blind-side applications. This technology has been successfully used for waterproofing large-scale subway stations in California. This article describes GTS's physical characteristics used as a composite waterproofing system and how it provides a high-performance solution for shotcrete and blind-side applications.

Selection of the waterproofing membrane system and appropriate engineering details are essential to the success of any tunnel or below-grade structural waterproofing application. Waterproofing poses distinct challenges in performance, design, and application. Two distinct methods of application are used for waterproofing structures: Positive Side and Blind Side applications.

- Positive Side Waterproofing: Applying waterproofing directly to the existing structure's concrete surface.
- Blind Side Waterproofing: Applying waterproofing to the support of excavation or outer lining and forming then casting concrete or spraying shotcrete against the waterproofing system.

Positive Side Waterproofing

Blind Side Waterproofing

For blind side applications, the final lining or structural wall is formed against the waterproofing membrane. This method reduces excavation and costs, particularly in urban environments where space constraints exist.

UNIQUE PHYSICAL CHARACTERISTICS OF THE GTS SYSTEM

GTS exhibits unique physical characteristics making it an ideal component of a dynamic waterproofing system:

- Adhesion to Concrete: Ensures no path for water migration.
- Responsiveness to Substrate Movement: Retains a waterproof seal during seismic events or joints that experience constant motion.
- Elongation: Ability to bridge cracks in concrete and construction joints without debonding or losing water tightness.
- Hydrostatic Pressure Resistance: Withstands continuous hydrostatic pressure without rupture.
- Self-Healing Capability: Self-heals small tears or punctures under direct hydrostatic pressure, mitigating common pre-construction waterproofing system damage.
- Chemical Resistance: Prevents degradation from aggressive soils.
- Environmental Friendliness: Made from non-toxic and recycled materials, with low VOCs during application and low odor.

GUIDELINES FOR EFFECTIVE WATERPROOFING

GENERAL DESIGN GUIDELINES AND WATERPROOFING SYSTEM SELECTION

Site factors must be considered for effective waterproofing of underground structures. A waterproofing system selection process should be based on the water tightness criteria, considering both physical site conditions and the type of construction chosen for the underground structure. The substrate for which the blind side waterproofing system is to be applied should be considered during the soil support of excavation design process.

Successful waterproofing of underground structures requires that the entire waterproofing system be continuous throughout the building envelope. Proper detailing for tie-backs to other structural systems, penetrations, protrusions, transitions, terminations, and seams within the waterproofing system are essential for maintaining the integrity of the continuous waterproofing envelope.

SITE CONDITIONS, CONSTRUCTABILITY, AND INSTALLATION

Site conditions and constructability play a strong factor in the waterproofing system design process. Often, waterproofing systems used on large-scale applications will be exposed to the elements for extended periods prior to concrete placement. Preconstruction meetings with the waterproofing applicator and project general contractor should be conducted to ensure proper work staging to limit exposure to potential damage.

KEY PHYSICAL GUIDELINES OF THE WATERPROOFING SYSTEM

After successful installation and proper detailing, a waterproofing system must perform based on the physical attributes of the product. Key performance criteria include adhesion to concrete, responsiveness to substrate movement, elongation, hydrostatic pressure resistance, self-healing capability, chemical resistance, and environmental friendliness.

ADDITIONAL WATER MITIGATING COMPONENTS

In addition to a primary waterproofing system, accessory components such as prefabricated drainage composites and various types of waterstops should be considered. For underground structures not below the water table, prefabricated drainage composites may be a suitable addition to remove direct hydrostatic pressure from the waterproofing membrane.

GTS COMPOSITE SHOTCRETE AND BLINDSIDE WATERPROOFING

THE CHALLENGES OF SHOTCRETE ASSEMBLY AND BLINDSIDE ASSEMBLY

For underground construction, shotcrete and blindside waterproofing systems play a significant role in protecting against water intrusion. The challenge in this type of construction is that the waterproofing must endure exposure to adverse environments and withstand the force of the shotcrete placement. Additionally, reinforcing bar must be supported, so the waterproofing will generally have numerous penetrations from tie-backs and supports for reinforcing bar, making these areas susceptible to water leakage. Most importantly, it is critical that the shotcreted concrete bonds to the waterproofing after placement, ensuring that water does not migrate between the membrane and the concrete. Inspection and monitoring during application are critical since the waterproofing will be inaccessible once the concrete is in place.

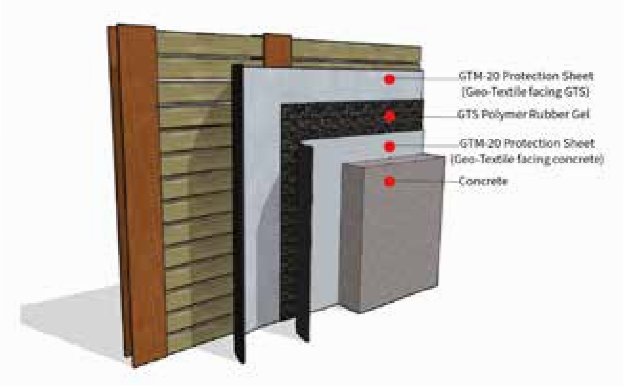


Fig. 1 Polymer rubber gel blindside Assembly

THE GTS POLYMER RUBBER GEL SHOTCRETE OR BLINDSIDE SYSTEM

The waterproofing system consists of a composite system of two layers of 20 mil HDPE fleece reinforced sheets sandwiched with a spray-applied 100 mil-110 mil thick polymer rubber gel layer in the center (Fig. 1). The durability and chemical resistance of the HDPE sheets combined with the flexibility of the gel create the dynamically responsive waterproofing system. The final layer of 20 mil HDPE is applied to the negative face of the system with the fleece facing the installer to protect the waterproofing system from job site contamination, weather, or damage (Fig. 2). The fleece layer forms a mechanical bond to the concrete. This three-layered GTS waterproofing system allows greater flexibility for timing of pours during construction.

Preparation of the soil support or excavation substrate for blind side application of the GTS system may require placing a plywood protection board or a shotcrete smoothing layer to create a sufficiently rigid and smooth substrate for the mechanical attachment of the waterproofing sheet. Typical applications where this would be necessary are for sheet pile walls or some types of deep soil mix walls. Care must be taken to prevent the possibility of protrusions from the wall or cavities that could damage the waterproofing assembly either during assembly or at the time of concrete pour or shotcrete placement.

The principal design concept with a GTS waterproofing system is to achieve a complete monolithic building envelope of the gel system. This requires proper detailing of the transitions from base slab to walls and walls to ceiling. Once the first layer of 20 mil HDPE is installed and penetrations and transitional details are in place, a layer of polymer rubber gel is sprayed (Fig. 3) creating a monolithic non-curing, self-healing membrane.

Once the GTS spray layer is in place, a final layer of fleece reinforced HDPE is installed with the fleece layer facing the rebar. This layer bonds to the GTS and creates a mechanical bond with the shotcrete or cast concrete. Due to the self-healing aspect of the GTS waterproofing assembly, the risk of damage during rebar installation is mitigated.

Fig. 2 Installation of the outer fleece reinforced HDPE sheet

Fig. 3 Spray application of GTS gel on fleece reinforced HDPE

CASE STUDY: CENTRAL SUBWAY AND PRESIDIO PARKWAY, SAN FRANCISCO, CA

Central Subway Application Photo

Central Subway Application Photo

Central Subway Application Photo

The **Central Subway Project** extends the Muni Metro T Third Line through SoMa, Union Square, and Chinatown, vastly improving transportation in some of San Francisco's busiest areas. The project includes the construction of four subway stations using top-down construction methods, incorporating GTS waterproofing systems. The design utilized GTS due to its superior flexibility, self-healing characteristics, and seismic performance.

The **Presidio Parkway Project** was designed to improve the seismic, structural, and traffic safety of the historic Doyle Drive route connecting San Francisco to the Golden Gate Bridge. The project succeeded in improving the roadway through the addition of new tunnels and more access points while improving views from within the National Historic Landmark District.

The Polymer Rubber Gel, Gel-Tech 500 blind side system was specified for the entire cut and cover highway tunnel box structure. Structural engineers were particularly concerned with improving seismic performance of the construction.

Presidio Parkway Application Photo

Presidio Parkway Application Photo

Presidio Parkway Application Photo

Conclusion

The innovative GTS Polymer Rubber Gel waterproofing systems are proven and effective for underground construction applications. The unique physical characteristics of polymer rubber gel combined with HDPE membrane sheets create composite waterproofing assemblies, advancing state-of-the-art cut-and-cover construction within the industry. Given proper design consideration and specification of composite GTS waterproofing assemblies, this provides excellent waterproofing performance along with enhanced methane/chemical protection for underground structures.

John H. Huh *is the CEO and founder of RE-Systems Group Americas Inc., a company specializing in waterproofing solutions for challenging underground construction. Huh has over two decades of experience in the industry. RE-Systems Group Americas led by Huh has been instrumental in major infrastructure projects across North America, showcasing their expertise and commitment to advancing waterproofing practices.*

Updated Fiber-reinforced Shotcrete Testing Standard – Faster, Easier and Better!

By Bill Geers and Benoit de Rivaz

FIBER-REINFORCED SHOTCRETE IN UNDERGROUND LINING APPLICATIONS

Ground support applications in tunnels and mines are considered the single largest use of shotcrete in the world. Historically, both macro-synthetic and steel fiber-reinforced shotcrete have been utilized as the initial or "temporary" ground support system in a tunnel, or caverns. This initial ground support layer (with rock or cable bolts when necessary) was then overlaid by a waterproofing membrane (if needed), and then a structural cast-in-place reinforced concrete layer installed as the final lining. The initial layer of fiber-reinforced shotcrete was not considered to provide any long-term structural benefit because of the uncertainty of the long-term quality and durability of the product. This system of lining used on conventionally excavated tunnels and caverns is sometimes referred to as the Double-Shell Method.

Over the last 30-years, modern sprayed concrete technology and quality has evolved (Fig. 1) and now equips the tunneling industry with a more economical tunnel lining system as a Permanent Sprayed Concrete lining (PSCL) that replaces the cast-in-place final lining (also known as the Single Shell Method). The use of high-performance steel fibers in the shotcrete eliminates the traditional reinforcement in the final lining, providing a reduction in the total quantity of reinforcing steel required, a reduction in lining thickness and quantity of concrete required. With less labor required, construction time savings, and significant cost savings, this new method provides a more durable and sustainable structure while reducing the carbon footprint of the project. Note, the term "single shell" does not refer to the placing of a single sprayed concrete layer but to the interaction of several layers as a single shell (initial support), rock bolts (if needed), water proofing membrane (if needed), and shotcrete final layer.

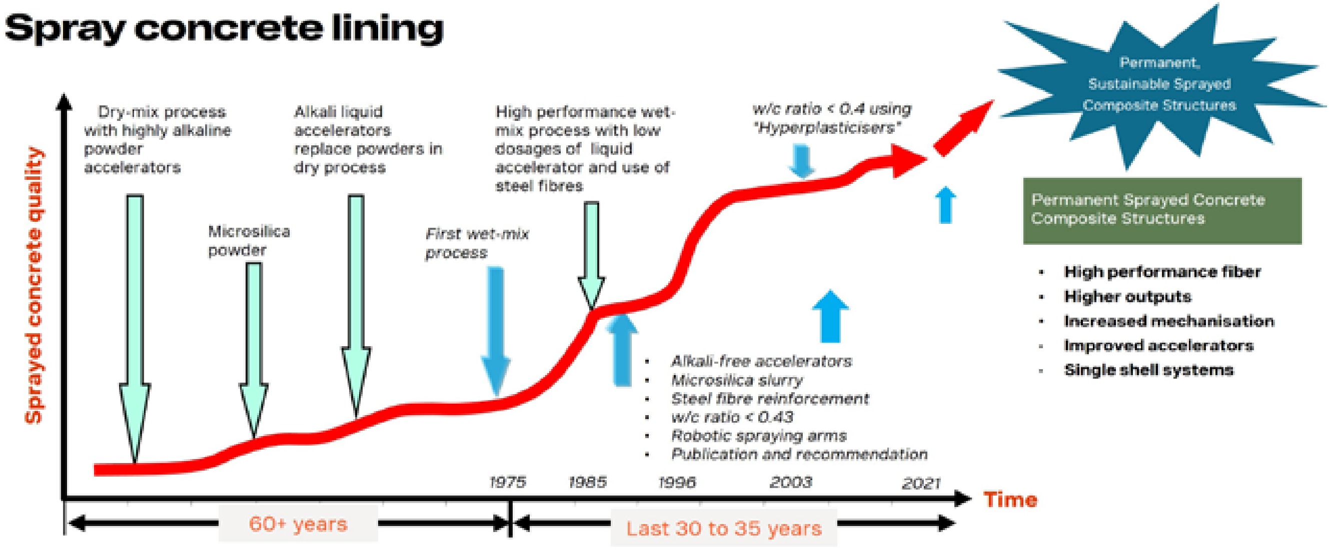


Fig. 1: Advancements in Shotcrete Technology and Quality

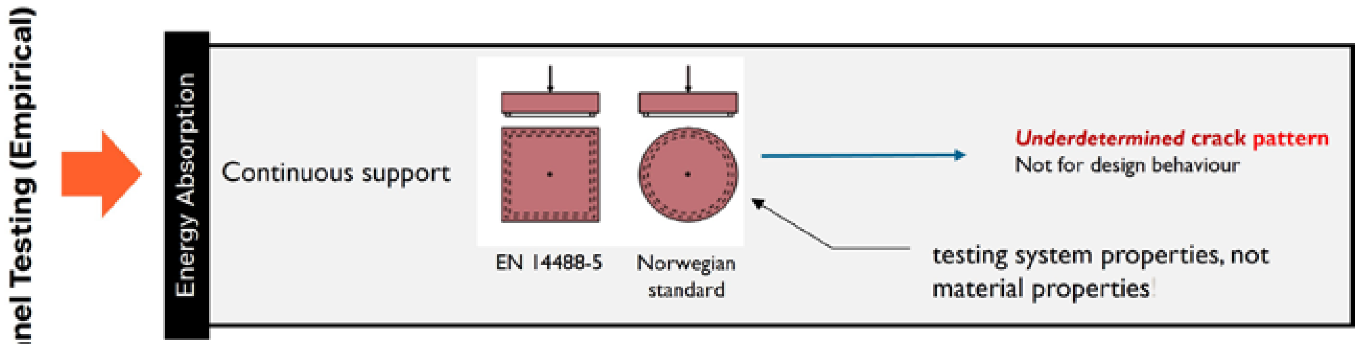


Fig. 2: Typical Panel Tests – For Empirical Design Values

CASE STUDY - BENEFITS OF DESIGNING STEEL FIBER REINFORCED PERMANENT SPRAYED CONCRETE LINING (SFRPSCL)

Designers have now employed and constructed tunnels and caverns using SFRPSCL worldwide. Research shows that more than 80% of the CO_2 emissions in the construction phase of a tunnel can be attributed to the cement and steel construction materials. It has been shown that reducing the quantity of cement and reinforcing steel used in a lining can significantly reduce CO_2 emissions.

An article in the June 2024 edition of Tunnel Business Magazine entitled “CARBON FOOTPRINT REDUCTION FOR MAJOR TRANSIT PROJECTS” by Verya Nasri, Medhi Bakhshi, and Pegah Jarast, of AECOM, New York, NY, details an evaluation of the tunnel lining system for the upcoming Montreal Blue Line Metro Extension project. This evaluation compared the historical double-shell lining method of conventionally excavated portions of the project to using the new SFRPSCL method.

The evaluation compared a conventional cast-in-place final lining constructed with conventional reinforcing and ordinary Portland cement concrete with a thin low-carbon permanent steel-fiber reinforced shotcrete lining. This evaluation detailed the embodied CO_2 emission calculations of the alternatives. By replacing the cast-in-place rebar reinforced final lining with a steel-fiber reinforced shotcrete lining and improving the mixture design (using portland limestone cement and 27% replacement of cement with supplementary cementitious materials) together with using real-time in-situ 3D laser scan technology in placing the shotcrete, CO_2 emissions were reduced by 80% (from 7.9 CO_2 kg per 1 m length of the tunnel to 1.7 CO_2 kg per 1 m length of the tunnel)! The study found that by converting the traditional double-shell lining to a SFRPSCL also provides for a significant reduction in construction costs and time.

With increasing government and owner mandates to decarbonize construction, and the fact that 80% of the embodied carbon from a typical tunnel project comes from the concrete lining, the shotcrete industry can expect SFRPSCL projects will increasingly become the standard method replacing conventionally reinforced cast-in-place linings.

FROM EMPIRICAL TO STRUCTURAL DESIGN

In the double-shell lining method, the design of the initial shotcrete support is considered non-structural and is typically accomplished using empirical tools such as the “Q” system and Barton Chart. The energy absorption value measured using a standard panel test is typically specified when, in the case of rock-bolting, emphasis is laid on energy which must be absorbed during the deformation on the rock. To determine the performance of the fiber-reinforced shotcrete in these applications, the standard testing methods use sprayed panels testing such as the ASTM C1550 round panel or the EN 14488 square panel to determine energy absorption values measured in Joules provided by the fiber-reinforced shotcrete. (Fig. 2)

For a structural lining design, the residual tensile strength provided by fiber-reinforced shotcrete using constitutive laws must be determined. In evaluating the behavior of fiber-reinforced shotcrete in tension, various test methods are possible. Typically, bending tests can be used to determine the load-deflection relationship of a beam under either a three-point (EN 14651 notched beam)

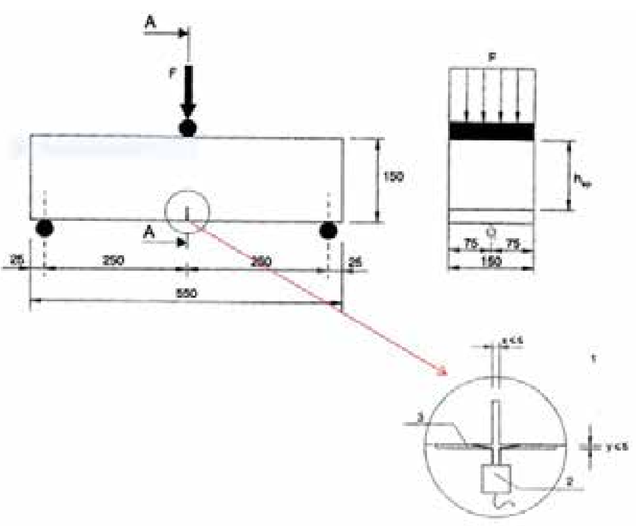


Fig. 3: EN 14651 Notched Beam Test for determining Structural Design Values

or four-point loading (ASTM C1609). From this, the flexural tensile strength can be determined.

The European EN 14651 three-point bending test with a notch standard is recommended by the international Tunnelling and Underground Space Association (ITA) Working Group 12 in their document entitled "Permanent Sprayed Concrete Linings", because the notch beam provides for better controlled crack growth and generally less scatter in the results. (Fig. 3) This test method is also preferred in many countries because it directly provides the parameters needed for structural designs done by the fib 2010 Model Code.

The different ways of specifying the ductility of fiber reinforced sprayed concrete in terms of residual strength and energy absorption capacity are not directly comparable. The increased use of permanent shotcrete final linings in underground construction means that there will be more specifications requiring the determination of the residual strength provided by the fiber reinforced shotcrete. (Fig. 4)

NEW TESTING STANDARD DEVELOPED - BS-EN 14488-3:2023 - 3 POINT BENDING TEST (PBT) ON NOTCHED PANEL)

Testing to determine the residual strengths for sprayed fiber-reinforced concrete can be difficult because specimens for the beam tests must be cut from sprayed panels. With the increased use of SFRPSCL, a new standard was developed which allows the residual strength parameters to be determined by performing a three-point bending test on the standard EN-type square panel. This new test combines the values provided by the standard notched EN 14651 type beam test with the advantages of the EN 14488-5 panel test used for energy absorption The same molds are used for the residual panel test and, due to the larger cracked section, the scatter is lower than the cut beams. (Fig. 5)

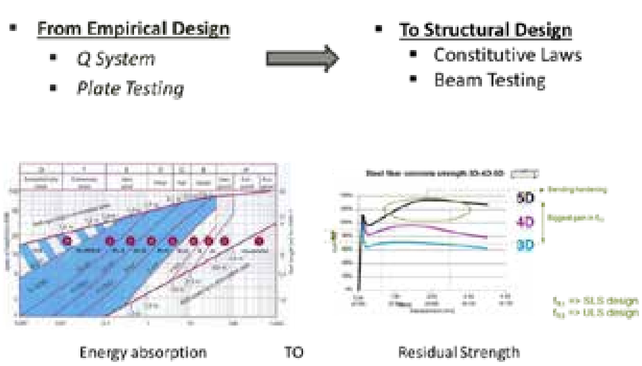


Fig. 4: Comparing Empirical to Structural Design

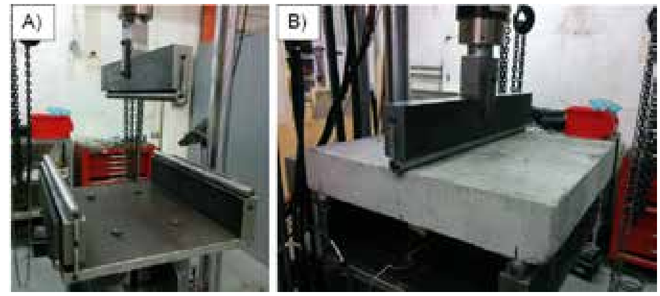


Fig. 5: A) Overview of 3PBT setup B) close-up during testing at Laval University

The advantages of this new 3 point bending test on a notched panel method in SFRPSCL applications include:

- The geometry and dimensions of the specimens, as well as the spray method adopted will ensure distribution of the fibers in the matrix, which is as close as possible to that encountered in the real structure.
- The dimensions of the test specimen will be acceptable for handling (no excessive weights or dimensions).
- The test will be compatible, with equipment and setups used in many normally equipped laboratories (no unnecessary sophistication).
- The geometry is the same as in the plate test for energy absorption.
- The plate can be sprayed on the job site — this eliminates the need to saw a beam out of a panel!
- The scatter will be lower than the current standardized beam tests because of the larger specimen size.
- The notch will provide a controlled cracking process, thereby reducing the risk of a sudden failure and fall.

- This test provides the required residual flexural strengths values needed forstructural designs.

Our hope in writing this article is that it encourages designers, contractors, and owners to specify and adopt the use SFRPSCL in future tunnel projects. Specifying permanent steel fiber-reinforced shotcrete linings in underground projects provides not just significant cost savings, but just as critical, helps us to significantly reduce the carbon impact of the underground construction industry and provide for a better environment and future for us all and our planet!

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__Benoit de Rivaz__ is a Global Technical and Business Development Manager for Bekaert Underground Solutions, with over 20 years dedicated to the technical development of Fibre Reinforced Concrete (FRC) for underground applications. Throughout his career, he has contributed to numerous large-scale international projects, research and development programs, and partnerships. Benoit has also authored over sixty papers which have been published in esteemed international conferences and magazines. Additionally, he is an esteemed member of several international committees, including ITA WG12, ITA TECH (Steering Board), EFNARC (Vice President), AFTES, and ASQUAPRO.

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Interviewing the Masters

Merl Isaak: A Pioneer in the Shotcrete Revolution

By Cara Baker, Managing Editor

Innovation may come from unexpected places, but it's almost always driven by individuals with a vision for improvement. One such individual is Merlyn "Merl" Isaak, whose contributions to the shotcrete industry and the formation of the American Shotcrete Association (ASA) have had a lasting impact. Isaak's journey from curious observer to key player in the shotcrete community is a story of dedication, collaboration, and a relentless pursuit of quality.

THE SPARK OF INTEREST

Isaak's involvement with shotcrete began through his work with the American Concrete Institute (ACI). As chairman of the Certification Programs Committee, Isaak was well-versed in the protocols of concrete testing and certification. It was during a presentation by Lars Balck (long-time ACI member and twice-former ASA President) that Isaak's interest in shotcrete was stimulated. Balck's proposal for an ACI shotcrete certification program had been turned down, but it caught Isaak's attention.

Around the same time, Chris Zynda (another prominent figure in the shotcrete industry and former ASA President), frequently brought shotcrete samples to Isaak's testing and inspection agency in Santa Clara, CA. Back then, shotcrete samples were often shot into wire cages, creating significant challenges to accurate testing. Isaak recalls the cumbersome process: "They'd bring in these specimens, and you had to strip the wire from the shotcrete so that the wire wouldn't influence the strength. It was really pretty awkward and very inaccurate."

Zynda's forward-thinking approach to shotcrete impressed Isaak, particularly its use in complex projects, like pools with curved surfaces or challenging forms. Zynda's efforts to replace traditional poured concrete with shotcrete due to its cost-effectiveness and versatility were making significant strides.

Inspired by these innovations, and recognizing the variability in the quality of shotcrete work across the board — especially between skilled shotcreters (formerly nozzlemen) and less experienced contractors — Isaak saw the need for a better system of quality control in testing the shotcrete and shotcreter workmanship.

THE BIRTH OF ASA

At about the same time, the idea of creating an organization to promote the shotcrete industry was taking shape; thus ASA was born. Isaak (and others) visualized collaboration between ASA and ACI, where ASA contractors and the American Shotcrete Association could sponsor the education and proctor the shooting of workmanship test panels, and ACI would handle the exams and certification processing.

To satisfy ACI's standards for establishing and maintaining a formal certification program, a survey was conducted of industry practice and needs. This was augmented with numerous meetings involving interested parties to work out details such as (but not limited to) oral and written exam questions, process and orientations to be tested (wet vs dry-mix shotcrete, vertical and overhead shooting, etc.), size and configuration of test panels, number of core samples, and grading of cores taken from shotcreted panels. All said and done, the resultant, formal industry-accepted program and its adoption into building code standards and specifications, attests to its success and the value it provides to the industry, supplying the quality standards necessary to ensure the advantages shotcrete brings to the industry.

LEGACY OF COLLABORATION

Isaak is quick to note that his participation was only a small part of a larger effort involving many industry experts. Along with Balck, he acknowledges the work of such other key figures as George Yoggy (50-year concrete veteran and recognized leader in the industry), Rusty Morgan and Patrick Bridger (both twice-former ASA presidents), and Richard Heitzmann and John Nehasil of the ACI, all of whom were also instrumental in advancing shotcrete technology

Entrevistando a los Maestros

Merl Isaak: Un Pionero en la Revolución del concreto lanzado

Por la Gerente de edición, Cara Baker

La innovación puede surgir de lugares inesperados, pero casi siempre es impulsada por individuos con una visión de mejora. Uno de esos individuos es Merlyn "Merl" Isaak, cuyas contribuciones a la industria del concreto lanzado y la formación de la Asociación Americana de concreto lanzado (ASA) han tenido un impacto duradero. El viaje de Isaak desde un observador curioso hasta una pieza clave en la comunidad del concreto lanzado es una historia de dedicación, colaboración y una búsqueda incesante de calidad.

LA CHISPA DEL INTERÉS

La participación de Isaak con el concreto lanzado comenzó a través de su trabajo con el Instituto Americano del Concreto (ACI). Como presidente del Comité de Programas de Certificación, Isaak estaba bien instruido en los protocolos de prueba y certificación del concreto. Fue durante una presentación de Lars Balck (miembro de ACI desde hace mucho tiempo y dos veces presidente de ASA) que se despertó el interés de Isaak por el concreto lanzado. La propuesta de Balck para un programa de certificación de concreto lanzado de ACI había sido rechazada, pero captó la atención de Isaak.

Al mismo tiempo, Chris Zynda (otra figura prominente en la industria del concreto lanzado y ex presidente de ASA) frecuentemente llevaba muestras de concreto lanzado a la agencia de pruebas e inspección de Isaak en Santa Clara, CA. En ese entonces, las muestras de concreto lanzado a menudo se lanzaban sobre jaulas de alambre, creando desafíos significativos para las pruebas precisas. Isaak recuerda el engorroso proceso: "Traían estos especímenes, y tenías que quitar el alambre del concreto lanzado para que el alambre no influyera en la resistencia. Era realmente bastante incómodo y muy inexacto."

El enfoque visionario de Zynda hacia el concreto lanzado impresionó a Isaak, particularmente su uso en proyectos complejos, como piscinas con superficies curvas o formas desafiantes. Los esfuerzos de Zynda para reemplazar el concreto colado de forma tradicional por concreto lanzado debido a su rentabilidad y versatilidad estaban haciendo avances significativos.

Inspirado por estas innovaciones, y reconociendo la variabilidad en la calidad del trabajo de concreto lanzado en general, especialmente entre lanzadores habilidosos (anteriormente llamados nozzlemen) y contratistas menos experimentados, Isaak vio la necesidad de un mejor sistema de control de calidad en la prueba del concreto lanzado y la mano de obra de los trabajadores.

EL NACIMIENTO DE ASA

Al mismo tiempo, la idea de crear una organización para promover la industria del concreto lanzado estaba tomando forma; así nació ASA. Isaak (y otros) visualizaron la colaboración entre ASA y ACI, donde los contratistas de ASA y la Asociación Americana de concreto lanzado podrían patrocinar la educación y supervisar la realización de paneles de prueba de los lanzadores, y ACI manejaría los exámenes y el procesamiento de la certificación.

Para satisfacer los estándares de ACI para establecer y mantener un programa de certificación formal, se realizó una encuesta de prácticas y necesidades de la industria. Esto se complementó con numerosas reuniones que involucraron a partes interesadas para resolver detalles como (pero no limitados a) preguntas de exámenes orales y escritos, procesos y orientaciones a probar (concreto lanzado vía húmeda versus vía seca, colocación vertical y sobre cabeza, etc.), tamaño y forma de los paneles de prueba, número de muestras de núcleos y evaluación de los mismos tomados de los paneles elaborados con concreto lanzado. Dicho y hecho, el programa resultante, formalmente aceptado por la industria y su adopción en los estándares y especificaciones del código de construcción, atestigua su éxito y el valor que proporciona a la industria, suministrando los estándares de calidad necesarios para garantizar las ventajas que el concreto lanzado ofrece a la industria.

and certification standards.

Even after his retirement, Isaak remained engaged with the industry, keeping track of developments and contributing as a consultant. Recently celebrating his 90th birthday, Isaak remains active, maintaining contact with the many friends he's made and encouraged over the years and sharing his time to provide this interview with *Shotcrete* magazine readers. He speaks highly of the current ASA leadership, particularly Charles Hanskat (ASA Executive Director), and the ongoing efforts to promote shotcrete through quality publications and educational resources. "ASA is the only real organization available to promote the shotcrete industry, and it's doing a fantastic job," he says. Similarly, ACI deserves credit for supporting and maintaining this highly recognized Certification program.

Isaak's story is a testament to the impact that dedicated individuals can have on an industry. His efforts not only helped establish ASA but also ensured that shotcrete would be recognized as a reliable, efficient, and essential construction method. The relationship between ACI and ASA continues to thrive, and the shotcrete industry has seen significant advancements in quality, testing, and application, benefiting construction projects worldwide. ASA is very thankful for the work of Isaak and the many others who have given so much of their time and knowledge to advance this industry!

SHOTCRETE ONLINE

Public access to the electronic version of Shotcrete magazine is available from www.shotcrete.org. To ensure notification of new issues, subscribe via **shotcrete.org/news/asa-e-newsletter-subscribe/**

LEGADO DE COLABORACIÓN

Isaak señala rápidamente que su participación fue solo una pequeña parte de un esfuerzo mayor que involucró a muchos expertos de la industria. Junto con Balck, reconoce el trabajo de otras figuras clave como George Yoggy (veterano de concreto de 50 años y líder reconocido en la industria), Rusty Morgan y Patrick Bridger (ambos dos veces presidentes de ASA), y Richard Heitzmann y John Nehasil de ACI, todos los cuales también fueron fundamentales en el avance de la tecnología y los estándares de certificación del concreto lanzado.

Incluso después de su jubilación, Isaak permaneció comprometido con la industria, manteniéndose al tanto de los desarrollos y contribuyendo como consultor. Recientemente celebrando su 90 cumpleaños, Isaak sigue activo, manteniendo el contacto con los muchos amigos que ha hecho y alentado a lo largo de los años y compartiendo su tiempo para brindar esta entrevista a los lectores de la revista concreto lanzado. Habla muy bien del liderazgo actual de ASA, particularmente Charles Hanskat (Director Ejecutivo de ASA), y los continuos esfuerzos para promover el concreto lanzado a través de publicaciones de calidad y recursos educativos. “ASA es la única organización real disponible para promover la industria del concreto lanzado, y está haciendo un trabajo fantástico,” dice. De igual manera, ACI merece crédito por apoyar y mantener este programa de Certificación altamente reconocido.

La historia de Isaak es un testimonio del impacto que los individuos dedicados pueden tener en una industria. Sus esfuerzos no solo ayudaron a crear la ASA, sino que también garantizaron que el concreto lanzado fuera reconocido como un método de construcción confiable, eficiente y esencial. La relación entre ACI y ASA continúa prosperando, y la industria del concreto lanzado ha visto avances significativos en calidad, prueba y aplicación, beneficiando a proyectos de construcción en todo el mundo. ASA está muy agradecida por el trabajo de Isaak y de muchos otros que han dado tanto de su tiempo y conocimiento para avanzar en esta industria.

HAVE YOU CHECKED OUT ICRI'S NEW WEBSITE?

ICRI's redesigned website and member portal officially launched in early 2024. The website includes important updates to their association's technology. The design connects customers and members with ICRI and improves the user experience.

ICRI's redesigned website offers many upgraded features, including:

- User-friendly navigation that is modern and mobile responsive — which looks great on both laptops and phones!
- Key ICRI features — chapters, committees, membership, certification and education, and our bookstore — are all easily accessible via the homepage.
- Dynamic events calendar keeps you updated on the latest programs, meetings, and webinars within ICRI and the industry.

Visit their website at **www.icri.org**.

SIKA UPDATES

SIKA BUILDS NEW STATE-OF-THE-ART WAREHOUSE IN MARION, OH

The Marion Regional Distribution Center is Sika's newest fully automated warehouse. This 150,000 ft^2 (14,000 m^2) facility opened July 17, 2024, and will inventory finished goods for multiple strategic construction and industry markets. It will serve as the Central/East Coast regional distribution hub with a direct-to-customer concept. The new warehouse is the first of its kind for Sika in the United States, using fully automated equipment including guided vehicles, self-directing forklifts, inbound and picking conveyors, and automated cameras and contour stations for tracking handling units and verifying pallet transport safety throughout the warehouse.

"Sika has significantly grown over the past years, continuously expanding the product range for our customers and our reach to the markets," said Sika Corporation USA CEO and President Jim Walther. "Our investment in building this state-of-the-art warehouse in the United States, using fully automated equipment, will strengthen our commitment of expediting the product supply to our valued customers."

SIKA BREAKS GROUND ON NORTHEAST ANCHOR PLANT IN NEW JERSEY

Sika, the world leader in the development and production of systems and products for bonding, sealing, damping, reinforcing, and protection in the building sector and automotive industry, has broken ground for a new state-of-the-art 250,000 ft^2 (23,000 m^2) mortar production plant.

This landmark investment marks a significant milestone in the history of Sika Corporation in the United States. The Northeast Anchor site will produce a full range of mortars including high-performance cementitious grouts, self-leveling mortars, and mixtures for shotcrete which include products for residential and commercial construction applications. Sika will create 50 jobs in Cumberland County.

"This new investment into our supply chain and manufacturing footprint is a testament to our unwavering commitment to the Northeast Region and the surrounding areas of the United States as a prime production hub," said Sika Corporation USA CEO and President Jim Walther. "This strategic move is poised to bolster Sika's leadership position in providing innovative construction solutions to our valued customers."

Sika's investment in the Northeast Anchor site is to handle the increasing volume demand within proximity to major strategic metropolitan markets, with a long-term strategy to expand technology product lines to extend reach into our markets. It's set to begin operations in the second half of 2025.

BLASTCRETE ANNOUNCES DISTRIBUTION PARTNERSHIP FORMING MECBO AMERICA

Blastcrete Equipment LLC, an industry-leading manufacturer of concrete pumps, shotcrete and gunite equipment, and accessories, announces a distribution and service partnership with Italian concrete equipment manufacturer Mecbo Srl. The alliance forms "Mecbo America: a Division of Blastcrete." This partnership will provide customers in North, Central, and South America access to cutting edge Mecbo products, enhance the Blastcrete offering with new models designed around Mecbo pump technology, and ensure a solid parts and service support network throughout North America.

"Blastcrete is well known and trusted in the North American market and has a team with specialized knowledge in concrete pumping and placement as well as servicing concrete pumps," said Mecbo Communications Director Daniella Tarozzi. "This partnership will ensure customers get the best product solutions for their application and local support and service."

Blastcrete will leverage the quality and innovative products designed by Mecbo with an internal capability to modify and customize the equipment design to customer specifications. Additionally, Blastcrete will incorporate Mecbo pump technology into their trailer-mounted pump designs to meet unique customer needs in pool installation, deep foundation installation, and other high-volume applications.

Mecbo America will offer multiple Mecbo products, including their Benton Cap concrete mixer and CARTRACK P6. The Benton Cap is a mixer-pump installed on an axle with a crawler undercarriage. The CARTRACK P6 pumping unit is highly versatile, capable of being installed on crawlers, wheels, trucks, or tracks.

Both models allow customers to choose between an electric or diesel engine, with a sound-proof option for diesel. Each also contains a work and maintenance station, water tank, and radio control for handling. Mecbo America will also offer the Scorpion, Robotrack, and Car Cingolo — all of which can be found on their website at Mecbo.it.

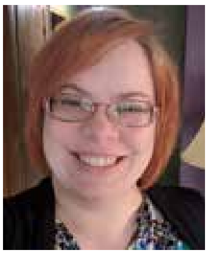
"We are incredibly excited to partner with Mecbo. This agreement allows us to expand our quality equipment offerings to our customers," said Blastcrete Co-CEO Scott Knighton. "It's a win for Blastcrete, for Mecbo, and most importantly, it is a win for our current and prospective customers across the Americas."

In addition to expanding availability of Mecbo products, the partnership provides customers the security of knowing a top-notch product service provider is backing the equipment close to home. Blastcrete's technicians are available online and by phone for equipment questions, troubleshooting, and replacement parts. They also offer free customer training. Contact them at 1-800-235-4867 or visit **www.blastcrete.com**.

ASSOCIATION NEWS

american shotcrete association asa

OUR NEW MANAGING EDITOR!



Cara Baker joined our team at the end of May 2024 as the new Managing Editor of Shotcrete Magazine. She loves all things word-related (etymology, word puns, typography, etc.) and is excited to bring years of editing, writing, and design skills to the ASA.

Having served in the U.S. Navy as a print photojournalist and editor, Cara has documented several historic events, including the maiden deployment of USS Ronald Reagan (CVN 76) during Operations Iraqi and Enduring Freedom. She rejoined the civilian population in 2007, earning her associate and bachelor's degrees in graphic design while writing for an online party supplies company. Following that up with six years as a corporate copywriter/editor, Cara twice served as that company's Relay for Life team captain, earning them the position of first team in Jackson County, MI to achieve Ruby Status ($50k+ raised during the year).

Cara jumped head-first into magazine development upon joining ASA, and she's ready and waiting to hear (and read) your shotcrete stories. Please reach out any time at cara.baker@shotcrete.org or 248.973.7832!

WOMEN IN SHOTCRETE SURVEY

Call to all women working in the shotcrete industry! The 4th Quarter 2025 issue of Shotcrete magazine wants to recognize you! Scan or click this QR code and share your journey to encourage and celebrate the women in shotcrete!

SUBMISSIONS NEEDED FOR SHOTCRETE SPOTLIGHT

ASA members, here's your chance to highlight the individuals and teams in your companies that help you shine! Scan or click the QR code to learn more or nominate someone!

2024 ASA FALL COMMITTEE MEETINGS

NOVEMBER 2, 2024
PHILADELPHIA MARRIOTT DOWNTOWN
PHILADELPHIA, PA

The work of ASA depends on volunteers like YOU to be active and contribute your experience and knowledge to better the industry. ASA Committees meet in person twice a year (Spring, in conjunction with ASA's annual Shotcrete Convention and Technology Conference, and Fall, near to ACI's Fall Concrete Convention). This Fall we will be meeting in the same hotel as the ACI Convention: Philadelphia Marriott Downtown. All are welcome to attend; registration is required this year for the meetings and the optional networking dinner Saturday evening. Scan or click the QR code to register!

MEETING SCHEDULE

8 – 9 a.m. Underground Committee
9 – 9:30 a.m. Morning Networking Break
9:30 – 10 a.m. Contractor Qualification Committee
10 – 11:30 a.m. Pool & Recreational Committee
11:30 a.m. – 12:30 p.m. Lunch
12:30 – 1:30 p.m. Education & Safety Committee
1:30 – 3:30 p.m. Membership & Marketing Committee
3:30 – 4 p.m. Afternoon Networking Break
4 – 6 p.m. Board of Direction

DISCUSSION HIGHLIGHTS

Membership & Marketing Committee

- Develop a mentorship program
- Create outreach opportunities for newer, younger companies to connect with seasoned, veteran companies

Underground Committee

- Support the development an ACI Shotcreter Certification for Mechanized Placement
- Work on a Position Statement on early-age strength testing of shotcrete

Pool & Recreational Committee

- Launch the new Pool Contractor Qualification Program
- Write Position Statements for the Skatepark industry and for Reinforcement in Pools

Education & Safety Committee

- Compile Safety Toolbox talks as a corporate resource

Contractor Qualification Committee

- Review & revise renewal criteria for qualification

This is your chance to not only help ASA develop programs and documents that move our industry forward, but to also network with the industry leaders committed to advancing shotcrete.

WU C2241: QUALITY SHOTCRETE PLACEMENT FOR POOLS — KNOW IT, DEMAND IT

Saturday, November 9
International Pool | Spa | Patio Expo
Kay Bailey Hutchison Convention Center | Dallas, TX

IACET – 0.8 Units
Cost: $1,200 Early Bird; $1,300 Regular

Although you may have used shotcrete subcontractors for years, do you know what to look for to be sure you're achieving a quality installation? Shotcrete is a familiar and widely used concrete placement method used for various applications, including swimming pools. Compared to poured concrete, it involves fundamentally different equipment, material selection, crew responsibilities, application techniques, testing, curing, and personal protection. This course from Watershape University, presented by the American Shotcrete Association, provides crucial guidance on over 40 critical elements of shotcrete application that on-site pool-contractor personnel can use to properly evaluate the overall quality of shotcrete placement. Armed with this information, observers can readily use visual clues that confirm that the material's placement is creating a high-quality and durable concrete pool shell. Key knowledge areas include an overview of material selections, equipment, placement techniques, finishing, curing, protection, testing, and jobsite safety. This vital information will help the pool contractor or owner verify they are getting quality work from their shotcrete subcontractors. It may also be useful to the shotcrete contractor to better communicate and confirm the quality of their work to their pool contractors or owners.

- **Learning Objective 1:** Gain a fundamental understanding of the wet-mix and dry-mix (gunite) shotcrete process.
- **Learning Objective 2:** Describe ACI and other Industry standards that detail acceptable shotcrete placement.

- **Learning Objective 3:** Identify quality materials and placement methods.
- **Learning Objective 4:** Recognize proper application techniques, and missteps that can reduce the quality of the final product.

WORLD OF CONCRETE®

WORLD OF CONCRETE 2025 – REGISTRATION OPENS SEPTEMBER 2024

JANUARY 21 – 23, 2025
LAS VEGAS CONVENTION CENTER
LAS VEGAS, NV

Save the date and use ASA's source code A17 for the lowest discounted exhibit-only admission pass at just $25, available online until December 12, 2024! Rates will increase afterward. Our General Membership meeting and reception will be held on Tuesday, January 21st, after the show. Look for Registration to open here: **www.shotcrete.org/woc**

SHOTCRETE CONVENTION & TECHNOLOGY CONFERENCE

2025 ASA SHOTCRETE CONVENTION AND TECHNOLOGY CONFERENCE

MARCH 9 – 11, 2025
THE DESOTO | SAVANNAH, GA

SAVE THE DATE! We are hosting our annual ASA Shotcrete Convention and Technology Conference at The DeSoto in Savannah, GA, where the warmth and charm of Savannah meet modern comfort to create an unforgettable atmosphere. Our convention offers a unique opportunity to explore shotcrete applications, innovations, and future advancements in the shotcrete industry. Attendees are also invited to participate in ASA's 2025 Spring Committee and Board meetings, and ASA will be celebrating our 2024 Outstanding Shotcrete Project Award winners at our Annual Awards Banquet on Tuesday. Join us for this excellent networking and learning experience! Look for details and registration to open in October: Click or scan the QR code for more info!

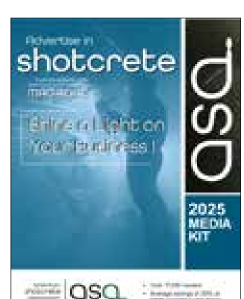
BOOST YOUR BRAND VISIBILITY AND CONNECT WITH YOUR TARGET AUDIENCE: BECOME A SPONSOR TODAY!

Make sure your company is recognized among the leaders of the shotcrete industry by sponsoring the 2025 ASA Shotcrete Convention & Technology Conference! As a sponsor, you will receive a variety of exposure opportunities:

- Convention Venue
- Recognition at the Awards Banquet (reception, dinner, & awards program)
- 1st Quarter 2025 Awards Issue of Shotcrete magazine
- ASA What's in The Mix (eNewsletter) & Social Media promotions
- ASA Website, Convention page – all year

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

- **BIG SHOOTER ($5000):** Exposure with the most prominent placement of your company logo throughout all promotional materials; one complimentary tabletop exhibit (first come, first served — must confirm interest at time of application); and unlimited Half Price Awards Banquet Tickets.
- **GOLD ($2500):** Exposure — prominently placed after Big Shooters — of your company logo throughout all promotional materials; one complimentary tabletop exhibit (first come, first served — must confirm interest at time of application); and one (1) Half Price Awards Banquet Ticket.
- **SILVER ($1000):** Exposure — prominently placed after Gold Sponsors — of your company logo throughout all promotional materials.



JOIN OUR SHOTCRETE MAGAZINE ADVERTISERS!

The 2025 Media Kit is now online! Place your insertion orders now to ensure inclusion in all four 2025 issues of *Shotcrete* magazine! Early Bird Discount Deadline: November 1, 2024. Advertising in Shotcrete magazine positions your company foremost in the shotcrete industry. With an average savings of 25% or more compared to other leading trade association magazines, you can reach the companies and people that you need to grow your business at a competitive price. These rates certainly provide you with the most bang for your advertising dollars! Visit **shotcrete.org/MediaKit** for more information or contact us at info@shotcrete.org to submit your insertion order.

Gary Spinelli
Patriot Shotcrete

Nominated by Frank Townsend

Gary started in this industry three years ago as a local 282 Union teamster. He is a husband as well as a father to some great boys, whom he cherishes. The man could be defined as a Swiss army knife: He can do it all or make sure it is done correctly. He asks questions and follows through. Gary is our Shop Manager and Procurements Manager.

Anytime and anywhere a mission needs to be done, Gary's name is attached. From inventory management to financial management (in getting the best price on supplies and materials), to marketing, he is the man. He's a leader for Patriot Shotcrete, inspiring the workforce, creating a fun, positive work environment, and 100% a team guy. Gary's organizational prowess is also impeccable: He knows where everything is, when the fleet needs to be serviced, and when he'll be making a run to pick up fixed chipping guns.

Anyone that works with and around Gary knows his radiant personality, and as for the vendors — well, sorry, he is a chewer and negotiates to get the bottom price with the best service.

He communicates early and often, and reinforces even when it's something you probably don't want to hear. He's a company man with the fortitude to correct anyone when a situation is wrong, and his work ethic is Thomas the Train: He doesn't stop. Early, late, weekends — his hard work contributes to the team's success.

Gary is surrounded by an excellent support system, including mechanics, friends and confidants. He works very closely with the field crew and Ismael, our mechanic. He also implements lockdown security measures for loss prevention, so we're confident that when it goes past Gary, he's identified everything that goes to and from every project.

He is a pusher, a driver to get the job done, and will often dive in to help the crew. Gary always goes above and beyond the call of duty in pursuing excellence. He is integral to the Patriot team, and to our success.

SHOTCRETE SPOTLIGHT NOMINATIONS

Highlight the individuals or teams that make your company shine. Scan or click the QR code to learn more or nominate someone!


steel fiber reinforced concrete
Dramix®
Bekaert
The future of reinforced low carbon linings
Sustainable & durable solutions
Safely saves concrete, steel & time
EPD certified
Dramix® 3D
Dramix® 4D
construction.bekaert.com
© Image by Crossrail

SUSTAINING CORPORATE MEMBER PROFILE

KAATERSKILL KAHNCRETE

The first time I saw shotcrete, I was 18 years old and watching my town's new skatepark being built. I was there with my dad, who is a builder, an artist, and my idol. His reaction? "This is the coolest thing you could ever do with concrete."

We'd been raising money with family and friends for five years to make this dream come true. When the company showed up to build the park, I had no idea that the rest of my life was about to be changed. Fifteen years and 100+ skateparks around the world later, I've never stopped building with concrete.

THE SKATEPARK INDUSTRY

Shotcrete is a necessity in the skatepark industry globally. For many years, my fascination with concrete revolved around making my ideas and other people's visions a reality. At this point, shotcrete placement, to me, was just another part of the process — I hadn't been shown how important proper shotcrete application was to the longevity of our finished projects.

Four years later, I was introduced to Oscar Duckworth. He was hired to shoot a skate bowl that I was a part of constructing in California. Up until this point, the shotcreter had just been whoever on the team was big enough to hold the hose. On day one with Oscar on that project, he held a meeting with our crew to make sure he understood our layout plan. His question, "What are your expectations for the day?" has stuck with me ever since. This was the first time I saw the leadership role of a shotcreter — something I now strive to do on every job.

OWNING & OPERATING

I bought my concrete pump seven years ago, a 1998 REED M40. It didn't run — it was filled full of concrete and needed a lot of love to be restored.

In an effort to gain as much knowledge as quickly as possible, I decided to become an ACI-certified shotcreter. I was lucky enough to take my certification with Oscar as my educator and examiner. He is a great role model on how to obsess over what you love, and to understand

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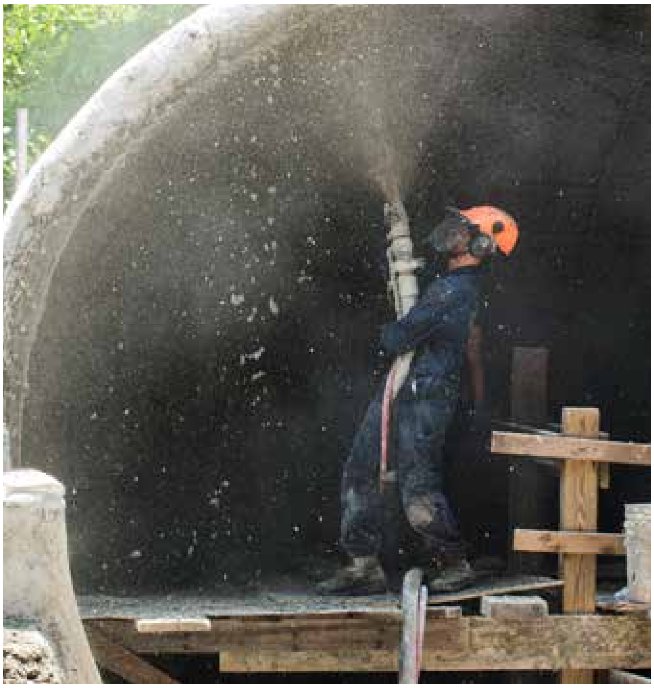


Jasper Kahn: FDR Skatepark Cradle in Philadelphia, PA

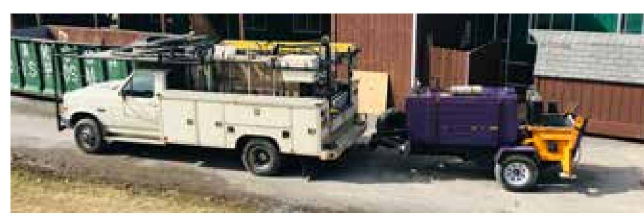
Abandoned Pool (Before): Johnny O'Connor's Windham Mountain Inn in Windham, NY

Skate Bowl Retrofit (After): Johnny O'Connor's Windham Mountain Inn in Windham, NY

Ceremonial Bowl (Artist - Chemi Rosado-Seijo): Art Omi in Ghent, NY

Team Kahncrete - Ryan Cardone, Justin McDowell, Brandon Chrisjohn, Matty Sorrano: TunnelTeller (Artist - Alicja Kwade), Art Omi in Ghent, NY

Jasper Kahn: Leominster Skate Park in Leominster, MA



Shotcrete Setup: 1998 REED M40, 2001 Compair 200 CFM, 1993 Ford F-Super Duty

that change is constant — today will be different, so will tomorrow, and every other day in the future. All the information that we know, we use to help us get through a new problem we haven't experienced yet; so we are always ready for the challenge!

Founded in 2019, Kaaterskill Kahncrete has been exploring what is possible with the versatility and creativity of shotcrete, with our main work centered around skateparks. We also do a variety of projects including swimming pools, decorative design builds, art installations, and structural concrete work.

I am most stimulated when working as part of a team, exchanging new techniques, ideas, and skills. My mission is to bring greater awareness of best practices for shotcrete application to our industry by hosting the first **Skatepark Summit: Shotcreter Certification** here in New York in March 2025. Though open to all interested in a Wet-Mix Shotcreter Certification, we hope that those involved in building skateparks would join us in this unique opportunity to network and engage with our community to share insights and grow our knowledge on shotcreting in the skatepark trade.

Working with shotcrete has shown me how much both perseverance and dedication are needed to be successful, and how much I enjoy pushing myself to my mental and physical limits.

Safety first, quality second — die hard!

JOIN US AT OUR SKATEPARK SUMMIT

ACI Shotcreter Certification Session (Wet-Mix)
March 21-23, 2025 | Saugerties, NY
Interested? Email: TeamKahncrete@gmail.com

CORPORATE MEMBER PROFILE

We are a three-generation, family-owned and operated business founded in 1975 by the late Patrick McNamara ('Mick' or 'Mickey', as most of you would've known him). It is with great pride that we look forward to our 50th anniversary next year with fathers, sons, cousins and grandsons actively involved in our operations.

Spillway Restoration: We specialize in the meticulous restoration of spillways. Our expert team handles projects like this 550 feet across, 30 feet tall, with up to 8 inches thickness of dry-mix shotcrete. All work was efficiently carried out using crane and barge equipment.

Mick's guiding principle was, "Excellence in work leads to remarkable success," and our mission has always been to ensure the longevity of our company through repeat and referral business achieved by customer satisfaction in all areas, including timeliness, attention to detail, and service-minded attitudes. We know that your reputation is only as good as the results of your last job; that's why we pride ourselves on a result-oriented approach.

"My day goes from 4 in the morning until night. I love it, and our team is awesome," said Premier Gunite LLC President Travis McNamara. "All of us have been together for a long time; at least 5 years minimum tenure. We treat them really well, and I keep them involved in all the decisions I make."

At Premier Gunite, LLC, we use our collective experience to keep your project on track, on time, and on budget. "We've had several projects where the team worked really well together to overcome logistical issues and make things happen. We wouldn't be here without the team that we have," McNamara said.

Our services include dry-mix shotcrete (Gunite), wet-mix shotcrete, and premixed bulk concrete materials, using only the latest and most effective technologies for our shotcrete equipment, along with top-quality materials and the experience of professionals to collaboratively assure a professional service is provided.

CONTACT INFORMATION:

Premier Gunite LLC
27484 258th Street, Holcombe, WI 54745
Phone 715.382.4296 | **PremierGuniteLLC.com**

Left & Above: *During the restoration of a dam Near Lake Superior, dry-mix shotcrete was employed based on logistical considerations.*

We were tasked with applying a wet-mix shotcrete overlay at a depth of 4+ in. on a 27 million gallon lagoon due to the improper placement of concrete that was either failing or had already failed.

Left & Below: *Stone foundation restoration using Wet + Dry Shotcrete*

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.

Geo Craft Builders
www.geocraftbuilders.com

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

Artisan Skateparks
www.artisanskateparks.com

Consolidated Shotcrete Inc.
www.consolidatedshotcrete.ca

REED Shotcrete Equipment
www.reedpumps.com

Coastal Gunite Construction Company
www.coastalgunite.com

Construction Forms
www.ConForms.com

Imerys
www.imerys.com

Geo-Rope Ltd. (Canada)
www.geo-rope.com

A & B Gunite
www.abpoolsub.com

Ocean Rock
www.oceanrockart.ca

MAPEI Underground Technology Team
www.utt-mapei.com

COST of Wisconsin Inc.
www.costofwisconsin.com

The Quikrete Companies
www.quikrete.com

Nationwide Shotcrete Inc
www.nationwideshotcrete.com

Shotcrete Contractors Inc.
www.shotcretecontractors.com

Lanford Brothers Company Inc.
www.lanfordbrothers.com

Buesing Corporation
www.buesingcorp.com

Master Builders
www.master-builders-solutions.com

Baystate Shotcrete LLC
www.baystateshotcrete.com

Prestige Gunite & Shotcrete Inc
www.prestigeconcrete.com

Western Shotcrete Equipment
www.wseshotcrete.com

CROM LLC
www.cromcorp.com

Kaaterskill Kahncrete
www.kahncrete.com

Sika STM - Shotcrete, Tunneling & Mining (Canada)
www.sika.com

Sika STM - Shotcrete, Tunneling & Mining (USA)
www.sika.com

SHOTCRETE FAQs

As a service to our readers, Shotcrete magazine includes selected questions and answers by the American Shotcrete Association (ASA). Questions can be submitted to info@shotcrete.org. Selected FAQs can also be found on the ASA website at www.shotcrete.org/FAQs.

QUESTION:

Can a waterproofing agent be added to dry-mix shotcrete?

ANSWER:

Shotcrete is a placement method for concrete. Dry-mix shotcrete materials are often supplied in prepackaged bagged mixtures. The supplier can include a variety of materials to reduce the permeability of the hardened concrete placement. Silica fume and fly ash are supplementary cementitious materials (SCM) that will reduce the permeability of the hardened concrete and are routinely available. There are also crystalline admixtures that can be included in the prepackaged mixtures and will reduce permeability.

However, good quality concrete is functionally liquid tight and should prevent water flow through a structural concrete section. ASA recommends a 4000 psi (28 MPa) minimum 28-day compressive strength of concrete for shotcrete placement. This provides adequate paste content for low permeability and a mixture that can more easily encase embedded reinforcement. Our ASA Pool and Recreational Committee Position Statements - "Compressive (Strength) Values of Pool Shotcrete" and "Watertight Shotcrete for Swimming Pools" gives background information that can be helpful in evaluating shotcrete mixtures for liquid tightness (**shotcrete.org/resources**).

QUESTION:

My wife and I have a CBS-constructed home in South Florida. Too frequently we have experienced hurricanes. We are planning on reroofing our home, and having read about the advantages of shotcrete, I wondered how shotcrete would perform in that service. I understand that issues of support would need to be reconciled. But how would shotcrete withstand the humidity, rain, and constant sun? Would cracks in time inevitably appear, leading to roof leaks? Could leaks be repaired relatively easily? Is this a viable option for shotcrete?

ANSWER:

Shotcrete is just a placement method for concrete. Using proper concrete materials, placement equipment and technique, you should have quality, high strength, low permeability concrete structure that will withstand the Florida environment for decades. Shotcrete placement is routinely used for constructing concrete pools and liquid storage tanks that are functionally watertight with substantial water depths. To help provide strength, low permeability, long life, and adequate paste to properly encase the embedded reinforcing, we recommend a minimum strength of 4000 psi (28 MPa) for all shotcreting.

Appropriate amounts of reinforcing in the design help to resist cracking of concrete. You should retain a professional engineer with concrete design experience to design the roof for the loading and exposure conditions expected. For the construction, hire a shotcrete contractor experienced in placing structural concrete, and using American Concrete Institute (ACI) certified shotcreters (formerly called nozzlemen) in the shotcrete process used, i.e. wet or dry. You may find our ASA position statement on the "Shotcrete Contractor and Crew Qualifications" helpful in establishing the credentials of a shotcrete contractor. You can also check our online Buyers Guide (**shotcrete.org/BuyersGuide**) for our member companies who provide services in Florida.

QUESTION:

We used a shotcrete crew to shoot walls for a small house. I have been calculating concrete for a few decades and the walls calculated at slightly under 20 yd^3 (15 m^3). We used 22.5 yd^3 (17.2 m^3) and still ran short by nearly 1 yd^3 (0.8 m^3) in the gables. There is 3 to 4 yd^3 (2.3 to 3.0 m^3) of concrete waste from the cutting that I had to buy and then haul off. My question is if this is considered normal or even close? Is there a print reference for better procedures than they were using? It is my opinion that poor technique caused excessive waste and excessive effort in the cutting/ finishing. In footers, flat work, and formed structure I don't have much waste and use a small crew without over tasking with use of good tools and techniques.

ANSWER:

ACI PRC 506-22 Shotcrete Guide has the table below. This is an excellent primer on shotcrete placement. You can order the downloadable PDF at the American Concrete Institute website, concrete.org.

Table 3.4.1.12.1—Approximate range of rebound losses based on experience

Surface	Percent of Rebound
Floor or slabs	0 to 10
Sloping and vertical walls	10 to 30
Overhead work	10 to 50

We often say 10 to 15% is normal for vertical walls. However, quantity of rebound depends on the shotcreter's placing techniques, orientation, and the slump of the concrete mixture. A good shotcreter should be able to shoot close to the final thickness to reduce cuttings. Proper concrete velocity and angle of shooting will also reduce rebound. So, your 23.5 yd^3 used and estimated as 20 yd^3 is about 18% overage because of rebound and apparently cuttings. If you assume rebound is half that and cuttings the other half, the rebound portion is 9% and not unusual.

Though shotcrete has slightly higher concrete material cost compared to form-and-pour, there are significant savings by cutting formwork expense substantially.

QUESTION:

I have been researching shotcrete industry standards and came across your information on the ASA website. I am reaching out for your knowledge regarding a severe epidemic of ASR in thousands of pools built in Central Texas (affected pools built between 2017-2023). We are one of those victims who built a pool in 2020, which now sits empty with extreme cracking throughout, unable to hold water, and progressively collapsing in on itself. Our pool first started cracking at 7 months old (even thought to be leaking at 4 months old) with no idea our pool was eventually going to cost thousands in water bills before learning about ASR. As a homeowner, we took on the burden of "proving" ASR, having an engineering report with cores from the pool shell analyzed petrographically. The testing confirmed that our pool is a complete loss (both ASR throughout pool and DEF in bottom lower third of pool- we have a very large 60 ft (18 m) resort style pool. I am reaching out to see if you had any insight into recognized standards for shotcrete in the pool industry with relation to: use of fly ash to mitigate ASR; any testing requirements prior to shotcreting; any requirement of retaining a receipt of mixture ingredients per job; necessary cooling techniques for thick applications of shotcrete; or any other helpful information you could offer.

ANSWER:

Shotcrete is a placement method for concrete. All hardened properties and resistance to internal and external deterioration are the same as cast-in-place concrete.

ASR was first identified over 70 years ago as a potential problem with some aggregates in concrete. ASTM has had standardized test methods to identify ASR potential for over 20 years. Concrete suppliers of ready-mix concrete are usually members of the National Ready-Mix Concrete Association (NRMCA).

NRMCA has a PDF "Guide to Improving Specifications for Ready-Mixed Concrete" that has detailed guidance for concrete suppliers and specifiers on ASR testing. The Portland Cement Association (PCA) also has a good document (co-sponsored by NRMCA) produced in 2007 "Diagnosis and Control of Alkali-Aggregate Reactions in Concrete".

Thus, one would expect the concrete supplier used on your project was aware of the potential for ASR and should have tested their aggregate sources. This would be something you, as a homeowner, would likely not be aware of or request.

Regarding DEF, it requires an internal concrete temperature of 70 °C (160 °F). Usually this is an issue with very thick (greater than 2 to 3 ft (0.6 to 0.9 m) thick mass concrete sections (like dams, large bridge piers). Thin pool floors and walls 6 to 12 in. (150 to 300 mm) would not be considered mass concrete. Concrete is usually delivered at no more than 95°F (35 °C) but builds internal heat by hydration of cement. There may have been a significant temperature increase by solar gain in the floor. Continuous water curing for a minimum of 7 days after placement is recommended and may have helped keep the concrete cooler. Some builders flood the pool soon after placement or use sprinklers or dripper hoses to keep the concrete surface moist. The American Concrete Institute (ACI) has many documents about mass concrete and the effects of DEF as well as recommendations and a specification for curing of concrete. We have an ASA Pool and Recreational Shotcrete Committee Position Statement "Curing of Shotcrete for Swimming Pools" (**shotcrete.org/resources**).

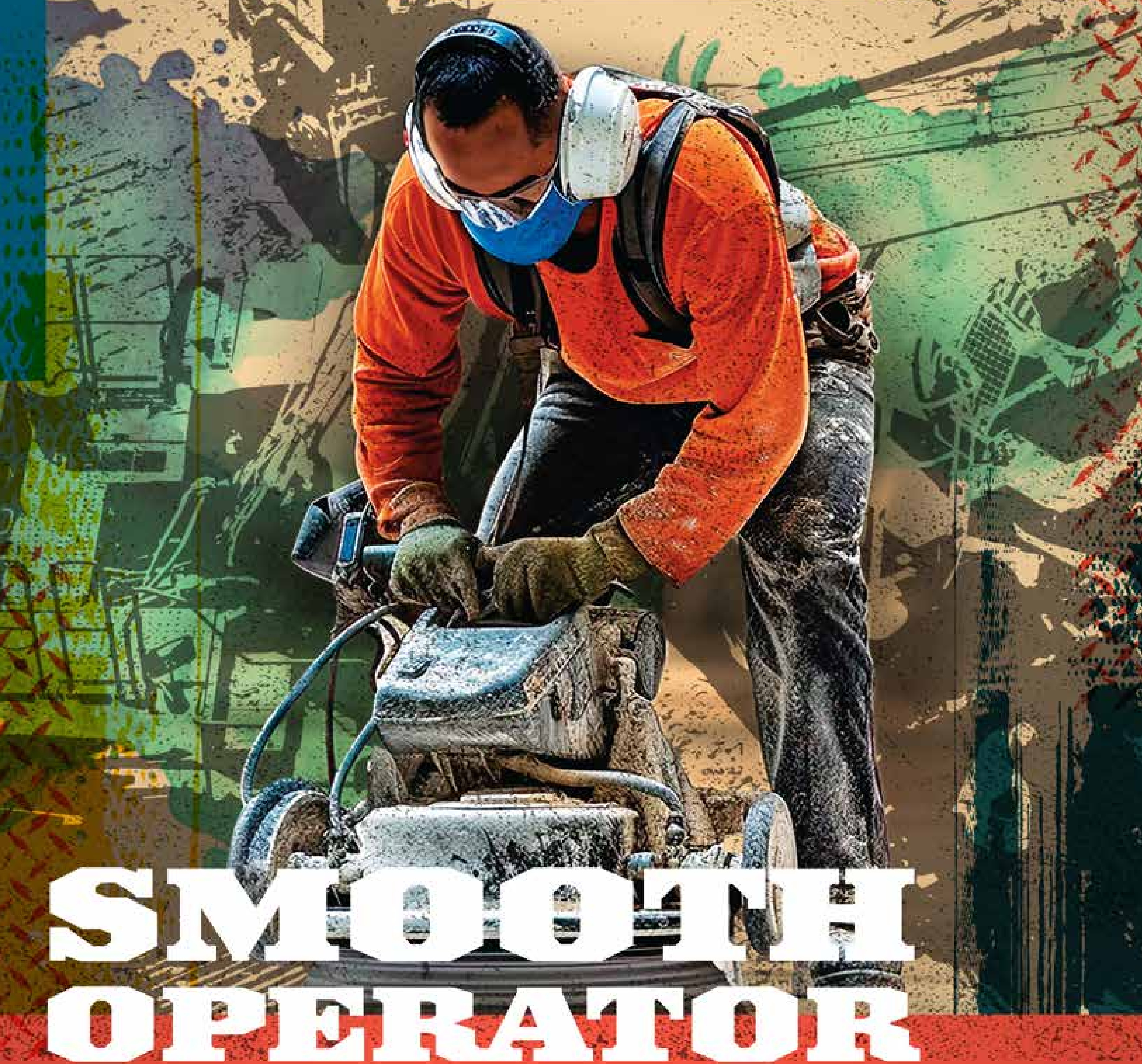
Thus, there is a lot of documentation about ASR and DEF that is readily available. And these have been available for decades. Your questions about fly ash, site testing of concrete, verification of concrete mixture design, are standard concrete construction procedures. ACI 301 Specifications for Concrete Construction (ACI 301-20) is a good reference specification. ACI 207.1R-05 Guide to Mass Concrete gives guidance on cooling for mass concrete, though one would not usually consider a relatively thin concrete floor as mass concrete.

Hope this helps explain why your concrete has issues and likely won't be serviceable long term. The engineering evaluation you provided looks reasonable and the conclusions are appropriate. As an owner, you certainly should expect quality concrete in your pool to be serviceable for decades. The responsibility for furnishing acceptable quality concrete in your pool lies between the concrete supplier and pool builder. The responsibility for protecting the concrete from excessive temperatures and ensuring proper curing falls on the pool builder.

SHOTCRETE CALENDAR

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

SEPTEMBER 23, 2024	**Recognizing Quality Shotcrete** ACI Mid-Atlantic Resource Center | Columbia, MD
SEPTEMBER 24-26, 2024	**Mine Expo 2024** Las Vegas Convention Center | Las Vegas, NV
SEPTEMBER 27, 2024	**Recognizing Quality Shotcrete** ACI MidWest Resource Center | Elk Grove Village, IL
OCTOBER 2-4, 2024	**ACI Shotcreter Certification (Wet & Dry Mix)** Minova | Millstadt, IL
OCTOBER 3, 2024	**Recognizing Quality Shotcrete** ACI SoCal Resource Center | San Bernardino, CA
OCTOBER 18-20, 2024	**ACI Shotcreter Certification (Wet & Dry Mix)** Applied Shotcrete | Sebastopol, CA
OCTOBER 22-25, 2024	**2024 ICRI Fall Convention** Sheraton Denver Downtown Hotel | Denver, CO
NOVEMBER 2, 2024	**ASA 2024 Fall Committee Meetings** Philadelphia Marriott Downtown | Philadelphia, PA
NOVEMBER 3 - 6, 2024	**ACI 2024 Fall Concrete Convention** Philadelphia Marriott Downtown | Philadelphia, PA
NOVEMBER 9, 2024	**ASA Quality Shotcrete for Pools — Know It, Demand It | IPSP (Pre-Show)** Kay Bailey Hutchison Convention Center | Dallas, TX
NOVEMBER 11, 2024	**ASA Pool Shotcrete Inspection &Quality Application | IPSP (Pre-Show)** Kay Bailey Hutchison Convention Center | Dallas, TX
NOVEMBER 12 - 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
MAR. 30 - APRIL 2, 2025	**2025 Spring ACI Concrete Convention** Sheraton Centre Toronto Hotel | Toronto, ONT Canada
MORE INFORMATION	To see a full list, current updates, and active links to each event, visit www.shotcrete.org/calendar.



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Grand Rapids, MI

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Daniel Orapello
NYSDOT
Albany, NY

ACADEMIC

Wei Victor Liu
University of Alberta
Edmonton, AB Canada

INTERESTED IN BECOMING A MEMBER OF ASA?

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

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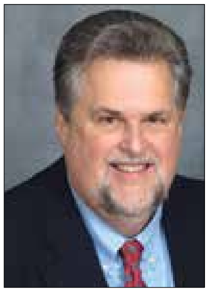
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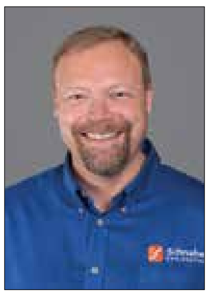
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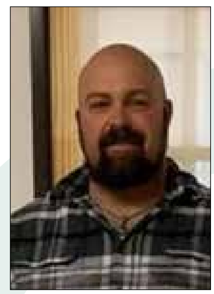
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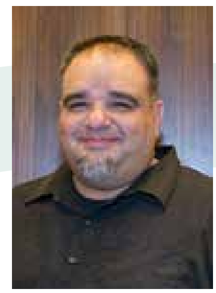
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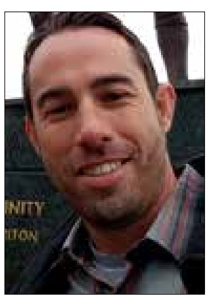
Justin Shock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Derek Pay

2024-2025

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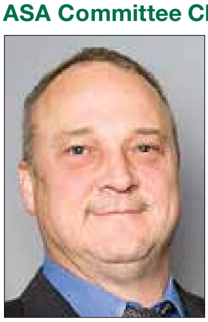
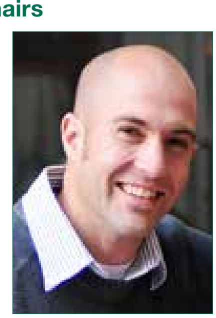
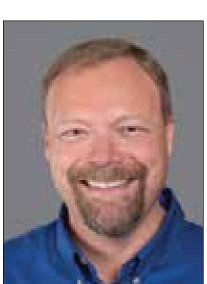
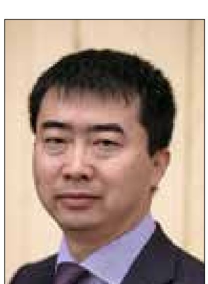

Marcus von der Hofen
Contractor Qualification


Derek Pay
Education & Safety


Jason Myers
Membership & Marketing


Ryan Oakes
Pool & Recreation


Christopher Goss
Underground


Lihe "John" Zhang
Technical

american shotcrete association | asa

American Museum of Natural History, Gilder Center | New York, NY

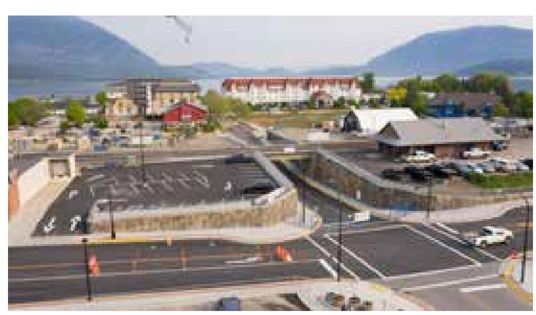
O'Hare Plaza West Drive and Executive Garage Restoration |Chicago, IL

2023 OUTSTANDING SHOTCRETE PROJECT WINNERS

Moyie Dam Repair | Bonner's Ferry, ID

Shaw Residence | Duck, NC

The Neville Island Bridge | Coraopolis, PA



LEFT: Ross Street Underpass | Salmon Arm, BC, Canada
BELOW: Water's Edge | Greenwich, CT

ABOVE: Rondout Bypass Tunnel | New York, NY.
LEFT: Shotcrete as Roadside Slope Protection in Brazil | SP 333 Highway, São Paulo, Brazil

Shotcrete 2024

Outstanding Shotcrete Project Awards

The application for the 2024 awards is now available! Projects must have been completed between January 1, 2022, and September 1, 2024, and can be submitted in the following areas:

- Architecture | New Construction
- Infrastructure
- International
- Pools and Recreation
- Rehabilitation and Repair
- Underground

Deadline to submit your project is October 1, 2024!

Submit your winning project at **www.shotcrete.org/projectawards.**

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OUTSTANDING

SHOTCRETE PROJECT

Awards

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