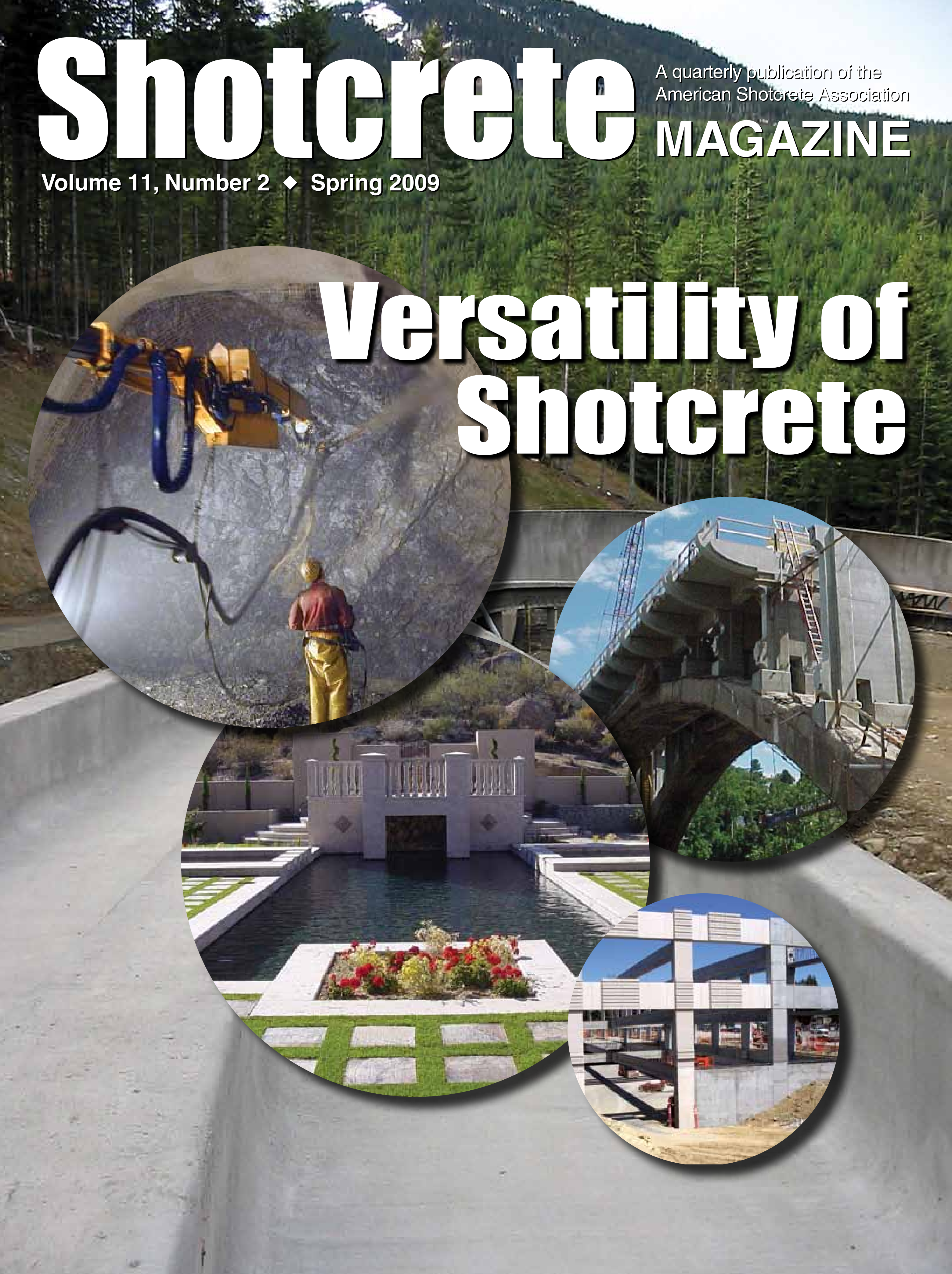
Shotcrete MAGAZINE

A quarterly publication of the American Shotcrete Association

Volume 11, Number 2 ◆ Spring 2009

Versatility of Shotcrete



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American Shotcrete Association
38800 Country Club Dr.
Farmington Hills, MI 48331
Phone: (248) 848-3780 • Fax: (248) 848-3740
E-mail: info@shotcrete.org
Web site: **www.shotcrete.org**

AMERICAN SHOTCRETE ASSOCIATION

Shotcrete MAGAZINE

Volume 11, Number 2
Spring 2009

Features

Departments

On the cover:
Shotcrete sprayers used in Vale Inco mines in Canada. Photo courtesy of Vale Inco, Copper Cliff, ON, Canada.

The Jefferson Street Bridge in Fairmount, WV. Photo courtesy of The QUIKRETE Companies, Atlanta, GA.

Residential pool in Scottsdale, AZ. Photo courtesy of Fisher Shotcrete, Inc., Higley, AZ.

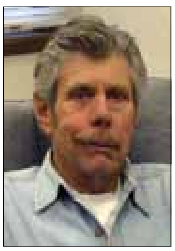
Shotcrete and precast parking garage in California. Photo courtesy of Joseph J. Albanese, Inc., Santa Clara, CA.

(Background) Completed section of the Whistler Sliding Centre in Whistler, BC, Canada. Photo courtesy of ConCreate USL Ltd., Calgary, AB, Canada.

Shotcrete—A Proven Process for the New Millennium

Super Bowl of Shotcrete

By Chris Zynda



I would like to thank all the ASA members and guests who attended the 2009 American Shotcrete Association Annual Meeting and Awards Banquet held recently in Las Vegas. We had a full house and everyone came ready to celebrate.

This was my first year as President and it was a great pleasure to be the spokesperson for ASA. Standing at the podium, you get a whole different view of the group and the energy in the room. Shotcrete contractors are a unique breed—they bid and construct very complex and difficult concrete projects and the awards banquet proved it.

This year I sat in on the final judging for the ASA Outstanding Shotcrete Project Awards. Let me tell you, the projects submitted came from all over the world and each was an outstanding candidate. The Awards Committee members, led by Chair Joe Hutter, had their work cut out for them. At times, I felt like I was sitting in a jury room, listening to all aspects of each project as the committee made the difficult selection of the winners.

Throughout the night, I could not help but look around at the attendees at the banquet and feel so proud to be the spokesperson of such an elite group. I thought to myself, the ASA members in this room are the pro players from all over the world, and this annual meeting is the "Super Bowl of Shotcrete."

During the banquet, I also announced a great addition to the ASA staff. Chris Darnell is the new ASA Executive Director. Chris has extensive experience in the concrete industry, including serving 20 years at the American Concrete Institute (ACI). I first met Chris about 10 years ago. At the time, he was the ACI Manager of Certification Operations, and we were both part of the group working on the launch of the ACI Shotcrete Nozzleman Certification Program.

In closing, I would like to pay tribute to my selection for the 2008 President's Award: Rusty Morgan. The President's Award was established in 2005 to recognize exceptional contributions to the shotcrete industry by an individual or organization and selection is at the sole discretion of the ASA President.

Rusty has made so many contributions to the shotcrete industry and to ASA that they almost cannot be counted. He has been a leading researcher, author, and consultant on projects on every continent except Antarctica. He is a founding member of ASA. He was Secretary for 13 of the 25 years he served on ACI Committee 506, Shotcreting. He has authored or co-authored over 140 papers on shotcrete. He has been a speaker at World of Concrete and numerous other seminars and symposiums around the world. Rusty has been a tireless contributor to the shotcrete industry. More importantly, he is a true gentleman and a great friend, and I was proud to present him with the ASA President's Award.

Who is *that* Guy?

by Chris Darnell, ASA Executive Director

As you may have noticed, there's a new face on this page. Tom Adams, the former Executive Director of ASA, has moved on to a new challenge with the American Coal Ash Association. I know I speak for all of ASA in thanking Tom for his service to this organization. We are certainly going to miss Tom's experience and leadership.

For all the ASA members reading this, rest assured that our outstanding Executive Assistant Melissa McClain is still with ASA. Melissa is very dedicated to ASA, and it shows in her great dependability and quality of work. I'm sure she will have me trained in no time!

My original introduction as the new Executive Director was at the ASA Awards Banquet that was part of the 2009 Annual Membership Meeting at the World of Concrete trade show. (*Note: if you have never had the chance to attend the ASA Awards Banquet, you need to put it on your bucket list. It was a great evening that anyone involved in the shotcrete industry would enjoy and be proud of.*) At the Awards Banquet, I had the opportunity to say a few words, and I would like to expand on them here.

I have worked for the American Concrete Institute (ACI) for 20 years. Eight of those years were spent in the ACI Certification Department. During that time, the Shotcrete Nozzleman Certification program came on line at ACI. It was then that I had my first opportunity to work with many ASA members and a number of things immediately struck me. Those folks really knew their stuff and worked very hard. Yet the most impressive thing was their passion for what they were doing. These impressions have only been reinforced since then. It is little wonder that you all have accomplished so much in just your first 10 years!

Sometimes it's hard to have an objective opinion of something when you are part of it. But as a neutral observer of ASA over the last few years, I can tell you this is a strong and respected association that is making a real impact on the concrete industry. I am very excited to be on board and am looking forward to meeting and working with all of you.

Rest assured that Melissa and I will be working hard on your behalf to build on the strong foundation that is already in place. We will be creative and timely regarding the development of new products and services and will respond quickly to member and industry needs. Perhaps most importantly, we will be reviewing all business processes to assure that they work as efficiently as possible. This will help maximize the resources and time available for the critical task of informing and educating the concrete industry on the versatility, quality, and economic advantages of the shotcrete process.

The Versatile Nature of Shotcrete

By Laurel Mellett

There have been times when many of us have driven along the highway and seen soil nailing used to expand the lanes of the freeway, canals being rehabilitated during a dry-up period, or new buildings with below-grade walls used for parking. These are all examples where shotcrete was used. Shotcrete pervades the places we live and travel. The process of shotcrete is truly one of the most versatile processes available for either new construction or repairs.

Versatility is such a broad word. When applied to the application of shotcrete, however, it is about the most descriptive adjective one could use. For over a century, shotcrete has been used in many applications and on the most diverse projects. Whether you are an engineer, project owner, contractor, or tradesman, shotcrete can be applied in almost every project where concrete is being used. More often than not, shotcrete can save time and money.

Some people associate shotcrete with the underground mining industry but shotcrete is also used in projects such as swimming pools, soil nailing, arch culverts, subgrade walls, and architectural enhancements. The following highlights some of the ways wet-mix shotcrete is being used in today's projects.

Vista Verde—Rio Verde, AZ

This project consisted of eight multi-barrel arch culverts. The sizes ranged from a triple-barrel 20 x 6 ft (6.1 x 1.8 m) to a 10-barrel structure that consisted of eight 28 x 6.5 ft (8.5 x 2.0 m) barrels and two 20 x 6 ft (6.1 x 1.8 m) barrels. Each culvert was built on a skew with horizontal and vertical curves. At any given point in time, there were no fewer than four culverts under construction. The original design for the Vista Verde project called for standard cast-in-place box culverts. The use of shotcrete arch culverts (the ProArch Shotcrete System) provided the owner a more aesthetically pleasing product, faster construction cycle, and an overall savings on the project that was close to $750,000 on an overall project of $2.3 million.

Shadow Hills—Indio, CA

Shadow Hills, a Del Webb Community, required a combination bridge/culvert/golf cart tunnel at the main entry of the project. The solution was two 48 x 10 x 190 ft (14.6 x 3.0 x 58 m) parallel arch structures. The aesthetically pleasing arch design represented a savings of $275,000 on a total of $650,000 and several weeks of construction time compared to other structural alternatives. The versatility and workability of shotcrete enabled the crew to hand-cut the unique "beveled" end

Bridge/culvert/golf cart tunnel combination at Shadow Hills in Indio, CA

Vista Verde eight-barrel arch culvert in Rio Verde, AZ treatment. This effect was chosen by the owner to omit constructing conventional headwalls and wing walls. Adding to the challenge was the fact the structures were aligned with a 20-degree skew with the roadway. Shotcrete allowed craftsmen to cut and hand-shape the final product, similar to an artist working with clay.

Monolith at Green Valley Ranch & Resort—Henderson, NV

The spa at Green Valley Ranch Resort, when being built in 2002, was touted as one of the premier resort and spas in the Las Vegas area. In fact, when the resort was undergoing a renovation in 2004, the resort enjoyed even greater success due to the reality TV show on A&E called "American Casino," which featured the day-to-day operations of the property. The resort elected to use a diagonal ellipse for its spa branding and wanted to reflect that symbol throughout the spa area. A divider wall in the spa pool was constructed separating the three swim lanes from the common area of the pool. This monolithic structure lent itself to shotcrete due to its 3 ft (915 mm) thickness, the ellipse in the middle of the structure, and the need for rounded edges. A foam insert was used for the elliptical shape in the structure. This structure is what catches the eye of the spa customer when entering in the pool area. Shotcrete was the most economical method due to the shape of the structure.

Smithsonian Patent Building—Washington, DC

The Patent Building was a remodeling project where the building needed more space and chose to dig up the courtyard in the front and create a basement. Shotcrete was chosen for the foundation structural walls as it was faster and less labor-

Smithsonian Patent Building below-grade wall retrofit project in Washington, DC

This monolithic structure is the main feature of the spa pool and cabana area at the Green Valley Ranch & Resort in Henderson, NV, and is made entirely out of shotcrete

Rio Vista Skatepark in Peoria, AZ, has many elements to its skatepark including two bowls; pipelines; ramps; and plaza elements, such as steps and railings, all of which were completed using shotcrete

This Peoria, AZ, municipal skatepark had to have an ultra-smooth finish for the safety and experience of the user

View looking down into the atrium of the newest room tower at the Venetian Hotel in Las Vegas, NV

intensive than conventionally cast-in-place walls. After completion of the walls, the area was made back into a courtyard with the new basement hidden from the naked eye until entrance into the building and new basement area.

Rio Vista Skatepark—Peoria, AZ

Skateparks have very discriminating users and this city in the Phoenix metro area did its homework and asked for a lot of community input from its users. Out of all of our projects, we have found that skateparks tend to evoke the most passion among its users and its designers. This 26,000 ft^2 (2400 m^2) skatepark was an ideal design for all skill levels due to its street plaza and bowl components. It consisted of almost 1000 yd^3 (765 m^3) of shotcrete with a trowel finish to provide a smooth finish. This finish could only be done with shotcrete due to its curvature and variety. Cast-in-place was not a valid option for the city of Peoria, as its constituents had stipulated a skatepark with specific elements and continuity.

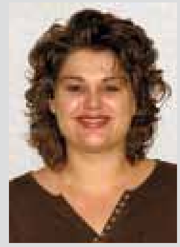
Venetian Hotel & Spa—Las Vegas, NV

When a new tower was being built at the Venetian Hotel in Las Vegas, the owner decided to build three luxury swimming pools on the 11th floor, which would be at the bottom of the atrium created by the four sides of rooms that towered above the pool area. The shotcrete had to be pumped 11 stories to complete this project. This is why shotcrete was the method of choice to complete the project. Not only is shotcrete commonly used in swimming pool construction for its imaginative design ability but also for its structural integrity. In this instance, these pools would be viewed by thousands of people each day: those staying at the hotel and those visiting for other reasons. The owner needed pizzazz to differentiate this property from others on the strip, and shotcrete was the key ingredient to achieve that goal.

Conclusions

Most backyard pools are constructed with shotcrete for the shell of the swimming pool, from a cookie-cutter shape such as the kidney or rectangle to Grecian-style corners and monuments with architectural rock designs, grottos, negative edges, raised spas, spillways, and swim-up bars. In the area of swimming pool construction, shotcrete makes all of these shapes, sizes, and bells and whistles possible due to the flexibility of shotcrete and infinite design possibilities. It is always interesting to have the homeowner watch the process and be in awe of how their “hole in the ground” comes to life when shotcrete is applied. It is like watching a child’s imaginative drawing turn into an artist’s architectural rendition—the possibilities are endless.

Many people have an idea of what shotcrete is and how it can be applied due to its inherent and versatile nature. These days, shotcrete can do wonders in terms of design and application. Industry contractors, engineers, owners, and tradesmen have just scratched the surface of the possibilities.



***Laurel Mellett** is the Operations Director for Fisher Shotcrete, Inc., Gilbert, AZ. She grew up in the shotcrete industry, starting her career by helping in the day-to-day operations of the family shotcrete business. She worked in the shotcrete business while attending Arizona State University, where she received a bachelor’s degree in both marketing and management and an International Business Certificate. While participating in a university exchange program, she received a Diploma of Management Studies from the University of Bradford in West Yorkshire, England. Mellett’s research interests include internal consulting and operations management. She has served on many ASA committees and ACI Committee 506, Shotcreting.*

Fiber-Reinforced Shotcrete in the Australian Underground Mining Industry

By E. Stefan Bernard

The majority of underground metalliferous mines in Australia, comprising more than 60 individual mines, now use fiber-reinforced shotcrete (FRS) and bolts as the primary means of ground stabilization. Numerous underground coal mines also use FRS for portal and decline construction. The popularity of this system of ground control has led to a steady increase in the volume of shotcrete used per annum over the last 15 years, with total consumption estimated at over 17,657,333 ft^3 (500,000 m^3) in 2008. Almost all of the shotcrete used is reinforced with fibers. Macrosynthetic fibers are the dominant form of reinforcement, with a small number of mines continuing with steel fibers, and a minority also including microsynthetic fibers for control of rebound and fall-outs immediately after spraying. Steel mesh is also used either to hold difficult ground in place prior to spraying or as an additional layer over the hardened FRS to enhance high-deformation ductility. The versatility of FRS, both in terms of structural capacity and mixture design, allows miners a higher degree of adaptability in the implementation of ground control and development of underground infrastructure than is possible using any of the currently available alternatives.

The competitiveness of FRS and bolts in a mining environment stems from four pivotal advantages over the alternatives. The first of these is the fact that the one system based on FRS and bolts is capable of stabilizing almost every ground condition encountered. This versatility is unmatched by any other method of ground control. When changes in stability and tunnel geometry occur, the bolt spacing and type will usually be maintained and only the thickness, toughness, and strength of the shotcrete need be altered. This means that the same spraying equipment, personnel, batching plant, and ancillary services are used every day for all ground control requirements and therefore do not stand idle. The result is a substantial improvement in productivity and amortization on equipment.

The second advantage of FRS and bolts is the increase in speed of heading advance possible through rapid ground support installation compared to other systems. Not only is the shotcrete applied quickly, but adaptations to varying conditions can be implemented immediately. Drilling jumbos are normally used to install mesh mechanically. Reliance on FRS frees the jumbos to fulfill their primary role, which is to drill headings. Hydroscaling also frees jumbos from the time-consuming task of mechanical scaling. The robustness of the ground support system based on FRS means that the cycle of excavation and support can proceed reliably in most circumstances. Because most mines employ at least two spraying machines, stoppages due to breakdowns can usually be tolerated through temporary rescheduling, thereby further enhancing the dependability of the system.

The third advantage of FRS and bolts is a substantial reduction in rehabilitation requirements compared to alternatives, especially mesh screens. This is possibly the principal economic advantage of ground control based on FRS, but usually takes at least a year of operation to become apparent. FRS is a highly durable material that can, if required, be designed to exhibit outstanding ductility. The fact that the ground surface is locked together and prevented from unraveling also enhances the stand-up time of ground stabilized using this system. Alternatives such as mesh merely catch the rain of unraveling rocks that fill the screens and require regular removal and replacement. Mesh also corrodes quite rapidly when saline groundwater is present, thereby limiting its life. In addition, FRS provides warning of impending failure by continuing to support localized instabilities even as cracks grow wider, especially when reinforced with high-performance macrosynthetic fibers. Regular inspection can therefore alert geotechnical engineers to a need for rehabilitation prior to failure instead of suddenly finding a pile of rubble blocking a roadway.

The fourth advantage of FRS and bolts is the improved safety of this system compared to alternatives, especially during the installation phase. Shotcrete is always applied remotely and only unmanned equipment such as the front end of boggers and robotic arms are permitted under unsecured ground, which is commonly taken to be any ground lacking shotcrete cover of less than 145 psi (1 MPa) compressive strength and bolts of the required design.[1] Operatives are only permitted to venture under newly excavated ground once the young shotcrete has exceeded this strength (which can be tested using the methods described by Bernard and Geltinger[2]) and bolts have been fully installed. The superior safety of this system has been demonstrated through experience in Australian and South African mines that have made the switch from older systems.[3] Death and injury from rock falls have been reduced from unacceptable levels prior to the introduction of shotcrete to a rarity today. The decline in death and injury has resulted in substantially reduced costs associated with stoppages, downtime, and compensation.

Several secondary advantages are also associated with ground control based on FRS and bolts compared to mesh and bolts. Minimum bolt spacings have been found to be larger when FRS is used, largely because bolt spacing is no longer dictated by mesh geometry, thereby partly offsetting the cost of the shotcrete. Vehicle productivity is also improved as a result of the general reduction in the number of obstructions on

Fig. 1: Successful ground stabilization with FRS and bolts

Fig. 2: Smooth, clean, and free of debris: mining with FRS and bolts

Fig. 3: FRS is not a bandage for poor bolt selection

roadways caused by fallen scats. Finally, the daily use of agitators and the presence of concrete-related personnel make other concreting jobs within a mine quicker and cheaper to implement.

The clean and smooth surfaces characteristic of FRS quickly reveal ground movement that may be problematic, hence geotechnical engineers can easily identify difficult ground instead of wasting their time checking large areas of bare ground obscured behind mesh screens. Observers unfamiliar with FRS are sometimes alarmed by the incidence of cracks in these linings, believing that cracks signal a failure of the system to stabilize the ground and that this requires immediate rehabilitation. This concern is misplaced because the FRS lining does not hold the ground up but instead assists the ground to redistribute stress around the fresh excavation. Continued ground movement is normal for an extended period after excavation due to this redistribution, and thus cracks usually occur throughout the life of the lining. It is only when maximum crack widths continue to increase and tunnel convergence becomes unacceptable that rehabilitation is required. It must be remembered that FRS is not a substitute for inadequate ground control using bolts (Fig. 3). It is the capacity of the FRS and bolt system as a whole that needs to be considered when developing a design for the conditions at hand.

The direct material and labor costs associated with initial ground control using the FRS and bolt system are about 20% higher than for alternatives such as mesh and bolts. When the superior speed, versatility, efficacy, durability, and safety of FRS are considered, however, their combined economic advantage make this system of ground control the most attractive presently available in the majority of circumstances.

Versatility for Ground Control

FRS and bolts are effective for ground control across a broad range of ground conditions, thereby enhancing productivity and competitiveness. The design of an FRS lining can readily be changed as conditions dictate,[4] and experience in the Australian underground mining industry has yielded the following broad guidelines for stabilization based on shotcrete and bolts:

- **Stable ground**—When support requirements are minimal, bolts are still used together with a 1.2 in. (30 mm) lining of FRS containing about 0.12 to 0.19 lb/ft^3 (2 to 3 kg/m^3) of macro-synthetic fibers to lock the surface together and protect the rock from weathering.
- **Moderate instability**—Under conditions typical of mining in shallow to moderate depths, effective stabilization can usually be achieved with 2 to 3 in. (50 to 75 mm) of 5801.5 psi (40 MPa) shotcrete with 0.31 to 0.37 lb/ft^3 (5 to 6 kg/m^3) of a high-performance macro-synthetic fiber. Steel fibers are still used occasionally but have seldom proved competitive against the leading macrosynthetics on the market. Most mines undertake regular quality control (QC) testing for toughness of FRS using the ASTM C1550 round panel test.[5] The benchmark minimum toughness requirement for moderately unstable ground is 360 Joules at 1.6 in. (40 mm) central deflection.[6]
- **Highly unstable ground**—In deep or highly fractured ground, including high stress and seismically active conditions, and when major excavations are undertaken nearby, the minimum thickness and toughness of the FRS must be increased to maintain control of the ground. Lining thickness typically lies in the range 4 to 6 in. (100 to 150 mm), and at least 0.5 lb/ft^3 (8 kg/m^3) of a high-performance macrosynthetic fiber is usually needed. The in-place strength of the shotcrete should be maintained at about 5801.5 psi (40 MPa). Steel FRS has frequently been found ineffective in highly unstable ground because ductility is limited to small maximum crack widths and embrittlement causes the energy-absorbing capacity of the material to fall with age.[7,8] Spraying is sometimes recommended in two or more layers over the first week or two after excavation to limit maximum crack widths.
- **Squeezing ground**—Stabilization becomes more challenging and expensive in very poor ground subject to high stresses. Multiple layers of FRS heavily dosed with high-performance macrosynthetic fibers have been found effective in several mines experiencing squeezing ground in Australia,[9] as shown in Fig. 4 and 5. The layers of FRS are applied progressively over

Fig. 4: FRS with mesh over the top in a high-stress Western Australia mine

Fig. 5: FRS with mesh over the top in squeezing ground at Perseverence Mine

several days following excavation, and this is then augmented by one or two layers of steel mesh installed and left bare over the top of the shotcrete. Numerous bolts are typically required to secure the mesh in place. The high toughness FRS acts as a contiguous membrane under the mesh that must be permitted to slide relative to the surface of the shotcrete until convergence ceases or additional measures are implemented. Such additional measures may involve either stripping out the converged ground and resupporting with new FRS and mesh overlay, or replacement with a thick shell if long-term support is required.

- **Soft nonsqueezing ground**—This type of ground is seldom encountered in a mining environment except during portal construction or excavation through cemented backfill. In these circumstances, the lining can be designed as a thick shotcrete shell in accordance with conventional practice.[10] The versatility of shotcrete means that the same equipment and personnel can be employed to produce this type of lining as are used in hard rock conditions.
- **Vertical shafts**—Ventilation and egress requirements have led to the frequent construction of vertical shafts in many mines, even though declines have supplanted hoists in most operations. The FRS required in shafts is similar to that used for conventional headings, but the equipment used is typically custom-built and remotely operated (Fig. 6). Numerous variations on these shaft lining machines have been constructed depending on the size and depth of the shaft required.
- **Secondary structures**—The versatility that has made shotcrete so widely used in aboveground construction makes it similarly useful for underground structures such as draw points, ore passes, backfill walls, ventilation bulkheads, and door surrounds. All of these can readily be constructed using the same

mixtures, equipment, and personnel used for ground control. In addition, smoothing layers of finely-graded plain shotcrete can be used when required in vents, offices, workshops, and canteens located underground.

Versatility in Mixture Design

The usefulness of FRS in underground mines is also due to the adaptability available in mixture design. Long gone are the days when operations had to be developed around inflexible requirements for spraying and curing shotcrete. Today, the properties of an FRS mixture, in particular the early age strength development characteristics, can be tailored to suit the requirements at hand.

Fig. 6: Shaft lining using a robotic shotcrete rig

Attractive early-age characteristics such as rapid set and strength gain, high stickiness, and resistance to fall-outs generally come at a price, so these properties are designed into a mixture only when they are actually required. Similarly, high later-age performance with respect to toughness and strength also come at a price, so these characteristics are only included when required. Toughness requirements are particularly easy to modify simply by changing the dosage rate of fibers. The other commonly desired characteristics of FRS, however, generally require a more detailed understanding of mixture design technology specific to shotcrete and specialists may need to be consulted.

As an example of the possibilities available for tailoring a mixture design to specific requirements, consider the case of the LGL Goldmine in Ballarat in Victoria, Australia. Using an older mixture design, miners experienced fall-outs in excess of 40% of the 176.6 ft^3 (5 m^3) sprayed in each round when tunneling through difficult ground at 1640 to 1968.5 ft (500 to 600 m) depth. High rates of water ingress combined with weak flaky rock and numerous small clay seams caused slabs of shotcrete up to 10.8 ft^2 (1 m^2) to fall out within 10 minutes of spraying, endangering the lives of operatives and slowing the rate of heading advance (Fig. 7). Stickiness was improved by modifying the aggregate grading curve and reducing the water-binder ratio, and cohesiveness in the young FRS was increased by adding 0.1 lb/ft^3 (1.5 kg/m^3) of synthetic microfiber, with the result that fall-outs were reduced to less than 5% on each round. The superior ductility of the very young shotcrete

Fig. 7: Very poor ground with high water ingress at LGL Ballarat Goldmine, Victoria, Australia

assisted the lining to bridge small areas of adhesion loss to the underlying substrate until strength increased to the point where the lining could support itself, and the ground, several hours later.

Summary

Underground mining is a risky and often dangerous undertaking that places stringent demands on equipment, systems, and personnel. A culture of innovation and boldness in the Australian mining industry has driven it to attempt many new and unproven approaches to mining over recent decades. In the case of ground control based on FRS and bolts, this strategy has reaped rich rewards that have resulted in the near universal adoption of this system in underground metalliferous mines. Versatility is one of the critical factors that have made FRS and bolts the system of choice for stabilization due to the unique range of options that shotcrete provides miners.

Acknowledgments

The author would like to thank M. Clements and K. Winder for reviewing this paper, and Jetcrete Australia, Mincor Mining Ltd., and LGL Mining Ltd. for assistance with photographs.

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***E. Stefan Bernard** is the Director of TSE P/L, Sydney, Australia, a private research company specializing in construction materials research. Bernard is Chair of the Australian Shotcrete Society; Chair of ASTM Committee C9.42, Fiber-Reinforced Concrete; and has extensive experience in shotcrete and fiber-reinforced concrete technology.*

A History of Shotcrete Use at Vale Inco

By John Larsen, Denis Thibodeau, and Joe Hutter

Vale Inco mining company is a leading producer of nickel, copper, cobalt, and precious metals and has been operating in Sudbury, ON, Canada, located about 240 miles (400 km) north of Toronto, for more than 100 years. The company's Sudbury operations form the largest fully integrated base metals mining complex in the world, consisting of five operating underground mines, mill, smelter, and refining plants to produce 149,000 tons (135,000 tonnes) of finished nickel metal and powder per year.

Shotcrete at Vale Inco—The Early Years

Vale Inco first began to use a form of shotcrete in the early 1970s. A thin layer of sprayed mortar (generally referred to as gunite) was applied, using the dry-mix process, as a water sealant for garages, shaft stations, and lunchrooms. The material was sprayed over bolt and screen and, in many cases, was subsequently painted to provide improved lighting for the workers. The material was not suitable for use in operating headings—with blasting effects—because the mortar layer would split, crack, and spall under intense dynamic loading conditions (Fig. 1). In these early years, the sprayed mortar was trialed in a ground support application at several Inco mines where ground conditions were extremely poor. The mortar was unsuccessful at providing support because it was applied too thin, too late after the ground "relaxed," and its compressive and flexural strengths were inconsistent and weak (Espley et al. 2001).

Fig. 1: First shotcrete attempt with cement, sand, and water mixture (mortar-like) showing poor performance with cracking

During the early 1980s, shotcrete manufacturers began to pay more attention to mixture designs in an effort to improve both the plastic and hardened properties of the shotcrete mixtures. More effective aggregate gradations (adding coarse aggregates) improved strength and shootability, the use of pozzolans such as silica fume allowed for thicker passes per application, the addition of noncaustic accelerators reduced set times and increased the rate of strength gain, and steel fibers were added to increase energy absorption capacity and improve toughness and post-cracking strength.

Shotcrete for Underground Construction

Before shotcrete was adopted extensively within the Vale Inco mines as a product for ground support, it saw wide use as a replacement for conventionally placed concrete in non-civil engineered underground construction. The challenges faced when handling and placing ready mixed concrete underground were significant. Ready mixed concrete delivered to the shaft head frame was dumped into steel boxes of 1 to 3 yd^3 (0.8 to 2.3 m^3) capacity. The steel boxes would travel via the shaft to the underground levels and then be handled by equipment designed primarily for mine production activities to distant and remote locations. Placement of the concrete into crude forms was difficult and often done by hand (using pails). The cycle time from delivery to the shaft collar on surface to the pour site (after multiple handling situations) could be 2 to 4 hours. Set retardants and other chemicals to modify hydration were not often used and quantities of concrete would be lost.

On the other hand, bagged dry-mix shotcrete provided an excellent solution to the handling problems. Bagged material on pallets could be handled by a variety of equipment and transported to construction sites by underground mine boom trucks. One-sided forms for construction were easier to build and contained a designed cage of reinforcing bar if required. Sprayed concrete was vastly superior to dumping conventional concrete into forms and overall construction times were reduced. For installations such as ore pass mantles, ventilation control walls, and minor dams, as well as for concrete repairs, dry bagged shotcrete provided a quick, simple, and cost-effective means for concrete construction in the underground environment.

Shotcrete as a Ground Support Tool

Vale Inco's first use of shotcrete as a ground support tool occurred in the very early 1980s at the company's Creighton Mine near Sudbury, ON, Canada. Shotcrete was used to supplement bolt and screen in high-stress conditions in a raise (Fig. 2). Since this time, the use of shotcrete at Vale Inco mines has increased, initially with site-specific applications and then, over time, with more mine-wide applications.

By the late 1980s, new and improved shotcrete materials were being used underground in the Vale Inco mines, initially as a structural support element (for construction) and for ground support in major underground excavations such as hoist rooms, garages, and crusher stations. Shotcrete was chosen for these applications when the cost of the product and installation seemed warranted. In many cases, the shotcrete that was used in permanent excavations was applied over existing support. The base support was usually quite extensive, with such items as cable bolts, screen, and grouted reinforcing bar bolts. Shotcrete improved stability of the entire support system. It was, however, very costly. At the time, shotcrete use was infrequent and its relatively low demand within the industry resulted in having its application contracted out—usually at high cost. The low-demand and high-cost factors obviously slowed the integration of shotcrete into the mining operations and, in particular, into the mining cycle.

Problems associated with material handling and shotcrete equipment also slowed the integration of shotcrete into existing mining operations. In fact, in most cases, the shotcrete equipment used in Vale Inco mines had undergone little change in several decades. Machines produced large amounts of dust; were expensive to operate; and involved labor intensive, hand-held nozzeling techniques. Materials were generally supplied in small, 66 lb (30 kg) bags, which when broken into hoppers, creating unacceptable dust levels. All of these factors led to the opinion that shotcrete was a costly, laborious, and slow method of ground support applicable only to permanent or special excavations and was not suitable as a routine method of ground support.

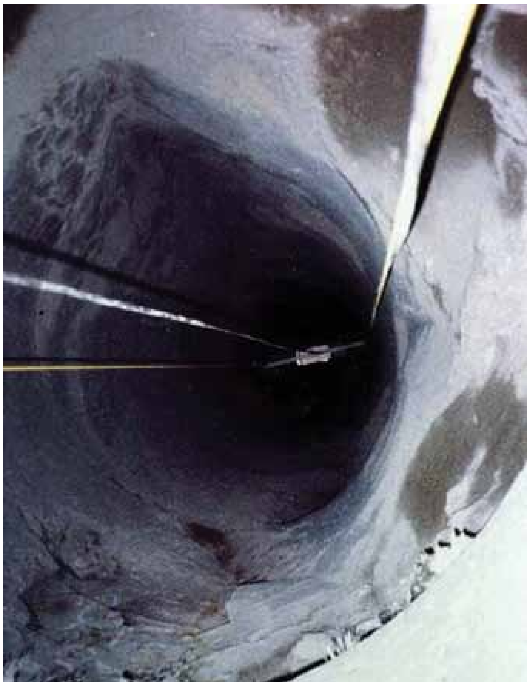

Fig. 2: Shotcrete use in raise

Fig. 3: Large, 2200 lb (1000 kg) bulk bags that allowed more material to be moved more quickly throughout the mine

In retrospect, it is now clear that the late 1980s signaled the turning point for shotcrete whereby a new credibility was growing for the product and for its emerging role as a key ground support tool, not only at Vale Inco but also throughout the mining industry. Equipment improvements and improvements in material handling contributed to the increased popularity of shotcrete at Vale Inco mines. The small paper bags were replaced by large 2200 lb (1000 kg) bulk bags that allowed more material to be moved more quickly throughout the mine (Fig. 3). New, more rugged shotcrete machines, designed to contain dust, were supplied

Fig. 4: Shotcrete sprayers increased the comfort level of the nozzelman, improved productivity, and created a safer work environment

Fig. 5: Corroded screen and bolts

Fig. 6: Blast damage in topsill

with hopper hoods that reduced dust levels and protected the arms of workers. The shotcrete nozzle, redesigned to reduce dust levels, was taken out of the hands of the nozzelman and placed at the end of remote booms. These "shotcrete sprayers" increased the comfort levels of the

Fig. 7: Rock burst

nozzelman, improved productivity, and created a safer work environment (Fig. 4).

During the late 1980s, it became apparent that there were three key roles for which shotcrete could be used to supplement bolt and screen:

1. For protection of the existing support from corrosion or from fly-rock damage due to blasting, for example, secondary-blasting chambers and top sills for vertical retreat mining (VRM) (Fig. 5 and 6);
2. For enhanced support in seismically actives zones, for example, rib pillars, crusher stations, headings at depth, and crown pillar regions (Fig. 7); and
3. For reconditioning or for mining in difficult ground conditions, for example, when mining through backfill, crushed zones, or through geological structures; severely relaxed ground; large intersections; draw-points; or large permanent openings. For all scenarios, the shotcrete application at Inco was typically applied at a thickness of 2 to 4 in. (50 to 100 mm). The excavation was usually completely mined and supported with the primary ground support and then the shotcrete was applied in one main process.

Shotcrete Use at Vale Inco's Frood Mine

By the late 1980s, a dry-mix shotcrete product was used for the first time at Vale Inco's Frood Mine, Sudbury, ON, Canada, to support and recondition heavily deteriorated ground on the 1000 Level gangways. In these areas, corroded bolt and screen and rotted timbers made for a challenging ground support strategy. Ultimately, shotcrete was considered a safer alternative to bolt and screen. The dry-mix shotcrete, supplied first in bulk bags, and later through a bulk carrier with a shotcrete machine mounted at the back, was sprayed over the existing bolt and screen to form an arched support. These conditions made it difficult to achieve a compacted, thick layer of shotcrete and, as a result, many voids were created behind the screen.

Even though the shotcrete application was far from optimum, it performed better than expected by controlling further deterioration of the rock mass and tying the loose rock together at the excavation surface. Because the results were good, the mine outlined several other areas that needed to be reconditioned with shotcrete.

One of the greatest challenges faced by the Frood Mine management was convincing the underground miners that what appeared to be a relatively thin layer of sprayed concrete would be able to support the thousands of tons of loose and fractured rock that remained overhead. Many looked at shotcrete as "hiding potential problem areas," most of which could be monitored by observing "loose," or chunks of fallen rock, that was found hanging in the overhead screen. Using case histories and scientific data, shotcrete material manufacturers conducted seminars that explained the theory of how shotcrete stabilized a rock mass and actually helped identify problem areas by identifying visible cracks in the shotcrete, many which formed when there was significant ground movement.

Frood Mine's first shotcrete-dedicated crew (most shotcrete personnel had other responsibilities among which shotcrete was included) was formed and trained in 1988 when Frood Mine purchased its first dry-mix machine. Shotcrete use grew beyond reconditioning during 1989 and 1990 to include construction of dump walls, ventilation barricades, backfill barricades, and ore pass mantles.

In 1990, Frood Mine tested mesh-reinforced shotcrete as primary ground support in some production headings on 1170 Level—mostly in late-stage pillar recovery zones with sand slots located above the headings (Fig. 8). The shotcrete was needed to provide stability in the crushed ground conditions and to control large deformations. In loose rubble conditions, it was extremely difficult to install bolt and screen. The mine developed the following shotcreting procedure for each 12 ft (3.6 m) development round:

1. Spray plain shotcrete 2 to 4 in. (50 to 100 mm) thick on the back and walls;
2. Allow shotcrete to cure for a minimum of 8 hours;
3. Attach screen to the shotcrete with bolts; and
4. Spray a second layer of plain shotcrete 2 to 4 in. (50 to 100 mm) thick over the screen.

Experience at Vale Inco's Stobie Mine—"Boltless Shotcrete"

Shotcrete was first used at Vale Inco's Stobie Mine, Sudbury, ON, Canada, in sublevel cave

Fig. 8: Frood Mine development heading

mining areas to provide corrosion protection to bolt and screen in the drill drifts and to provide additional support to the brows during production mining. By 1993, problems associated with drilling led mining engineers to consider using shotcrete as a replacement for bolt and screen in the sub-level cave production headings. This change was prompted by the following:

1. Constant complaints of stuck rods with the top-hammer drills and with excessive wear of the bits (due to drilling into the back bolts);
2. The support capacity of a bolt being compromised when the production drill would hit and damage the bolt's steel shaft; and
3. Difficulty with loading the drilled production holes with emulsion explosives due to deterioration of the ground around the collars, as well as the loading process becoming quite dangerous.

A trial in which boltless shotcrete would replace conventional ground support provided Vale Inco engineers with an opportunity to test the limits of a ground support system in which shotcrete played a primary role and bolts were eliminated (Espley et al. 1994).

The trial was performed in three distinct phases:

Phase 1: In 1993 and 1994, a two-pass, boltless-mesh reinforced shotcrete system was tested on the 2400 Level in a number of drill drifts in which remnant pillar mining was taking place. The mesh-reinforced shotcrete performed well under production and blasting conditions and provided an important support role even with tensile cracking and rock fracturing "onion skinning" behind the shotcrete liner. From the results, it was apparent that some reinforcement of the shotcrete was required to provide effective support in areas of moderate to high deformations and dynamic loading.

Phase 2: In 1994, consideration was given to replacing the mesh with steel fiber in an effort to improve development rates through the implementation of a single pass system. An underground trial was started on 1850 Level and 1930 Level, where several hundred feet of standard bolt and screen were removed and replaced with boltless steel fiber-reinforced shotcrete (Espley et al. 1996). These shotcreted drifts became production headings for the sublevel cave mining. The monitoring of these drifts during the production phase showed that the necessity to rehabilitate the brows was significantly reduced when compared to conventionally supported headings (screen and bolts). It was also determined that +3 in. (+75 mm) of shotcrete was required to provide effective support during production mining.

Phase 3: In 1995, the success of the second phase led to the evaluation of the support effectiveness of boltless fiber-reinforced shotcrete when applied during the development phase and used throughout the entire production phase. A boltless-steel fiber-reinforced shotcrete liner was designed using site data, empirical data, laboratory information, and through experience with shotcrete in civil and mining operations (Espley 1996).

Fig. 9: Application of boltless SFRS

Fig. 10: Sublevel drill drift supported with boltless SFRS

Fig. 11: Brow of mucking drift with boltless SFRS

In 1995, the drill drifts on 2000 Level were sprayed with steel fiber-reinforced shotcrete (SFRS) as part of the development mining cycle as follows: 1) drill, load, blast, and muck the heading; 2) scale using an air/water spray; 3) apply 4 in. (100 mm) of SFRS to the back and walls (at a dosage rate of 100 lb/yd^3 [60 kg/m^3]). After a cure time of 12 hours, personnel were permitted to reenter the heading. Field observations and performance evaluation during these trials led to the conclusion that the support system worked quite well for back support. It was also determined that boltless shotcrete greatly improved the collaring, drilling, and loading of production holes as shown in Fig. 9 to 11.

The support design has since been expanded to all sublevel cave development headings with good to very good ground conditions and low to moderate stress levels. It was also determined that all drift intersections be supplemented with grouted reinforcing bar bolts on a 4 ft (1.2 m) square pattern. From the standpoint of shotcrete materials, improvements in shotcrete mixture design led to an improvement in process cycle time whereby the 12-hour reentry time was reduced to 8 hours. It was also determined through testing that the specified steel fiber dosage could be reduced from 100 to 84 lb/yd^3 (60 to 50 kg/m^3).

Shotcrete Use Expands to Other Vale Inco Properties

The experience gained from Frood and Stobie Mines and the initial proof of shotcrete's ability to support rock in challenging ground conditions, led to the logical progression to question if shotcrete would be able to withstand high vibration from production blasting. To answer this question, trials were undertaken to test the effectiveness of shotcrete under these conditions. Each trial was site-specific, with an emphasis on monitoring the support performance both during development and during production phases of mining. Additionally, all other operational aspects and costs for each trial were tracked and used in a post-trial assessment.

In 1991, Vale Inco selected Copper Cliff North Mine, Copper Cliff, ON, Canada, near Sudbury, to conduct the next phase of shotcrete testing in which shotcrete would be used as a secondary support for bolt and screen (O'Donnell 1991). The shotcrete was used in a VRM top sill to protect the steel support elements from the fly-rock ejected during production blasts. This trial was extremely successful and, as a result, most Inco mines now use shotcrete as secondary support in the VRM sills (Fig. 12). In the top sills, shotcrete controls damage of support from blasting. In bottom sills, the shotcrete is sprayed over bolt and screen to improve brow conditions and to eliminate the need for cable bolts. Since the introduction of this application, the added shotcrete layer has eliminated a large amount of reconditioning of bolt and screen (and cable bolting in brows) in the sills.

In 1992, Vale Inco began to use shotcrete in earnest in various other operations. One of the first and very successful trials was to test shotcrete for the replacement of steel and timber sets (Fig. 13). This was first examined at Frood Mine as a replacement of the sets and later shotcrete was trialed at Creighton Mine, near Sudbury, ON, Canada, in the production sills, as a replacement to its timber sets. This worked well where deformations were not excessive (Fig. 14).

Another important application for shotcrete at Creighton Mine was to provide support when mining through backfill. In this application, 6 ft (1.8 m) rounds were developed and supported with layered elements: 1) the first layer of plain (unreinforced) shotcrete, approximately 2 to 4 in. (50 to 100 mm) thick, was applied and cured for a minimum of 8 hours; 2) screen was pinned to the back and walls with short friction bolts; and 3) the second layer of plain shotcrete, approximately 2 to 4 in. (50 to 100 mm) thick, was applied to cover the screen.

At Creighton Mine deep (7800 ft level [2377 m]), consideration must be given to the moderate- to high-stress environments encountered when mining at these depths. The shotcrete must have energy absorption (that is, dynamic) capacity to survive potential bursting conditions. As such, laboratory or observational data were required for an estimate of the dynamic capacity of the shotcrete systems to compare to the estimated dynamic loads. When evaluating the effectiveness of shotcrete under the conditions at Creighton Mine and other Vale Inco mines, it was determined that infrastructure damage (caused by seismic activity) was reduced considerably when shotcrete was integrated into the support system (Fig. 15).

The Increased Use of Shotcrete as a Construction Tool

Through the 1990s, there was an increasing familiarity and use of dry-bagged shotcrete as a ground support tool in the underground mining environment at Vale Inco. This familiarity and the increasing availability of shotcrete underground resulted in the increased use of shotcrete as a construction material. Strength testing through the extraction of cores and stringent quality-control programs incorporated by shotcrete material suppliers provided Vale Inco engineers with the confidence that shotcrete would provide the

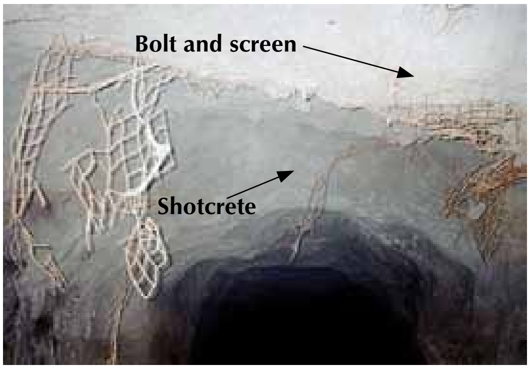

Fig. 12: Shotcrete use in VRM topsill


Fig. 13: Timber sets at Creighton Mine


Fig. 14: Shotcrete use to replace timber sets


Fig. 15: Shotcreted drift at Creighton Mine (after seismic activity)

consistent in-place properties required to incorporate shotcrete process into the construction design process. Critical applications such as the construction of arched backfill barricades are now designed using shotcrete, allowing the elimination of expensive timber as the fill barricade material and creating a much less labor-intensive construction process. Performances of the barricades are also vastly improved.

Placed concrete has been virtually eliminated as the construction material in non-load and low load-bearing walls and low head dams for ventilation control, installation of fans, sumps, and material storage bunks. Nonaccelerated shotcrete is used for low load-bearing floors in permanent installations such as refuge stations, materials storages, and shaft stations. In permanent, long-term installations where replacement and reconditioning of steel bolt and wire mesh ground support would prove disruptive to the operation, shotcrete is used exclusively to seal and protect the ground support. This includes:

- underground garages;
- electrical, shaft, crusher, and fan stations;
- bins;
- conveyor galleries;
- equipment and material storages; and
- powder and fuse magazines.

New high-performance shotcrete mixtures, developed by shotcrete materials manufacturers to protect and extend the life of ore bins, are now replacing steel plate liners. These mixtures use high-performance, aluminate-based cements that improve abrasion resistance and allow ore bins to be reopened days after the application of the shotcrete. Steel fibers protect the liner against impact and provide improved energy absorption.

Fig. 16: Wet-mix shotcrete material is delivered from a bore hole on surface and dropped several thousand feet (meters)

These mixtures are now being used in high impact areas such as draw points, truck dumps, around grizzlies, surface bins, ore passes, and other areas subjected to high impact and high abrasion. Vale Inco's Coleman Mine, Levack, ON, Canada, located 31 miles (50 km) north of Sudbury, has monitored the performance of these calcium aluminate cement (CAC)-based mixtures in ore passes by lowering video cameras into the ore pass and examining the condition of the shotcrete liner. The results have prompted Vale Inco engineers to specify more CAC, steel fiber-reinforced mixtures in high impact areas at other Vale Inco properties.

Wet-Mix Shotcrete at Vale Inco

The use of wet-mix shotcrete at Vale Inco has been limited to the extensive application at Frood and Stobie mines as a principal part of the ground support at each site. As a result, shotcrete volumes at these two adjoining operations are sufficient to justify the capital expense of surface to underground boreholes to deliver wet-mix shotcrete underground at the sites and mobile equipment for application. As volumes have increased, typically beyond 7848 to 10,464 yd^3 (6000 to 8000 m^3) per year, other Vale Inco mines (Coleman, Garson) have instituted plans to implement a wet shotcrete system.

The primary advantages of wet-mix shotcrete are the improvements in materials handling and increases in productivity. At Vale Inco, current procedures require material delivery (via conventional ready mixed truck) to a bore hole on the surface from where it is dropped several thousands of feet (meters) and received in a bulk carrier at specified production levels (Fig. 16). The bulk carriers are used to transport the shotcrete throughout the mine to development headings where shotcrete sprayers (with a concrete pump, accelerator dosing units, and remote spray arms) apply shotcrete at much increased rates of application. These productivity improvements have allowed Frood and Stobie Mines to expand the use of shotcrete and investigate the support systems that include boltless, steel fiber-reinforced shotcrete liners.

Health and safety issues are also at the forefront when evaluating the benefit of a wet-mix shotcrete program. Dust levels become less of a factor during the shooting process. Reduced manual handling and reduced time exposure for comparable amounts of shotcrete applied also play a role in improving the health and safety conditions underground.

The Future of Shotcrete at Vale Inco

The growth of shotcrete use at Vale Inco has been expeditious since the days when underground miners were uncomfortable with its use as a ground control tool. Properties (both plastic and hardened) achieved using early mixture designs were inadequate; therefore, shotcrete was limited to nonstructural construction applications or as a secondary form of ground support. Today, however, shotcrete mixture designs have undergone exceptional improvements. Improved hardened properties have allowed engineers to incorporate the shotcrete process into the design of structural elements, equipment improvements have led to reduced dust levels, steel and macro-synthetic fibers have improved the ability of shotcrete to absorb energy, and the use crews dedicated to shotcrete have resulted in improved nozzelman skills and, in turn, more consistent, high-quality shotcrete applications.

In the future, shotcrete use at Vale Inco is expected to increase as the commercial benefits of shotcrete support systems become more apparent. The need to bring ore bodies on line quicker will contribute to production improvements. Shotcrete will be used as primary support in narrow vein mines and wide cut-and-fill headings. Improved early-age strength testing procedures will allow reductions in reentry time. Increased use of fibers will reduce the need for wire mesh and speed up the development cycle. Automation of the shotcrete process will also contribute to a faster mining cycle.

Vale Inco mines will also benefit from improvements in material handling. Wet-mix shotcrete will play a bigger role in ground support strategies as mixtures are delivered via bore hole and larger volumes are transported in bulk carriers. "Dry to wet" systems will be developed, allowing preblended dry materials to be delivered either in bags or in bulk (also through bore holes) to mixing stations where wet-mix shotcrete can be produced on demand and without many of the costly admixtures currently used.

Perhaps one day, the shotcrete application will be automated to the point where automated bulk shotcrete carriers, controlled from the surface, can be maneuvered from the shaft station to headings several thousands of feet (meters) away. At the heading, automated shotcrete sprayers will be operated by nozzlemen remotely controlling spray arms from the surface; and shotcrete mixture designs, capable of providing higher strengths minutes after application, will improve productivity, reduce costs, and make more ore bodies commercially viable.

Whereas these concepts may seem like a long way from current mining methods, one must realize that implementation of video technology, telecommunications, modems, and PCs have allowed automated load-haul-dump vehicles to be used underground at Vale Inco's Creighton Mine since 1991. If this technology can be applied to the shotcrete process (bulk carriers and shotcrete sprayers), the concept of automated shotcrete processes may not be too far away.

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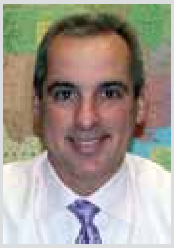
***John Larsen**, PEng, is the Operations Superintendant on Vale Inco's Copper Cliff Deep Project. Larsen received a BS and an MS in mining engineering from Queen's University, Kingston, ON, Canada, in 1985 and 1990, respectively. He joined Vale Inco in 1989 as a Mine Planner and has worked in several roles in engineering, operations, and safety at the Ontario operations, including Mine General Foreman and Chief Mine Engineer. In 2005, Larsen became the Superintendent, Mines Business Analysis and Planning, and was responsible for mine business systems, the Life of Mine Plan and associated activities, external ore feeds, and open pit operations. He became the Operations Superintendant on the Copper Cliff Deep Project beginning in 2007 and is the Operations Representative on the feasibility study team. Larsen is a member of the Association of Professional Engineers of Ontario (APEO) and the Canadian Institute of Mining, Metallurgy and Petroleum (CIM).*

***Denis Thibodeau**, PEng, is the Superintendent of Strategic Rock Mechanics and Ground Control Projects at Vale Inco and has 18 years of experience in the mining industry working for Vale Inco and Barrick. He received a BE in mining from McGill University, Montreal, QC, Canada; a BS in geology from Montréal University, Montreal, QC, Canada; and a doctorate in civil and mining engineering from Institut National Polytechnique de Lorraine, Nancy, France.*



***Joe Hutter** is Vice-President, Sales, for King Packaged Materials Company. He has more than 20 years of experience in the cement/shotcrete industry. He has been an active member of ASA and has chaired the ASA Marketing Committee since its inception.*

2008 Outstanding Pool & Recreational Project

Canterbury High School

Every so often our company, Drakeley Industries, is confronted with a set of beliefs by some design professionals that the shotcrete process, particularly in the pool industry, is not viable for high-profile structural concrete. The pool market is viewed by many as saturated with less-than-qualified contractors and specification writers who mistakenly think that shotcrete compressive strength in psi (MPa) should be no more than your average high school student's SAT score. Mediocrity and its promotion in the pool market have made commercial institutions hesitant to use the shotcrete process. We came across such a case in Connecticut. A private high school was going to build a state-of-the-art aquatic center with a competition eight-lane tile pool as its focus. Its bid specifications originally called out for cast-in-place concrete. Our challenge was to sell our company as a qualified contractor, but more importantly, sell the shotcrete process.

The Canterbury High School project is a high school competitive swimming facility in the western hills of Connecticut. Our company was asked to submit a shotcrete structure for bidding purposes against and compared to a poured-in-place typical architectural specification. We leaped at the chance to show off why our concrete monolithic pool shell constructed with the shotcrete process was superior in many ways to the typical poured pool.

History has shown that cast concrete pools have expansion-joint and water-tightness issues that sooner or later produce a water loss that can never fully be repaired. Our aim was to prove to the specification writers that shotcrete was a viable solution to cast concrete in terms of water-tightness and longevity of the structure, as well as the finished surface bond ability. There is almost always a failure in the applied surface (tile or plaster) that started from a bond delamination that was initiated by water penetrations.

During the interview with the school's design group, a question arose from the engineering team regarding how or what we were going to use for an expansion or movement joint. Our response was "what joint?" We had to sit down and explain that one of the best advantages in the shotcrete process is that there is not an expansion joint or even a bonding adhesive between days of placement. We explained that finishing an application from one day to the next included preparing the concrete in a construction joint format on a 45-degree angle and a gun or broom finish. All exposed steel would be clean of overspray and the previous day's shoot would be in a saturated surface-dry (SSD) condition to prevent any moisture exchange between the previously shot material and the new shotcrete. We elaborated on the bonding capabilities of the cement paste under such conditions. We explained that by using proper velocity of the shotcrete process to drive the cementitious product into the concrete of the previous day's shoot, this would in turn make for a tremendous physical and chemical bond.

A second concern arose as to how and what products our company was going to add to the concrete surface for a water- or damp-proofing agent against potential leaks. Test holes were dug prior to the specification writing and the groundwater table was found to be 2 ft (600 mm) higher than the bottom of the dig elevation during certain seasons. The answer again was "what agent?" The team's response was that if the shotcrete process is done correctly there would be no scenarios that would call for a water- or damp-proofing agent. Properly applied shotcrete will result in a high-density concrete that has very low permeability, very low porosity, and eliminates the need for a membrane designed to make the shell hold water. Cast-in-place concrete with porosity issues will call out for water-proofing. Referring to some of the ACI documentation, CP-60(02) "Shotcrete Nozzleman Certification," 506R "Guide to Shotcrete," and 506.4R "Guide to Evaluating Shotcrete," we were able to show the intended strengths and characteristics of properly placed shotcrete. Academia was now more educated but still hesitant about the process. It was time for our construction company to be the first player in the negotiations to differentiate ourselves from the competition. Our proposal was that we would guarantee that the pool would reach the minimum acceptable concrete compressive strength in 28 days and that the concrete would be watertight without the use of water-proofing agents. If those criteria were not met, we would demolish the pool and install cast-in-place concrete. Once the arguments were made and debated, the design team felt strong enough about the process to award us the contract.

Our construction sequencing started with excavation, drainage, and forming. All forms were solid, nonvibrating members that would ensure no shadowing or voids behind the steel reinforcement. Once forming was complete we installed the steel reinforcement. The walls and floor were 12 in. (305 mm) thick with a double matting of No. 5 (15M) and No. 4 (13M) bars, Grade 60, 12 in. (300 mm) on-centers offset between cages. The crew inserted polyvinyl chloride (PVC) chairs and wheel spacers to keep the reinforcing bar properly spaced, which allowed the necessary concrete coverage of each reinforcing bar. Guide wires were set for elevations and shooting depicting slopes of the floor and radius for the walls as well as the multiple levels of the bond beam.

Wet-mix shotcrete applications took 7 days to complete over a total span of 10 days. The mixture design called for a minimum of 4000 psi (27.6 MPa) after a 28-day wet cure. Installation started in the radius sections where the wall and floor met to establish the critical transition points. From there, the floor was shot in sections. The wet-mix process was chosen over the dry-mix process because our environment was somewhat controlled and we could easily apply a high-volume output with no strain on our finishers and reach the minimum designed compressive strengths. Once on the floor, we consolidated and leveled off each shoot with a power screed and then a very light broom finish. Tolerances were critical and everyone on the crew knew that the finish surface was all 1 x1 in. (25 x 25 mm) ceramic tile. After each section shoot, we set up soaker hoses and kept the concrete in a saturated condition. This allowed the mixture water to stay in the concrete and promote the hydration process for optimal strength gain with no surface evaporation. As mentioned previously, each construction joint was in an SSD condition prior to receiving new concrete. Scaffolding was set up to build the walls. An excavator was kept with a long reach on site to remove all excess concrete after cutting and trimming and some rebound. Because it was a competition pool, the depths were very deep at 12 ft (4 m) and 7 ft (2 m) at each end, respectively, and we needed equipment help lifting out unusable material with those elevation depths. The pool required 350 yd^3 (265 m^3) of our special concrete mixture design over a 7-day period. The applicators were all ACI-certified shotcrete nozzlemen. Test samples were taken by

Cove wall and floor intersection on the first day of the project

Floor construction joint

Removal of rebound and concrete trimmings an independent lab hired by the high school. They did a typical concrete analysis including the compressive strengths of the samples. The first test sample was measured after 7 days in the lab. All involved were quite pleased with 6200 psi (42.8 MPa) test results. We cured the concrete for a 28-day period. Over the next week after the curing, the shell filled with water and remained water-tight. There is not one expansion joint in the pool and not one area that a chemical bonding agent was used.

After the mechanical systems were installed, we applied the tile interior with its setting bed directly to the shot material. Because of the low permeability and the high density of the concrete, we did not have any issues with bleed water or bond ability to this shot surface. Having multiple layers of bonding agents or water/damp-proofing agents to properly-placed material will act as a bond breaker. Throughout construction, our goal was that, if done properly, our water-tight surface formed an excellent bond with the tile and its setting bed. This particular job and its specifications for the pool structure are now being used by this design team on other commercial projects around the New England area.

Raising the bar in the pool industry means the quality of the product must improve. Some organizations (such as the Genesis 3 Design Group) have embraced a higher quality in pool construction. For far too long, however, builders, designers, and pool professionals have neglected simple standards set forth by the American Concrete Institute. Entire organizations have built their business based on the notion that pool concrete is supposed to be porous, have minimal compressive strengths (less than 4000 psi [27.6 MPa]), and rely on some top coating to make the vessel hold water. This thought process and those who subscribe to it are exactly the reasons why the pool industry as a whole has never improved. Until all of us accept the fact that there are higher standards to be reached (as did Canterbury High School), we will never get by the prejudice against the shot concept.

Pool curing for 28 days

The finished product

Outstanding Pool & Recreational Project

Project Name
Canterbury High School

Project Location
New Milford, CT

Project Owner
Canterbury High School

Shotcrete Contractor
Drakeley Industries*

General Contractor
Drakeley Industries*

Architect/Engineer
Drakeley Industries*

Material Supplier
Sega Ready Mix

*Member of the American Shotcrete Association


GUNITE.
Dry-mix done right.
AIRPLACO
914 MOBILE BATCH PLANT
AIRPLACO
914 MOBILE BATCH PLANT

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41st Street Bridge Baltimore Shotcrete Repair: A Scaffolding Challenge

By Ted W. Sofis

In the late 1980s, the 41st Street Bridge in Baltimore, MD, a 22-span bridge over the Jones Falls Expressway, underwent rehabilitation. The entire bridge deck was removed, including the shotcrete-encased beams of the bridge superstructure. When the bridge pier caps were replaced and all pier and abutment work completed, the shotcrete-encased beams of the bridge superstructure were replaced on all 22 spans. The stay-in-place metal decking was installed and the bridge deck and parapets were poured in place. The existing shotcrete, at all connection points, as well as where new diaphragms were to be installed, was removed while the beams were on the ground. During the removal and subsequent replacement of the beams, much of the shotcrete encasement on the beams was damaged.

Piers on the east end of the bridge

Damaged beams on one of the spans

Sofis Company Inc., as the subcontractor for the shotcrete repairs, faced several challenges that needed to be resolved. First and foremost, the general contractor, Dick Corporation, had expended much of the time allotted for the project and faced liquidating damages of $8400 per day beyond the scheduled completion date, so it was imperative that the project be completed on time. In addition, there was an antique car show and celebration scheduled for the bridge opening, so there would be pressure from the political end. The general contractor had planned on and purchased a traveling platform for the additional chipping of the damaged areas and for the placement of the dry-mix shotcrete. The platform, however, did not reach all the areas where repairs were necessary and thus there was no way that it would be possible to access all the areas where work needed to be done. To maintain the schedule, we needed to work on more than one span at a time and needed access to all the areas in each span.

To overcome these obstacles, it was decided that the traveling platform would be discarded and the bridge needed to be rigged. The access had to be good because, in addition to the chipping and removal of the damaged shotcrete, proper shooting angles were essential, as much of the shotcrete work was overhead. To achieve this, we erected cables that stretched the entire length of the 22-span bridge resting on the pier caps of each span. From these cables, we suspended Swing-Lo cable scaffolds with hand rails on both sides that hung low enough that we were able to shoot the underside of the beams. The use of the cables and Swing-Lo cable scaffold enabled us to

One of the spans after the damaged shotcrete was removed and the anchors and mesh were installed

Close-up of the 41st Street Bridge connections

Bridge after repairs

reach all the areas on each span where work needed to be done.

Shortly after the erection of the cables and Swing-Lo cable scaffolding, we began chipping and removing the damaged shotcrete from the beams. Closely following the removal operation, another crew began stud welding T-Slot anchors and installing galvanized 2 x 2 in. (50 x 50 mm) 10-gauge wire mesh in all the connection points and areas where damaged gunite was removed. Due to the time constraints, this work was done during the winter months. After the removal of damaged shotcrete and the installation of the anchors and wire reinforcement, we began shotcreting operations. The repair work on the piers was accessed with the use of sky climbers and lift trucks where ever possible.

To expedite the work and keep on pace, we ran a two-gun operation, mixing our sand and cement with Airplaco Mix Elevators and shooting with rotary dry-mix shotcrete machines. Schedules were maintained and, despite the overhead shooting and tough shooting angles, the work was completed on time. Liquidated damages were avoided and the bridge opening and the parade of antique cars went on as scheduled.

__Ted W. Sofis__ and his brother, William J. Sofis Jr., are principal owners of Sofis Company, Inc. After graduating from Muskingum College, New Concord, OH, with a BA in 1975, he began working full time as a shotcrete nozzleman and operator servicing the steel industry. He began managing Sofis Company, Inc., in 1984, and has over 34 years of experience in the shotcrete industry. He is an ASA-approved Shotcrete Nozzleman Educator, serves on the Board of Directors of the American Shotcrete Association (ASA), and is a member of the ASA Publications and Education Committees. Over the years, Sofis Company, Inc., has been involved in bridge, dam, and slope projects using shotcrete, as well as refractory installations in power plants and steel mills. Sofis Company, Inc., is a member of the Pittsburgh Section of the American Society of Highway Engineers (ASHE) and ASA.

The QUIKRETE Companies

The QUIKRETE Companies is the largest manufacturer of packaged concrete and cement mixtures in the U.S. and Canada, and an innovative leader in the commercial building industry. QUIKRETE products are manufactured and bagged in 90 manufacturing facilities in the U.S., Canada, Puerto Rico, and South America, allowing for unsurpassed distribution and product depth.

Contributing to this continued growth, The QUIKRETE Companies acquired Target Products, Ltd., the leading producer of dry-mix concrete and cement-related products in Western Canada, in 2008. With manufacturing and distribution facilities near Vancouver, BC, and in Edmonton and Calgary, AB, Target Products offers a diverse product line and technical expertise, in addition to specialized engineering services for the mining and concrete products industry.

QUIKRETE commercial-grade shotcrete products are formulated to provide rapid-strength gain and high ultimate compression strengths, minimal rebound, and low permeability. The QUIKRETE Companies possess a high level of experience in blending fibers, admixtures, and coarse aggregates into shotcrete mixtures. Product designs can be enhanced with a variety of fibers and admixtures, such as synthetic; alkali-resistant fiberglass; or carbon steel fibers, microsilica fume, set accelerators, polymers, and various aggregate sizes.

From our standard shotcrete mixtures to custom mixtures, The QUIKRETE Companies can deliver quality-produced material to meet any specification or project need. QUIKRETE dry- and wet-process shotcrete product designs are available in 50 and 80 lb (23 and 36 kg) bags and 3000 lb (1361 kg) bulk bags.

The QUIKRETE Companies have supported a multitude of structural repair and rehabilitation projects nationwide with American Shotcrete Association (ASA) members. Some of these more recent projects include the Liberty Tunnels in Pittsburgh, PA; the Bonner Bridge in Nags Head, NC; the High Level Bridge in Fairmont, WV; the Norfolk Southern Railroad Radford Tunnels in southern West Virginia; Stanford Linear Accelerator Center in Menlo Park, CA; Lenihan Dam near Los Gatos, CA; and Noblestown Road Bridge outside Pittsburgh, PA.

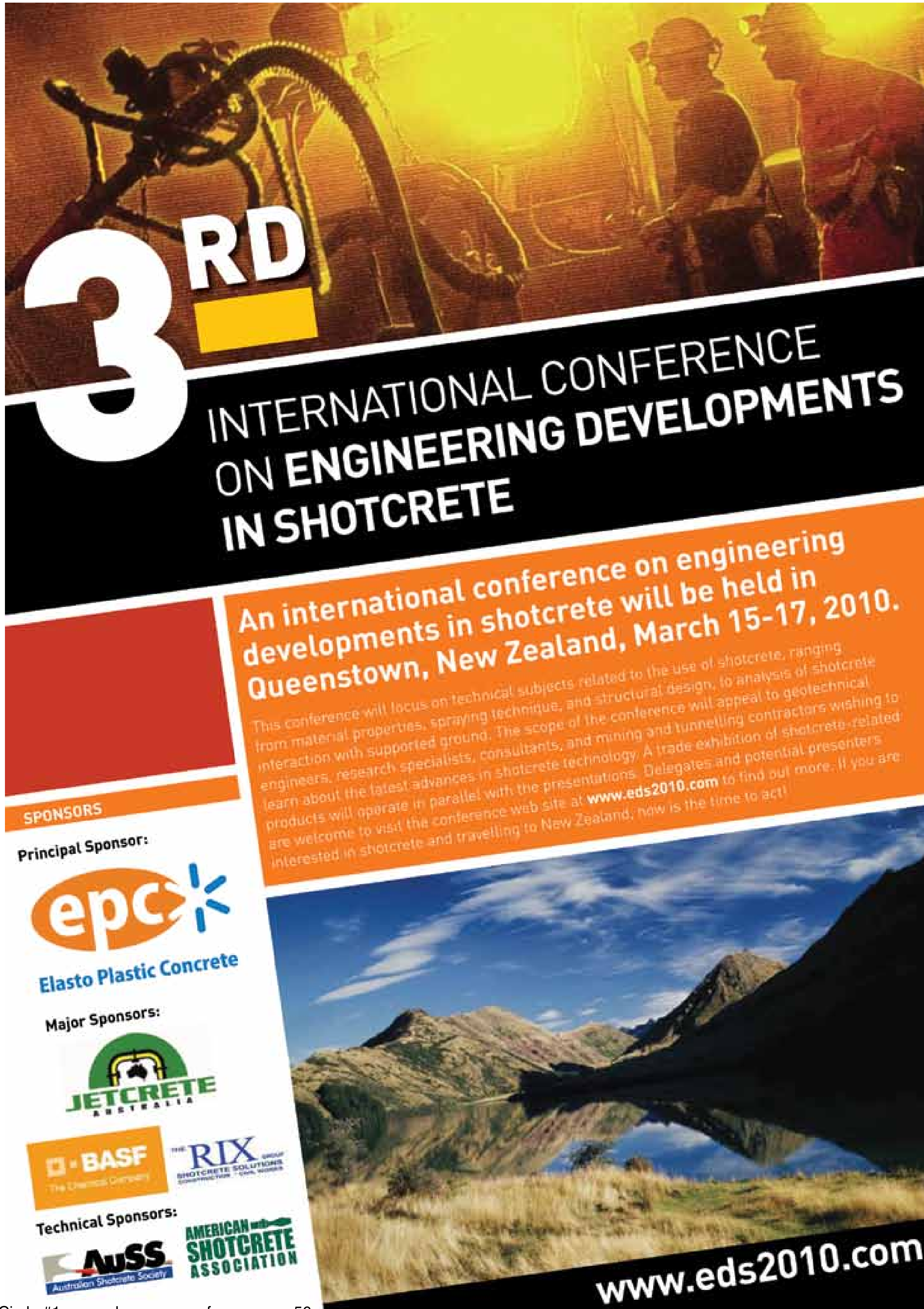
Originally founded in Columbus, OH, in 1940, The QUIKRETE Companies is now headquartered in Atlanta, GA. Operated for more than 68 years, customer service is a main priority for The QUIKRETE Companies. Highly trained and knowledgeable field representatives assist customers through all phases of a project. Field representatives are backed by a state-of-the-art technical center and world-class production facilities, whose goal is to provide customers with the most technically innovative products on the market. The QUIKRETE Technical Center continues to be an industry leader in new product research and development.

For more information or assistance with all your shotcrete needs, visit The QUIKRETE Companies' Web site at **www.quikrete.com** or contact the QUIKRETE Corporate Office at (404) 643-9100.

QUIKRETE Shotcrete MS with corrosion inhibitor used in the structural repair of a bridge pier

QUIKRETE Shotcrete MS used in a mining application

QUIKRETE Shotcrete MS with corrosion inhibitor being applied to a hammer head



Circle #1 on reader response form—page 56

Negative Edge Swimming Pool, Perimeter Edge Spa, and Runnel Connector

Cold Spring, NY

By Jamie Scott

A client had recently built a new weekend home in Upstate New York, with a distinctly modern style interior and exterior. Although there was an existing pool on the property, it had no relation to the new home. Even though the house overlooks the Hudson River, the existing pool actually managed to truncate the view. The homeowners wanted a watershape that would not only open the view to the Hudson River Valley but also fit their modern taste.

The final design consisted of a negative edge swimming pool and perimeter overflow spa with a multilevel runnel system connecting the two bodies of water. Within the main pool was a dividing wall that created a private sitting area in the shallow end. While these design features certainly met the clients' requirements, they added a level of complexity not seen very often in the industry. Building this watershape would require significant thought and preparation.

Swimming pools can be, and are, constructed from various materials. Examples would include vinyl over steel, fiberglass, concrete blocks, placed concrete, or shotcrete. Due to the demanding requirements of the design, shotcrete was determined to be the optimal choice for this project because of its versatility. The shotcrete process would allow for efficient creation of the repeating curves seen in the pool design, as well as the multiple shapes and elevation changes within the spa and runnel complex.

Negative edge pool—reinforcing steel being installed over the sloping floor profiles

A contractor was hired to supply and install the shotcrete, using the dry-method of shotcrete. The dry method proved particularly versatile during this project, as it allowed breaks in the shooting, thereby giving the crews shaping the details time to catch up. Strategies were discussed during advance meetings with the contractor; ultimately, it was decided to shoot the project in four phases.

After demolition of the existing pool, focus was put on the construction of the new pool and its catch basin. The location of the undisturbed topography was determined through site analysis, which was of proper bearing capacity (1000 lb/ft^2 [4882 kg/m^2]), as required by the structural engineer. This information was used to calculate how far away from the house the pool should be located to give the desired effect of the negative edge. Placement of a negative edge pool is always critical to the success of how it relates to the downhill views and, therefore, how happy the clients will be! In this case, the pool needed to be placed out of ground and pushed toward the edge of the slope, which necessitated additional engineering.

Construction began with excavation and the stacking of crushed stone bags, which created the various floor profiles. Care was taken to ensure that the forms were properly braced to avoid vibration during the shotcrete application. Bracing points were spaced no more than 36 in. (910 mm) apart and many times closer. Wood forms were used instead of the more common expanded metal forming material to help achieve the needed rigidity. Later, proper consolidation of the shotcrete and encapsulation of reinforcing bar was shown to have been achieved during core tests of the pool shell. This pool, in particular, had an extraordinary amount of footage where all the wall and floor

Phase 1 of shotcrete. Note top of freestanding wall is cut to an angle, with dividing wall to the right

The base of the perimeter edge spa ready for Phase 3 of shotcrete

Catch basin for pool, with fieldstone veneer being applied

The multi-level runnel system around the spa that will carry overflow water to the pool

planes came together. Hand-shaping the coves in these areas was handled easily because of the shotcrete's one-sided forming ability. This detail would not have been possible had the concrete been placed.

The shotcrete was reinforced with No. 4 (13M) Grade 60 deformed steel reinforcing bar. Also, in addition to the obvious addition of tensile strength, reinforcing bar was installed within interior elements of the pool (steps, benches, and dividing wall) to aid the nozzleman in applying the shotcrete in a timely manner. Recirculation plumbing was rigid schedule 40 polyvinyl chloride (PVC) 1-1/2 to 4 in. (40 to 100 mm) in diameter. The plumbing lines were pressure tested for 24 hours prior to each shotcrete phase to confirm that there were no leaks, and pressure was kept on the lines during all shotcrete applications.

The first shotcrete phase began in August 2007. Using a 4:1 mixture, the contractor began by applying 80 yd^3 (61 m^3) of shotcrete to the pool shell. With care to throw out rebound and trimmed material, a tapered, clean joint was left between the negative edge wall and adjacent catch basin.

The second day was Phase 2, during which the hydration process of the pool began. After stripping the forms in the morning and cleaning and saturating the shotcrete joints to a saturated surface-dry (SSD) condition, the catch basin structure was shot using 23 yd^3 (18 m^3) of shotcrete. The next 7 days were spent soaking the structures to aid in hydration. The pool's structural shell was now complete.

The second half of the project focused on the perimeter overflow spa and multi-level runnel system leading into the pool. The first step was to form the bases of the spa and runnel system. Beneath the runnel, excavation went down 42 in. (1 m), and local 3/4 in. (20 mm) crushed stone was installed as engineered fill to protect against frost heave. The plumbing trunk lines were brought into the base of the spa, and reinforcing bar splices were left projecting from the base—all of which would be picked up for completion during the final construction of the spa.

Phase 3 began at the beginning of October 2007, at which time the spa base and runnel were shot using 15 yd^3 (11 m^3) in total. After hydrating the base and stripping the forms, the next week and a half was spent creating the steel reinforcement for the spa itself and installing the rest of the plumbing. The fourth and final shotcrete phase came later that month, which entailed shooting the spa walls, benches, and steps, and took 12 yd^3 (9 m^3) of shotcrete.

Once the structures were in, the tie wire holes and any forming defects were patched with a nonshrinking grout. This grout also helped seal around all plumbing protrusions through the walls. The shells were now ready for installation of fittings and masonry finishes: ceramic and glass tile, aggregate plaster finishes, and custom precast red concrete panels on the spa. By this time, the outside temperature was dropping, and the winter winds were picking up, so the remainder of the finish work was put on hold until the following spring. The pool was finally ready for its first plunge by Memorial Day of 2008, and the spa followed a month later.

As was discovered early on, it was relatively easy to design these structures, but building them was quite a different story. The success of this watershape relied on moving water without loss, and shotcrete's abilities and characteristics enabled that success. Specifically, a good shotcrete application produces a dense structure that could be created in a noncontiguous manner, without having to use water-stops. The spa and surrounding runnel system contained so many angles, drops, and changes of direction that it would have increased costs and schedules significantly if the concrete had been placed.

Although this project eventually included landscaping, masonry, and carpentry, there is no doubt that the focus of this property was to be the pool. The versatility of shotcrete allowed all phases to proceed with relative ease and allowed this unique pool setting to be created to the homeowner's satisfaction. Without the use of shotcrete, it would not have been possible to accomplish this multi-dimensional project.

Pool & Recreational Shotcrete Corner

The pool and spa connected by the runnel system

The perimeter overflow spa and pool in the fall of 2008

A view of the runnel leading back to the spa

The dividing wall in the pool, along with benches. Coping and tile are being installed

The overflow nature of both the pool and the spa make for highly reflective surfaces

The pool is complete, and the spa is nearing completion as it gets clad with red concrete panels

Acknowledgments

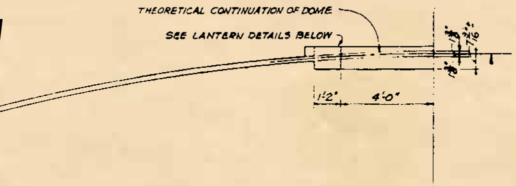
Group Works LLC would like to acknowledge the participation of Shur Shot Gunite Corporation, Mark Lacko of Betonas LLC, and Salvatore Libertino on this project.

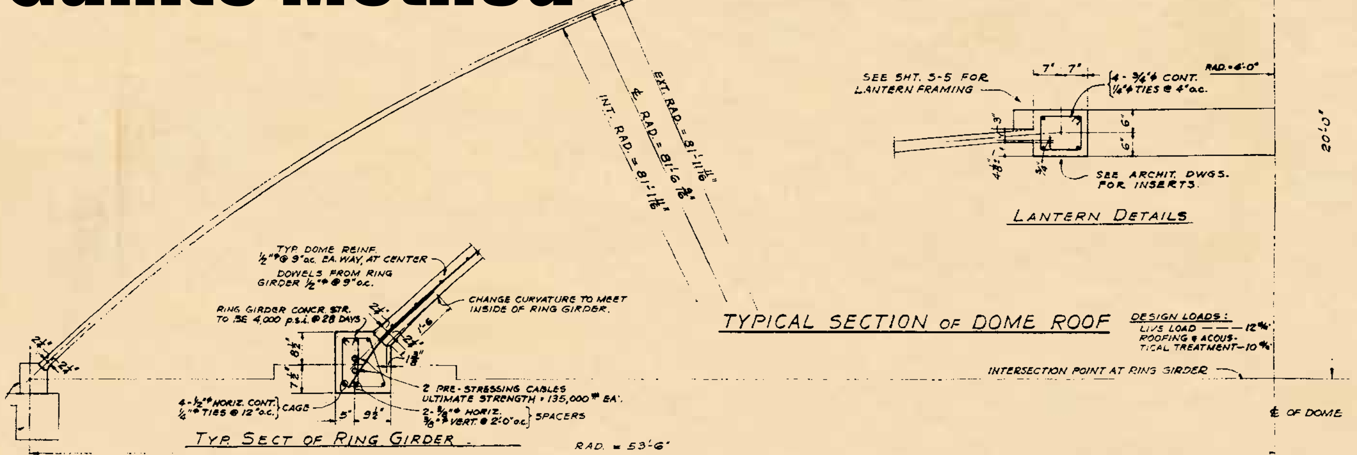
***Tom Norman**, ASA member and Chair of ASA's Pool & Recreational Shotcrete Committee, wants your input. Your comments, suggestions, and the topics you'd like to see covered are welcome. Perhaps you'd like to become a contributing author to Pool & Recreational Shotcrete Corner. Norman and the ASA staff encourage you to contact ASA with your questions and comments at: info@shotcrete.org.*

***Jamie Scott** is a third-generation watershape designer and builder, who has worked in the industry for 37 years. He developed and managed the Sales, Design, and Construction Departments of his co-owned family business. In 1998, Scott started a new firm, Group Works LLC, based in Wilton, CT. Through Group Works LLC, he aligned himself with organizations that focus on continuing education and increasingly higher standards in the swimming pool industry. Scott is a Platinum Member of Genesis 3 and a certified member of the Society of Watershape Designers. He is also an APSP Certified Professional Builder, American Shotcrete Association member, and has trained with the Portland Cement Association. Scott is currently training to becoming a registered landscape architect as well.*

Pre-Stressed, Post-Tensioned Ring Girder Resists Horizontal Component at Base of

Thin-Shell Concrete Dome Constructed by Gunite Method





REQUIREMENTS OF the owner for an auditorium-type church, economically built, determined the design of the edifice under construction at Brooklyn Ave. and Bailey St. in Los Angeles for White Memorial Seventh-Day Adventist Church. The church will seat 2000 people, one-third of them in a balcony; an adjoining chapel will seat 250. The two buildings will be connected by a classroom wing.

Cost of the buildings will approximate $600,000; the floor areas will total 49,000 sq. ft. The church, which is a Type 1 structure, will have an area of 35,000 sq. ft.; the classrooms 10,000 sq. ft., and the chapel 4000 sq. ft.

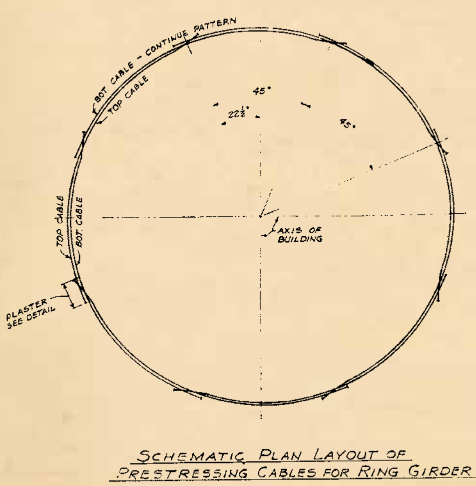
The architects are Heitschmidt & Thompson and the structural engineer is Robert M. Wilder. Hilburg, Hengstler & Turpin are the mechanical engineers, Chauncy Mauk is the electrical engineer, and Donald R. Loye the acoustical consultant. Havstad & Jensen are the general contractors; J. C. Nicholson their superintendent on the job. The gunite work on the dome was performed by the F. W. Case Corp.

The church is poured concrete on conventional spread foundations, with walls of varying thickness. A system of heavy concrete girders was used to carry the balcony, which cantilevers 25′ over the main floor area. The exterior facing will be architectural concrete and brick; the interior wall treatment will be one-half board-type acoustical material and the other half exposed concrete.

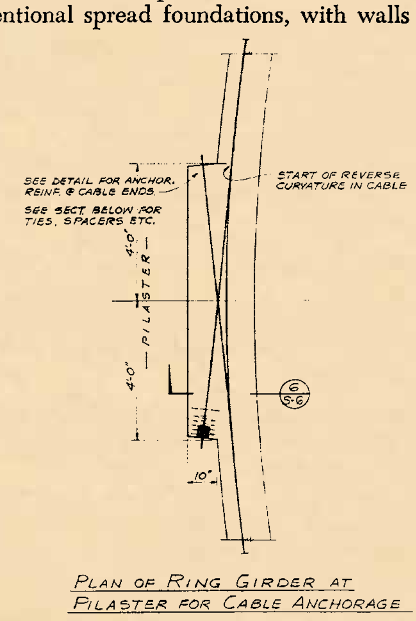
The octagonal shape of the auditorium determined the use of a dome roof, which is the principal structural feature of the building. Steel trusses and other methods of spanning the auditorium were considered; thin-shell concrete was chosen because it offered the most economical solution.

The dome

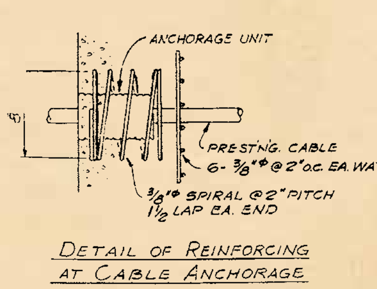
Height of the dome above the floor is 70′; the diameter 107′, ranking in size with some of the largest in the West. It has a post-tensioned ring girder at the spring line, supported at eight sides by walls or by principal girders and by minor girders angling across the corners



SCHEMATIC PLAN LAYOUT OF PRESTRESSING CABLES FOR RING GIRDER



PLAN OF RING GIRDER AT PILASTER FOR CABLE ANCHORAGE



DETAIL OF REINFORCING AT CABLE ANCHORAGE

Shotcrete Classics

From the library of Chris Zynda

Chris Zynda *is President of ASA and Safety Committee Chair. He is a member of ACI Committees 506, Shotcreting, and C660, Shotcrete Nozzleman Certification; an ASTM International member; and a certified ACI Examiner.*

HEITSCHMIDT & THOMPSON, A.I.A.
Architects

ROBERT M. WILDER
Structural Engineer

HAVSTAD & JENSEN
General Contractors

F. W. CASE CORPORATION
Gunite Construction

of the octagon as shown in the half plan. The elimination of connections between ring and balance of structure, at the time of stressing, gave the dome a "free floating" characteristic, permitting horizontal expansion and contraction without affecting the rest of the building. After stressing, parapets and fill were poured, preventing subsequent displacement. A mineral-surfaced cap sheet goes on top of the dome; the under side will have a sprayed on acoustical material.

The following paragraphs describing the dome, including the pre-stressing elements, tensioning procedure, ring girder concrete and concrete for the shell, were taken from office record data prepared by Mr. Wilder.

The dome shell is 107′ 0″ in diameter at the spring line, with a height of 20′ 0″. The thickness varies from 4½″ at the base to 3″ at the edge of the lantern ring. It is supported directly by the walls for part of the circumference and by an appropriate system of girders for the balance, as illustrated.

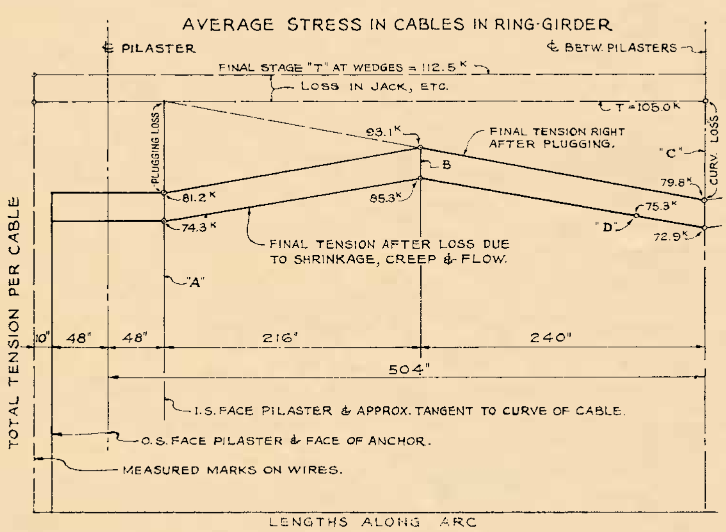
The horizontal component at the base is resisted by a ring girder of concrete containing high-tensile, pre-stressed, post-tensioned cables. By this method some of the difficulties of using the usual reinforcing bars were avoided. When conventional reinforcing is used the tensile stress must be kept quite low or the elongation under load could result in a considerable drop of the crown and distortion of the shell from its calculated position. But if low stresses are used, then a considerable number of the largest size bars would be required and the size of the ring girder is much larger. Furthermore, when conventional reinforcing is stressed, the concrete in the ring girder is necessarily in tension. Yet, the concrete in the portion of the shell immediately adjoining is calculated to be in compression. By post-tensioning, this anomaly is overcome and the other difficulties are avoided.

Pre-stressing elements

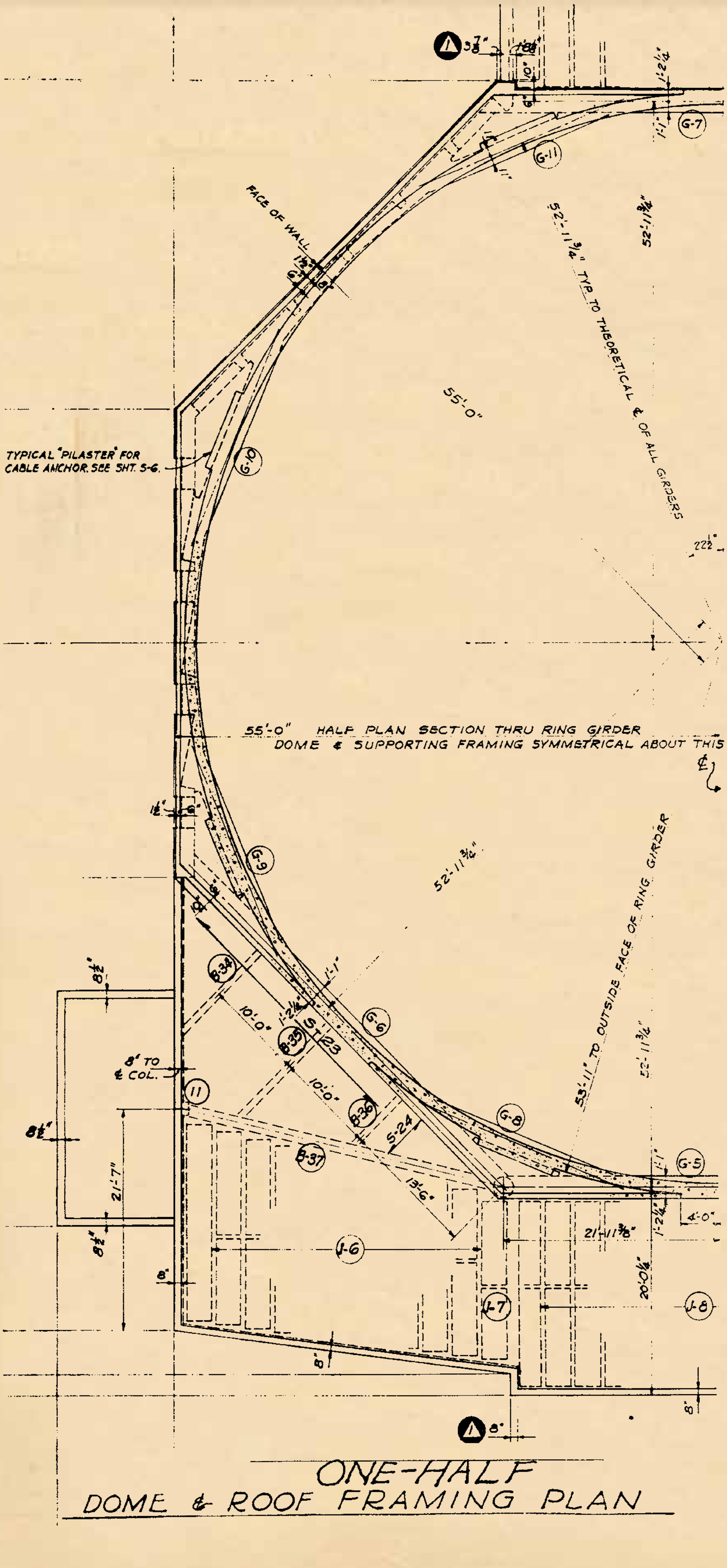
It was decided to use eight separate cables in the entire circumference, each covering an area of 90 degrees. In order to provide for anchorage and tension-

Photographs by Gunite Contractors Association

Guniting operation under way on the dome of White Memorial Seventh-Day Adventist Church. Height of dome above the floor is 70 ft; the diameter is 107 ft



Overall view of White Memorial church and classroom wing which connects it to chapel (not in picture). Dome ranks in size with some of the largest in the West



ing, eight pilasters at 45 degree intervals were detailed as a part of the ring girder. One cable from each side could thus terminate at the opposite face of the pilaster and one cable pass by, thus providing a minimum of two cables at all points. The "Schematic Plan Layout" illustrated will clarify this arrangement. Each cable consisted of a flexible galvanized metal sheath containing 18 ungalvanized wires 0.196" in diameter. The total area of the wires in each cable is 0.543 sq. in.

The specifications required the wire to have a minimum ultimate strength of 250,000 psi. with a minimum elongation in 10" of 2%. The wire was furnished by the American Wire Rope Co. and manufacturers tests showed a strength of from 250,000 to 255,000 psi. with an elongation of about 5%. Confirming tests made by Smith-Emery Co. of samples of the wire furnished showed an average strength of 268,670 psi. and elongation from 4% to 6%. A certificate was furnished by the Blue Diamond Co. that material furnished to the jobs was the same as that sampled and tested by Smith-Emery.

The cables were installed and stressed by the Blue Diamond Co. The cables were laid to a uniform curvature in a cage of conventional reinforcing and attached to anchorage assemblies by the Freyssinet method. Care was taken that the form at the anchorage face of the pedestal was a plane at right angles to the cable at that point. As the sheath was rather flexible and the wires contained inside tended to regain the original curvature of the coil in which they were shipped, there was some difficulty in maintaining the cable at a uniform curve until the ring girder was cast, and considerable additional ties had to be secured to the cable for this reason

Tensioning procedure

As soon as the type of anchorages and other elements had been selected by the contractor and approved, a detailed procedure was prepared covering each step to be followed, giving the required jack pressures and expected elongations at each stage. A chart was also prepared for recording all observations.

The actual tensioning was carried out in two stages; the first when the ring girder concrete had sufficient strength and before casting the dome shell; the second and final stage when the shell itself had acquired sufficient strength. This procedure had two advantages. The first stage could be used as a test run to uncover any "bugs." Since the stress at this stage was only about ⅜ of the final, any such "bugs" could not be serious and time would be available to program changes in the procedure before starting the final stage. Also, initial adjustments due to early shrinkage and other adjustments could take place before final stressing and recording of elongations.

After attaching the hydraulic jacks to the wires in the first stage, they were first pumped up to a piston pressure of 500 psi. This initial tension took up the slack in the wires, so that elongation measurements were meaningless. Consequently this part of the elongation was calculated and added to subsequent observed elongations to arrive at a figure for the total elongation. Three wires at each end were then marked with scotch tape at a constant distance from the anchorage to the near edge of the scotch tape and subsequent measurements could be made at any stage to determine actual elongations at different increments of stress. A much smaller elongation than anticipated might indicate that the stressing was not effective over the entire length, and these observations were desirable for that and other reasons. A further precaution that might be desirable would be to mark all wires, even though only three would be measured. This would make possible visual observation if any single wire should slip or otherwise not move in unison with the others.

The balance of the first stage pressure was then applied, elongation recorded, the anchorage units plugged, and elongation again recorded. In the final stage, the cables were brought up to the final desired tension and plugged, with elongations recorded as before. Grout was then injected to fill the space between the wires and the sheath. The ends of the wires were not cut off, as they would later be encased in concrete roof fill on the area adjoining the dome.

Using the average of observed actual final tensions and the average of the actual loss of elongation at plugging, the total elongation was calculated and found to agree with the average of the total observed elongation within 2%, although, as might be expected, there were deviations in the individual cables from this mean value. The diagram shows the final tension along its length of this "average" cable.

Ring girder concrete

The concrete for the ring girder was cast on a trowelled surface which had been treated with an anti-bonding material so as to permit free movement when the post-tensioning took place. A 28-day strength of 4000 psi. had been specified and a design mix was set up by Smith Emery Co. with the dry loose proportions of 1C:1.77: 2.41R(1″), 4.75 gal. of water per sack and 0.5 lb. Plastiment per sack. The yield was 7.65 sacks of cement per yard. Special qualifying cylinders showed strengths from 2760 to 2890 psi. at 7 days, and from 4665 to 4755 psi. at 28 days. Job cylinders showed an average strength of 3145 psi. at 3 days, 3785 psi. at 7 days, and 5890 psi. at 28 days. The ring girder was cast July 26. The first stage of post-tensioning was done at an age of 5 days, when it had an approximate strength of 3785 psi. The final stage of post-tensioning was done at the age of 28 days, when it had a strength of 5890 psi. Concrete was kept nearly continuously moist from the time it was cast until stressed.

Concrete for dome shell

The concrete for the dome shell was specified as only 2000 psi. at 28 days, as the actual dome stresses were quite low. Because of concern about placing

This photograph shows special staging used by the guniting contractor to enable workmen to stay off of the concrete. In shooting the job he used two units working from opposite sides of the dome

Here, workmen are shown shooting one of the four annular rings of gunite, shot on four successive days. Principal reinforcing is No. 4 bars, 9 in. o/c both ways and centered in slab

Control of curvature was provided by using pencil rods set on 6 in. spikes driven into the sheathing. As shown here, the rods were removed before screeding began difficulties at the steepest part of the dome, the contractor elected to use gunite instead, with a mix designed to reach 3000 psi. in 28 days. The guniting was done by the F. W. Case Corp. under the supervision of a registered deputy inspector. Work was started at the bottom by two crews and brought up to annular pour joints at the end of each day. In addition to the usual test cylinders, special small panels were shot for each day's pour from which cores could be taken and tested. The cylinders had an average 28-day strength of 4948 psi., while the cores had an average 28-day strength of 440 psi.

The shell was gunited from Aug. 8 to Aug 11 and was sprayed continuously during the curing period. It was approximately 16 days old at time of final stressing, with an approximate strength of over 4000 psi. Shores were lowered Aug. 29 by starting at the center and loosening uniformly all the way to the outside, after which the work of stripping forms was commenced. Any settlement at the crown was so small it was not measurable and, thus, demonstrated the value of pre-stressing the ring girder. At conclusion of guniting it was noticed that some areas showed high spots and flat spots. Small cores were drilled to make sure the thickness of shell had not been reduced at the flat spots. It was found that minimum thickness was as calculated and that thickness was exceeded at high spots.

Gunite application

Good control of curvature and proper screeding to get a uniform finish were essentials in concreting the dome shell to design requirements. At first the gunite contractor considered doing the work in vertical panels, like the segments of an orange, but decided he would have better control with horizontal joints and shot the job in a series of four annular rings on four seccessive days.

His control was provided by the use of pencil rods (removed before the screeding began) set on 6″ spikes driven into the sheathing to the proper depth. The rods were placed about 4′ apart, circumferentially, at the elevations required to give correct taper to the finished dome.

In shooting the job, the contractor used two units working from opposite sides of the dome. He also doubled up on the number of finishers employed, using twice as many as is customary in order to keep the slope uniform.

Particular care was taken to keep the joints clean in order to get good bond between annular sections. Reference to the accompanying photographs will show the special staging used by the contractor to enable workmen to stay off of the concrete.

Forming for the dome concrete, performed by the general contractor, was from 50′ to 70′ in the air. Four-by-four shoring was used, tied at frequent midpoints, and the form was composed of 1x6's, placed in an annular pattern. Shimming for final levels was done at the top of the shoring.

Circle #35 on reader response form—page 56

U.S. Stimulus Act Includes $130 Billion in Construction Spending

On February 17, 2009, U.S. President Obama signed the $787.2 billion American Recovery and Reinvestment Act (ARRA) of 2009. The measure contains about $130 billion for highways, buildings, and other public works. The package's appropriations portion includes most of the construction-related spending. It is estimated that only $34.8 billion, or 11% of the bill's $308.3 billion in appropriation outlays, will occur by September 30, the end of fiscal 2009. But 2010 will be a much bigger year, with $110.7 billion in outlays, according to the Congressional Budget Office (CBO).

Of the $130 billion in construction spending, transportation received the largest share, more than $49 billion, with $27.5 billion of that for highways. A surprisingly big winner was high-speed rail which emerged in the final bill with $9.3 billion.

PCA Elects Escalante as Chairman

The Portland Cement Association (PCA) Board of Directors elected Enrique Escalante as Chairman during the association's late-December board meeting in Dallas, TX. Escalante will serve a 2-year term as Chairman, succeeding Charlie Sunderland of Ash Grove Cement Co.

Escalante is currently the President of Denver-based GCC of America. He joined that company in 1999 as President of its Mexican division, moving to his current position in 2000. Prior to joining GCC, Escalante had more than 20 years of experience in management and sales positions in heavy industry and construction materials.

In addition to serving as PCA's Vice Chairman for the past 2 years, Escalante served as the Chairman of the Research and Technical Council and Product Standards and Technology Committee. He was a member of the Regional Promotion and Publications Committees as well.

Aris Papadopoulos, CEO of Titan America, the U.S. subsidiary of Titan Cement Group, was elected Vice Chairman at the PCA meeting. In addition, he serves as Chairman of PCA's Sustainable Development Committee.

Cement and Concrete Shipments Continue to Lag

Total shipments of portland and blended cement in the U.S. and Puerto Rico were about 10.1 million tons (9.2 million metric tons) in October 2008, according to the U.S. Geological Survey. This was 16% lower compared with shipments for October 2007. Year-to-date shipments were 92.6 million tons (84 million metric tons), down 14% from the same period in 2007.

Masonry cement shipments were about 291,010 tons (264,000 metric tons) in October 2008—28% lower compared with shipments in October 2007. Year-to-date shipments totaled 3 million tons (2.7 million metric tons), down about 28%.

The preliminary estimate of ready mixed concrete produced in November 2008 is 24.4 million yds^3 (18.7 million m^3), down 30% from 2006. For the first 11 months of 2008, ready mixed concrete production was down 15% from the same period in 2007.

ASA Annual Membership Meeting and Awards Banquet

The 2009 ASA Annual Membership Meeting held at the Monte Carlo Resort and Casino in Las Vegas, NV, on February 2, 2009, was once again a very enjoyable evening, showing off some of the best the shotcrete industry has to offer. A special thanks to our event sponsors on behalf of all participants for making the evening possible.

Chris Zynda, ASA President and Chair of the Safety Committee, started the event by presiding over the business meeting. He thanked the ASA committee Chairs for their hard work and leadership (**Ray Schallom**, Education Committee; **Joe Hutter**, Marketing Committee; **Patrick Bridger**, Membership Committee; **Tom Norman**, Pool and Recreational Shotcrete Committee; **Howard Robbins**, Publications Committee; and **Dan Millette**, Underground Committee). All of these committee's reports can be found in the 2008 ASA Annual Report. All ASA committee meetings are open to any interested member. Contact ASA directly for information on the next round of meetings.

Zynda then recognized the ASA elected leaders for 2009 and thanked two individuals who had just completed 3-year terms of service as ASA Directors: Tom Norman, Airplaco Equipment Company, and **Joe Tortorella**, J. Tortorella Swimming Pools. He extended a special thanks to all who have volunteered to serve ASA.

Once the business meeting side of the evening was complete, it was time for The Fourth Annual Outstanding Shotcrete Project Awards Banquet. First was The Carl Akeley Award, established to recognize the best technical article appearing in *Shotcrete* magazine. The 2008 winning article came from the Summer 2008 issue and was titled "Embrittlement of Fiber-Reinforced Shotcrete" by **E. Stefan Bernard**.

Next up were the Outstanding Shotcrete Project Awards presented by President Zynda and Marketing Committee Chair Joe Hutter. Recipients were selected by the ASA Awards Committee: Joe Hutter, **Ed Brennan**, **Marc Jolin**, Dan Millette, and Ray Schallom. Each winning project team made a brief presentation and explained the role shotcrete played in their projects. A list of each award and the winning project participants can be viewed at **www.shotcrete.org/08Awards**.

The ASA President's Award was established in 2006 to recognize individuals or organizations that have made significant contributions to advancing the use of the shotcrete method of concrete placement. The award recipient is selected solely by the

ASA New Members

CORPORATE MEMBERS

StrataCrete Pty Ltd
Brisbane, Qld, Australia
Primary Contact: Alby Loncaric
alby@stratacrete.com.au
www.stratacrete.com

Pristine Pools and Spas
Boise, ID
Primary Contact: TJ Brown
tj@pristinepoolandspa.com
www.pristinepoolandspa.com

Northern Sierra Corporation
Saginaw, MI
Primary Contact: Ross Lake

CORPORATE ADDITIONAL MEMBER

Newell Graf
Knowles Industrial Services Corporation
Gorham, ME

INDIVIDUAL MEMBERS

Bruce Liberti
B.L. International
Fort Lee, NJ

David Seffer
Deerfield Beach, FL

Edwin Brady
Edwin Brady Construction Company, Inc.
Paris, KY

Patrick Wheeler
Precon Corporation
Newberry, FL

INTERESTED IN BECOMING A MEMBER OF ASA?

Find a Membership Application on page 52, and read about the benefits of being a member of ASA on page 53.

AMERICAN SHOTCRETE ASSOCIATION

current ASA President and is known only to him/her prior to the actual award presentation. The 2008 recipient was **Dudley R. "Rusty" Morgan**. In making the presentation, President Zynda noted that Rusty has made "so many contributions to the shotcrete industry and to ASA, that they almost cannot be counted."

Again, congratulations to all award winners and thanks to the event sponsors for making the evening possible. We invite you to take a moment and view the details on all award winners and the event sponsors at **www.shotcrete.org/08Awards**.

2009 World of Concrete Trade Show

Hanley Wood, owner and manager of World of Concrete, which ASA cosponsors, announced that over 65,000 persons attended this year's event, held February 3-6, 2009, in Las Vegas, NV. Traffic at the ASA booth was steady and the ASA seminar "Shotcrete: A Versatile Construction Solution," was well received. All in all, we had a great opportunity to continue our mission of "encouraging and promoting the safe and beneficial use of the shotcrete process to the concrete industry."

ASA 2009 Election Results

Members of the Board of Directors whose terms continue in 2009 are **Jean-François Dufour**, King Packaged Materials Co.; **Dan Millette**, The Euclid Chemical Company; **Ryan Poole**, DOMETEC International; **Andrea Scott**, Hydro Arch; **Ted Sofis**, Sofis Company; and **Ray Schallom**, Allentown Shotcrete Technology, Inc. Reelected to a 3-year term as a Director was **Howard Robbins**, Con-Arch Engineering. Newly elected to a 3-year term as a Director were **Marcus von der Hofen**, Johnson Western Gunite, and **Curt White**, Coastal Gunite.

President **Chris Zynda**, J. J. Albanese, Inc., and Vice President **Patrick Bridger**, Allentown Shotcrete Technology, Inc., continue in office in the second year of their terms.

Reelected to a 1-year term as officers were Secretary **Joe Hutter**, King Packaged Materials Co., and Treasurer **Michael Cotter**, American Concrete Restoration.

In addition, two changes to the ASA bylaws were approved. You can view the current bylaws at **www.shotcrete.org/bylaws**.

Circle #45 on reader response form—page 56

Reprinted with permission from the Fall 2003 issue of Shotcrete *magazine*

Shotcrete Rebound—How Much is Enough?

By Michael Ballou

Rebound is an essential element in the application of shotcrete. Rebound is defined as follows: "Mainly large aggregate with some sand and cement that bounces or ricochets off the receiving surface and falls on to lower surfaces."[1] There is a vital function that is achieved in the rebounding of shotcrete. The secret lies in knowing how much rebound is enough.

To paint a mental picture for the reader to understand rebound, consider a baseball. If you take a baseball and dip it into some fresh concrete and pull it out, it will be covered with mortar—a paste consisting of the cement and fine aggregate and water—that acts as the glue required to create an artificial rock called "concrete." If you took this baseball covered with mortar and threw it at a high velocity against a solid block wall at a 90-degree angle to the wall, the ball would strike the surface and bounce off. Because the paste is also in motion at 95 miles per hour and the paste is not securely bonded to the ball, some paste will leave the surface of the baseball, contact the wall, and adhere to the surface. In layman's terms, it would "splat" onto the wall. The harder the baseball is thrown, the more the paste would leave the surface of the ball and stick to the wall. As you might guess, if the same ball is thrown at the wall at a slower speed, the ball would still bounce off, but only a small portion of the paste would stick to the wall. The paste would not be forced into the pores of the wall. It would either strike the wall and fall to the ground or stay on the baseball.

What would happen if you kept throwing a mortar-covered ball repeatedly at the wall? There would be a layer of mortar accumulating on the wall. Eventually, the ball would also embed itself into the mortar and stay on the wall.

What if the baseball is thrown at an angle to the surface of the wall, not perpendicularly? The ball would still bounce off, but there would be even less mortar transferred to the wall. The ball would not become embedded on the surface. It is only by throwing the ball perpendicular to the wall that we get the desired results, with layers of paste being forced into the pores of the surface and adhering to the wall.

The same physical principles are true with shotcrete as with the baseball example. The aggregates and other particles are being blasted out of a nozzle at a high velocity. They are covered with mortar. If the nozzleman keeps the nozzle perpendicular to the surface and makes small circular motions with it, the aggregate particles bounce off the surface and the paste begins to accumulate, creating a sticky surface for subsequent shotcrete material to become compacted into the surface.

For this reason, some rebound is needed and expected. Without some rebound, the desired adhesive properties of the shotcrete will not be achieved. Mortar will either not stick and slough off the surface and fall to the ground, or worse still, fail later on due to poor bonding qualities. This principle holds true for both wet-mix and dry-mix shotcretes. Rebound is, however, inherently higher in the dry-mix shotcrete process than the wet-mix process. More rebound is expected when shooting through welded wire mesh or reinforcing steel. This is especially true if the wire mesh or reinforcing bar is not anchored properly to the surface. The reinforcing material may vibrate when struck by the shotcrete, thus increasing the amount of rebound. Rebound is also higher when there are small openings in the welded wire mesh.

Conclusions

- Do not reduce the pressure and the velocity of the shotcrete in an attempt to control rebound. Shotcrete is properly applied at high velocity.
- Stay perpendicular to the spraying surface, and not too far away.
- Use small, circular motions instead of large, sweeping circular motions when applying shotcrete to reduce wasteful rebound.
- Start at the bottom and move higher on the spraying surface.
- Rebound from shotcreting onto rock and other hard surfaces will have a dramatic impact on the ratio of rebound to shotcrete adhering to the surface. The amount of rebound will be higher with thin layers of shotcrete.

There is a fine line between too little rebound and too much rebound. If there is too little rebound, there may not be sufficient mortar penetrating the pores on the surface and the bond between the shotcrete and the host surface may be inadequate. Too much rebound results in excessive costs for materials. It is the role of the shotcrete industry to make known the mechanics of shotcrete application. Shotcrete must be applied properly or it will not deliver the desired performance. We must work to educate owners, architects, engineers, and contractors on the need to use trained and certified personnel to achieve maximum value from the shotcrete process.

References

1. *Shotcrete Nozzleman Craftsman Workbook*, CP-60, American Concrete Institute, Farmington Hills, MI, 24 pp.

***Michael Ballou** is the President of Bullhide Fibers & Shotcrete Supply, Taylorsville, UT. He is a Graduate Civil Engineer with over 25 years of experience in tunneling and mining throughout North America and he has been a member of ASA for many years. He served for a term on the ASA Board of Directors, the Publications Committee, and the Underground Committee. Ballou is also a member of ACI Committees 506, Shotcrete, and 552, Cementious Grouting, along with several ACI shotcrete subcommittees.*

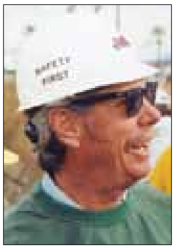
A *Shotcrete* feature:

Reprinted with permission from the Spring 2006 issue of Shotcrete *magazine*

SAFETY SHOOTER

Hard Hats and Beer Cans...Now and Then

by Chris Zynda, Director of Shotcrete Operations, Joseph J. Albanese, Inc., ASA President and Safety Committee Chair



Why do we wear hard hats? Is it because the sky is falling? Let's say you are pouring a 10,000 ft^2 (930 m^2) slab-on-ground with no concrete boom and nothing overhead. Why the need to wear a hard hat? How about a backyard residential swimming pool 8 ft (2.4 m) deep with nothing overhead? Is a hard hat really needed? Or what about the engineer who comes by the job with the architect? Do they really need hard hats? Why do job sites post "HARD HATS REQUIRED" signs?

It's called job-site awareness and everyone must wear a proper hard hat. I realized this when one of my employees showed up with one of those cowboy hard hats and the owner of the project asked me if we were at a rodeo or at his job site building his structure. Needless to say, cowboy hard hats are no longer permitted.

Canal lining project in southern California using dry-mix shotcrete, 1954

Double chamber dry-process shotcrete machine used on seismic retrofit project, 1954

Structural retaining wall project using dry-mix shotcrete, 1955

This concept of job-site awareness extends to all personal protective equipment (PPE). It seems to bother many employees that companies require items such as safety goggles, steel-toed boots, long pants (no shorts), and gloves. Being properly equipped needs to become a habit. That means PPE is used all the time. Vince Lombardi, legendary coach of the Green Bay Packers, said, "Winning is not a "sometimes" thing. It is an 'all-the-time' thing." The same goes for safety.

Years ago things were quite different on job sites. I hope you enjoy the old-time pictures from my father's jobs. See if you can find anyone with a hard hat. The last picture is from one of our current jobs. Notice the contrast with the old days—now there are hard hats, safety vests, certified scaffolding radios for pump operations, and so on. And if you found a beer can at this job site, it would cost over $500,000 in lost billings and attorney fees. Be safe.

Gunite shoring and basement wall project using dry-mix shotcrete, 1955

Gunite shoring and basement wall project using wet-mix shotcrete, 2005

Shotcrete Calendar

March 15-19, 2009
ACI Spring 2009 Convention
Theme: "Infrastructure—Concrete Practice & Placement"
Marriott Rivercenter
San Antonio, TX
Web site: **www.concrete.org**

March 31, 2009
Ground Control Colloque—Association miniere de Quebec
Val d'Or, QC, Canada
Web site: w**ww.amq-inc.com**

April 1, 2009
ASA Underground Shotcrete Conference
Val d'Or, QC, Canada
Web site: **www.amq-inc.com**

June 7-10, 2009
11th International Conference for Shotcrete for Underground Support
Davos, Switzerland
Web site: **www.amberg.ch**

June 14-17, 2009
ASTM International Committee C09, Concrete and Concrete Aggregates
Vancouver, BC, Canada
Web site: **www.astm.org**

June 14-17, 2009
The International Bridge Conference®
Pittsburgh, PA
Web site: **www.eswp.com/bridge/index.htm**

November 7, 2009
ASA Fall Committee Meetings
Marriott New Orleans
New Orleans, LA
ASA Executive Committee Meeting—CLOSED
7:00 am–9:00 am
Publications Committee Meeting
9:00 am–10:00 am
Pool & Recreational Shotcrete Committee Meeting
10:00 am–11:00 am
Education Committee Meeting
11:00 am–12:00 pm
Safety Committee Meeting
12:00 pm–1:00 pm
Marketing & Membership Committee Meeting
1:00 pm–3:00 pm
ASA Board of Direction
3:00 pm–5:00 pm

November 8-12, 2009
ACI Fall 2009 Convention
Theme: "Spice Up Your Concrete"
Marriott New Orleans
New Orleans, LA
Web site: **www.concrete.org**

November 9, 2009
ASA Underground Committee Meeting
Marriott New Orleans
New Orleans, LA
5:00 pm–7:00 pm

November 13-18, 2009
International Pool/Spa/Patio Show
Conference: November 13-18
Exhibits: November 16-18
Mandalay Bay Convention Center
Las Vegas, NV
Web site: **www.poolspapatio.com**

December 7-9, 2009
ASTM International Committee C09, Concrete and Concrete Aggregates
Atlanta, GA
Web site: **www.astm.org**

March 15-17, 2010
Australian Shotcrete Society's International Conference/Engineering Developments in Shotcrete
Millennium Hotel
Queenstown, New Zealand

Shotcrete FAQs

As a service to our readers, each issue of *Shotcrete* will include selected questions and provide answers by the American Shotcrete Association (ASA). Questions can be submitted to: info@shotcrete.org. Selected FAQs can also be found on the ASA Web site: **www.shotcrete.org/ASAfaqs.htm**.

Question: *What is the maximum thickness for shotcrete used for shear walls? Can we use more than 12 ft (3.7 m) if we use a double layer of reinforcing?*

Answer: There is no stated maximum thickness for shotcrete used in shear walls or any other type of wall. Walls have been successfully placed to a thickness of 36 in. (914 mm) for some time. The two main concerns are the heat of hydration and proper encapsulation of the reinforcing steel. Because shotcrete mixtures typically contain more cement per cubic yard or cubic meter than formed and poured placements, there will be more heat generated by the shotcrete mixture. The ability of the nozzleman to encapsulate the reinforcing will be a function of proper mixture design, proper selection of shotcrete equipment, and the skill level of the nozzleman and the crew.

Question: *We would like to get approval to use shotcrete on the perimeter walls of an existing laboratory building. We would be shooting against a waterproofing membrane and shoring lagging. The project engineer is concerned that the shotcrete will damage the membrane, resulting in leaking into the occupied space. Are there any examples where this type of shotcrete placement has been used?*

Answer: This is a commonly used technique in the Western U.S. and Canada, and has been used successfully from Stanley Hall at the University of California at Berkeley, Berkeley, CA, to the Baltimore Hilton Convention Center near Camden Yards, Baltimore, MD. There are a number of suppliers of waterproofing materials to choose from for this application. In selecting a supplier, be sure there is field service available to inspect the project before placement of the shotcrete.

Allentown Introduces MR-1T

Allentown Shotcrete Technology, Inc., announces the MR-1T trailer-mounted mixer-pump, the newest addition to its refractory industry product line.

"We know that downtime on a refractory installation compromises productivity and profitability. That's why our durable and reliable mixer-pump is invaluable to refractory material producers, contractors, and plant owners," notes Patrick Bridger, Allentown's President. "Its small footprint allows for setup in confined spaces and promotes easy transport and storage."

The compact and maneuverable Allentown MR-1T mixer-pump easily navigates through working plants or warehouses with minimal disruption of other activities.

Standard features for the 8300 lb (3765 kg) mixer-pump include:

- Seven yd^3/hour (5 m^3/hour) maximum volume output;
- 2000 psi (13.8 MPa) maximum material pressure;
- 12 ft^3 (340 L) hopper capacity;
- 2000 lb (907 kg) mixer capacity;
- 99 in. (2.5 m) mixer load height with bag cutter;

The MR-1T trailer-mounted mixer-pump

- No special road permits required;
- Parts readily available;
- Proven reliable Putzmeister S-valve with splined shaft;
- High-performance diesel engine; and
- Removable hopper extension for easy cleanout and access to parts for maintenance.

The MR-1T launched in 2008 and is available now. You can visit the company's Web site at **www.allentownshotcrete.com** to view specifications and download product literature.

Allentown Introduces AST 25

Allentown Shotcrete Technology, Inc., announces the newest addition to its underground industry product line: the AST 25 robotic nozzle manipulator.

The AST 25 features a track-mounted robotic boom for use with a concrete or shotcrete pump. "The robotic boom allows the nozzleman to stay out from underneath newly excavated, exposed rock," says Patrick Bridger, Allentown's President. "In addition, it offers a maximum spraying height of 25 ft (7.62 m) and 35 ft (10.67 m) side to side."

Other standard features of the AST 25 include:

- 10 hp (7.5 kW), 460 V/60 hz electric motor for boom and nozzle functions;
- 26.5 hp (20 kW) water-cooled diesel engine for tracks and outriggers;
- Accommodates large nozzle sizes of 2.5 in. (65 mm) or 3 in. (80 mm);
- For use with wet- and dry-process work;
- 20 gal (75 L) hydraulic tank capacity; and
- 50 ft (15 m) tethered remote with shoulder straps for boom and nozzle functions.

"Ideal for slope protection, tunneling, and even water blasting, the machine can be set to automatically oscillate for smooth coverage, giving the contractor even more of an advantage over manual spraying," adds Bridger.

The AST 25 also offers heavy-duty rubber Caterpillar® tracks that are independently driven with two-speed track control, hydraulic outriggers, and a diesel engine.

The AST 25 robotic nozzle manipulator

Tires + Cement Kilns = A Solution to Landfill Disposal

Research released this year by the Portland Cement Association (PCA) supports findings from previous air emission studies conducted by government agencies and engineering firms that indicate that tire-derived fuel (TDF) use in cement kilns does not adversely affect the emissions profile of various air pollutants.

During the November 2008 Greenbuild International Conference and Expo in Boston, MA, PCA officials highlighted the report and emphasized the environmental benefits of using scrap tires as supplemental fuel in the cement manufacturing process. PCA Director of Regulatory Affairs Tyrone Wilson said, “This study shows that tires, which pound for pound have a greater fuel value than coal, can also help manufacturers recycle tires without adversely affecting emissions. The nearly 300 million used tires generated by the United States each year can create an environmental nuisance and eyesore. By simply disposing of these tires in landfills or junkyards, society misses an important recycling opportunity: the chance to recover energy and conserve fossil fuel resources.”

The study, conducted by Air Control Techniques, PC, is based on emission data collected by PCA from 31 cement plants presently firing TDF. The emissions of particulate matter, nitrogen oxides, most metals, dioxin-furans, and sulfur dioxide from kilns firing TDF with conventional fuels were slightly lower than emissions measured from kilns firing only conventional fuels. The emission levels for carbon monoxide and total hydrocarbons were slightly higher for TDF-firing versus non-TDF firing kilns. None of these differences in emissions were significantly different.

Additionally, cement plants using TDF reduce the amount of coal burned. For each ton of TDF used, the plant reduces the need to use 1.25 tons (1.13 metric tons) of coal. This means that less carbon dioxide (CO_2) is produced.

Portland cement kilns are especially well suited for the safe and efficient consumption of the millions of used tires generated each year. Wilson said, “The intense heat of the cement kiln ensures complete destruction of the tires. Because the fire is contained within the kiln under intense heat, there are no visible emissions from the tires such as the heavy black smoke seen in an open-air tire fire.”

The use of TDF provides a solution to a serious, significant health and safety problem while helping to reduce the CO_2 generated from cement production. This is just one more contribution to sustainability from the cement and concrete industry.

AMERICAN SHOTCRETE ASSOCIATION

Membership Application

Name ____

Title ____

Company ____

Address ____

City ____

State/Province ____________________ Zip/Postal Code ____________________

Country ____

Phone ________________________ Fax ________________________

E-mail ____

Web site ____

Sponsor (if applicable) ____

Please indicate your category of membership:

❏	Corporate	$750
❏	Individual	$250
❏	Additional Individual from Member Company	$100
❏	Employees of Public Authorities and Agencies	$50
❏	Nozzleman	$50
❏	Student	Free

Requires copy of Student ID card or other proof of student status

NOTE: Dues are not deductible as charitable contributions for tax purposes, but may be deductible as a business expense.

Payment method:

❏ Check enclosed (U.S. $)

❏ MC ❏ Visa

Card# ____

Expiration date ____

Name on card ____

Signature ____

ASA, a young and dynamic national association representing professionals and companies within the shotcrete industry, was organized in March 1998. The purpose of this nonprofit trade association is to promote the use of shotcrete by educating, encouraging, and supporting all persons or organizations that could benefit from the use of this concrete placement method. The focus of this organization is to provide current and accurate information to all in the industry who wish to improve the quality and expand the use of shotcrete.

As a professional national trade association, ASA is committed to excellence and dedicated to providing the association's members and the industry with the most accurate and reliable information related to shotcrete. This commitment provides the member with the opportunity to achieve greater success within this burgeoning industry.

AMERICAN SHOTCRETE ASSOCIATION
38800 Country Club Dr. Farmington Hills, MI 48331
Phone: (248) 848-3780
Fax: (248) 848-3740
E-mail: info@shotcrete.org
Web site: www.shotcrete.org

Please note your interest in involvement in the following activities:

❏ Education and Certification
❏ Marketing
❏ Membership
❏ Pool & Recreational Shotcrete
❏ Publications
❏ Safety
❏ Underground

Please mark your company's specialties below:

❏ Engineer/Specifier
❏ Equipment supplier
❏ Landscape
❏ Material supplier
❏ Mining and underground
❏ Refractory
❏ Repair
❏ Slope protection
❏ Structural
❏ Swimming pools
❏ Tunnels
❏ Other ____________________

Please provide a brief description of your company's primary business:

____
____
____
____
____

AMERICAN SHOTCRETE ASSOCIATION

Membership Benefits

CORPORATE

- Voting privileges at meetings and director/officer elections (company names a corporate contact person for voting purposes)
- All company employees have opportunity to receive discounted Corporate Additional ASA Memberships ($150 off regular membership price for each employee)
- Company contact information and web link listed on Corporate Member page of Web site
- Discounts on advertising in *Shotcrete* magazine
- Free logo and link advertising on ASA Web site homepage for duration of each issue you advertise in *Shotcrete*
- Opportunity to submit entries into the annual Outstanding Shotcrete Project Awards Program
- 25 complimentary ASA shotcrete brochures annually ($50 value)
- 10 complimentary ASA reflective hardhat stickers ($10 value)
- Discounted prices on additional ASA shotcrete brochures and pocket safety manuals
- Reduced advance registration fees to ASA annual meetings
- Networking and participation opportunities at Annual Membership Meeting and committee meetings
- Subscription to quarterly *Shotcrete*
- Opportunity to submit items for Company Profile, Industry News, and New Products & Practice sections of *Shotcrete* at no charge
- Permission to include ASA logo on corporate letterhead, business cards, and Web sites
- Free advance general admittance registration to World of Concrete
- Discount on ACI Nozzleman Certification program and ACI Recertification program
- Opportunity to become a trainer or certification examiner

CORPORATE ADDITIONAL INDIVIDUAL

- Subscription to quarterly *Shotcrete*
- Opportunity to submit items for Industry News and New Products & Practice sections of *Shotcrete* at no charge
- Discounted prices on ASA shotcrete brochures and pocket safety manuals
- Permission to include ASA logo on corporate letterhead and business cards
- Reduced advance registration fees to ASA annual meetings
- Free advance general admittance registration to World of Concrete
- Opportunity to become a trainer or certification examiner
- Networking and participation opportunities at Annual Membership Meeting and committee meetings

INDIVIDUAL

- Voting privileges at meetings and director/officer elections
- Discounts on advertising in *Shotcrete*
- One complimentary ASA shotcrete brochure with membership
- Discounted prices on ASA shotcrete brochures and pocket safety manuals
- One complimentary ASA reflective hardhat sticker
- Reduced advance registration fees to ASA annual meetings
- Networking and participation opportunities at Annual Membership Meeting and committee meetings
- Subscription to quarterly *Shotcrete*
- Opportunity to submit items for Industry News and New Products & Practice sections of *Shotcrete* at no charge
- Permission to include ASA logo on corporate letterhead and business cards
- Free advance general admittance registration to World of Concrete
- Opportunity to become a trainer or certification examiner

EMPLOYEES OF PUBLIC AUTHORITIES AND AGENCIES

- Discounts on advertising in *Shotcrete*
- Subscription to quarterly *Shotcrete*
- Opportunity to submit items for Industry News and New Products & Practice sections of *Shotcrete* at no charge
- Permission to include ASA logo on corporate letterhead and business cards
- One complimentary ASA shotcrete brochure with membership
- Discounted prices on ASA shotcrete brochures and pocket safety manuals
- One complimentary ASA reflective hardhat sticker
- Reduced advance registration fees to ASA annual meetings
- Networking and participation opportunities at Annual Membership Meeting and committee meetings
- Free advance general admittance registration to World of Concrete
- Opportunity to become a trainer or certification examiner

NOZZLEMAN

- Subscription to quarterly *Shotcrete*
- Opportunity to become a trainer or certification examiner
- Discounted prices on ASA shotcrete brochures and pocket safety manuals
- Reduced advance registration fees to ASA annual membership breakfast
- Networking and participation opportunities at Annual Membership Meeting and committee meetings
- Free advance general admittance registration to World of Concrete
- ASA promotes nozzleman certification on a national basis in conjunction with ACI

STUDENT

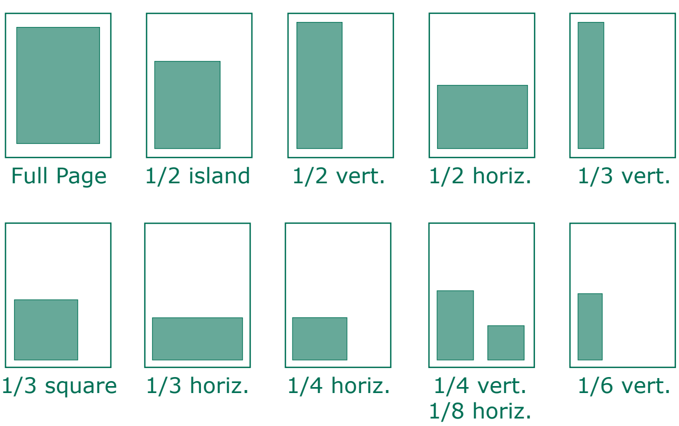
- Subscription to quarterly *Shotcrete*
- Free advance general admittance registration to World of Concrete
- Reduced advance registration fees to ASA annual meetings
- Networking and participation opportunities at Annual Membership Meeting and committee meetings

2009 Advertising Rates

Advertising—Black & White

The below ad rates are for nonmembers.
ASA members receive 30% off all ad rates.

Space	1X	2X	4X
Full Page	$1560	$1495	$1430
1/2 Page	$1079	$1040	$1014
1/2 Page Island	$1144	$1105	$1066
1/3 Page	$741	$708	$676
1/4 Page	$611	$578	$546
1/6 page	$364	$338	$312
1/8 Page	$195	$175	$156



Space	Width (in.)	Depth
Full page with 1/8″ bleeds	$8^{3}/_{8}$″	$11^{1}/_{8}$″
Full Page (no bleeds)	7″	10″
1/2 Island	$4^{9}/_{16}$″	$7^{3}/_{8}$″
1/2 Vertical	$3^{3}/_{8}$″	10″
1/2 Horizontal	7″	$4^{7}/_{8}$″
1/3 Vertical	$2^{3}/_{16}$″	10″
1/3 Square	$4^{9}/_{16}$″	$4^{7}/_{8}$″
1/3 Horizontal	7″	$3^{3}/_{8}$″
1/4 Vertical	$3^{3}/_{8}$″	$4^{7}/_{8}$″
1/4 Horizontal	7″	$2^{3}/_{8}$″
1/6 Vertical	$2^{3}/_{16}$″	$4^{7}/_{8}$″
1/8 Horizontal	$3^{3}/_{8}$″	$2^{7}/_{16}$″

Keep live matter at least 1/4 in. from trim: $8^{1}/_{8}$″ x $10^{7}/_{8}$″.

Additional Color

2nd Color (cyan, magenta, or yellow) $375
Four-color $750

Covers

All covers must be four-color. Sold on a 4X basis only.
Outside back cover .... add 25%
Inside front cover .... add 15%
Inside back cover .... add 10%

Classified

Per column inch $30
(text only—ads with logos/artwork considered display ads)

Commission / Discount

Agency Discount 15%
Prepayment Discount 5%

Reader Response Service

No Charge

Ads are preferred in electronic format

PC or Macintosh (or compatible).
All files are converted to PC format for printing.

Media accepted: Zip or CD-ROM disks.
FTP site available for sending large files.

Supported Applications: Illustrator and Photoshop saved in TIFF or EPS format, InDesign, or high-res PDF. Resolution: 300 dpi. Do not use any compression scheme on the graphics (JPEG, LZW).

Color images should be saved in CMYK format.

Include all placed graphics on disk. Do not embed images in the file. Do not trap files. If necessary, this will be done in our preflighting.

All fonts must be converted to outlines. If this is not possible, all fonts used must be provided on disk.

A proof must accompany your disk. Color proof required for four-color and two-color ads. Laser printout or blueline required for black & white ads.

Questions?
Contact Melissa McClain at ASA. She will be happy to work with you to make your ad effective.

AMERICAN SHOTCRETE ASSOCIATION
38800 Country Club Drive
Farmington Hills, MI 48331
Phone: (248) 848-3780 Fax: (248) 848-3740
E-mail: info@shotcrete.org

Shotcrete MAGAZINE

A quarterly publication of the American Shotcrete Association

2009 Advertising Insertion Order Form

❑ **Advertiser:** ❑ ASA Member ❑ Nonmember

Company ______________________
Address ______________________
City/State/Zip ______________________
Country ______________________
Telephone ______________________
Fax ______________________
E-mail ______________________
Contact ______________________

❑ **Agency**

Company ______________________
Address ______________________
City/State/Zip ______________________
Country ______________________
Telephone ______________________
Fax ______________________
E-mail ______________________
Contact ______________________

Send invoice to: ❑ Advertiser ❑ Agency

❑ **Discount:** Agency Discount 15%

Issue	Features	Size	Color	Base Rate	Color Charge	Order Deadline	Materials Deadline
Winter '09	Repair & Rehabilitation	________	________	________	________	11/1/08	11/1/08
Spring '09	Versatility of Shotcrete	________	________	________	________	2/1/09	2/1/09
Summer '09	Shotcrete Equipment	________	________	________	________	5/1/09	5/1/09
Fall '09	Recreational Projects	________	________	________	________	8/1/09	8/1/09

Ad Materials Information

❑ Ad materials enclosed ❑ Ad materials to follow ❑ Pick-up ad from issue ______________

❑ Graphic design services requested

Special instructions:

____

Please reserve space in the issue(s) indicated on behalf of the advertiser listed above. No cancellations after space closing allowed. Neither ASA or the publishers will be held responsible for statements made in advertisements. The advertiser shall indemnify and hold ASA harmless from liability of any kind arising from such claims, including attorney's fees and all other costs of litigation. By submission of copy, the advertiser certifies that consent has been obtained for use of photographs, endorsements, or other copyrighted materials. ASA reserves the right to refuse any advertisement determined to be inappropriate or conflicting with the interests of ASA.

Authorized signature ______________________________ Date ______________

AMERICAN SHOTCRETE ASSOCIATION

Return to:
American Shotcrete Association
38800 Country Club Drive
Farmington Hills, MI 48331
Phone: (248) 848-3780
Fax: (248) 848-3740

OFFICE USE ONLY

Ad materials received:

❑ Disk ❑ Color proof ❑ B/W proof

❑ Electronic format (e-mail) ❑ Other ______________

American Shotcrete Association

Reader Response Service

Please send information on the products or services circled below:

1	2	3	4	5	6	7	8	9
10	11	12	13	14	15	16	17	18
19	20	21	22	23	24	25	26	27
28	29	30	31	32	33	34	35	36
37	38	39	40	41	42	43	44	45
46	47	48	49	50	51	52	53	54

Please Print Clearly

Name ____

Company ____

Address ____

City ____

State/Province ______________ Zip/Postal Code ______________

Country ____

Phone: ____

Fax: ____

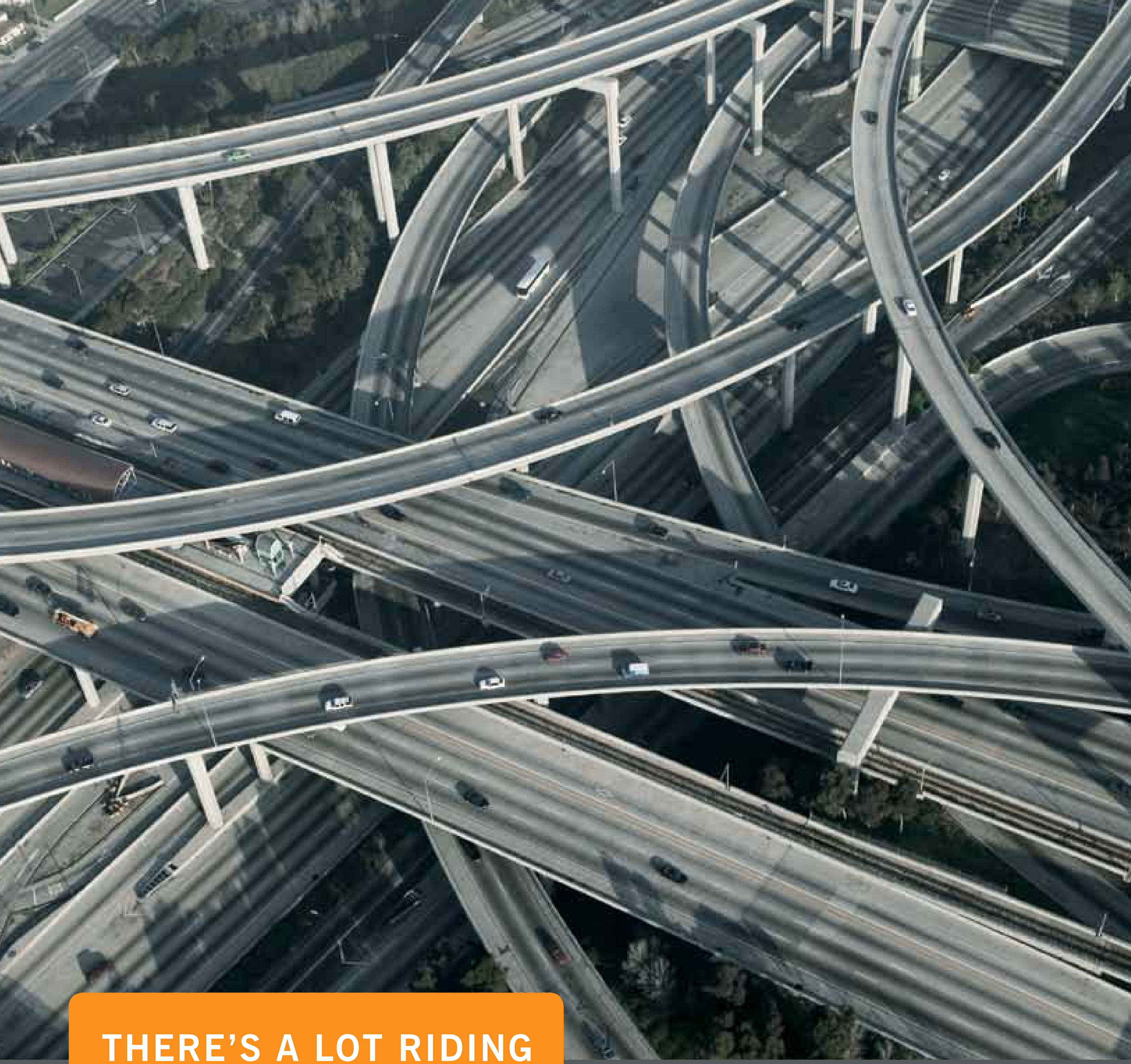
E-mail: ____

Spring 2009

Fax or mail to: American Shotcrete Association
38800 Country Club Dr. • Farmington Hills, MI 48331
Phone: (248) 848-3780 • Fax: (248) 848-3740

ADVERTISERS IN THIS ISSUE

Reader Response Numbers in Parentheses Page



Circle #29 on reader response form—page 56

Circle #11 on reader response form—page 56