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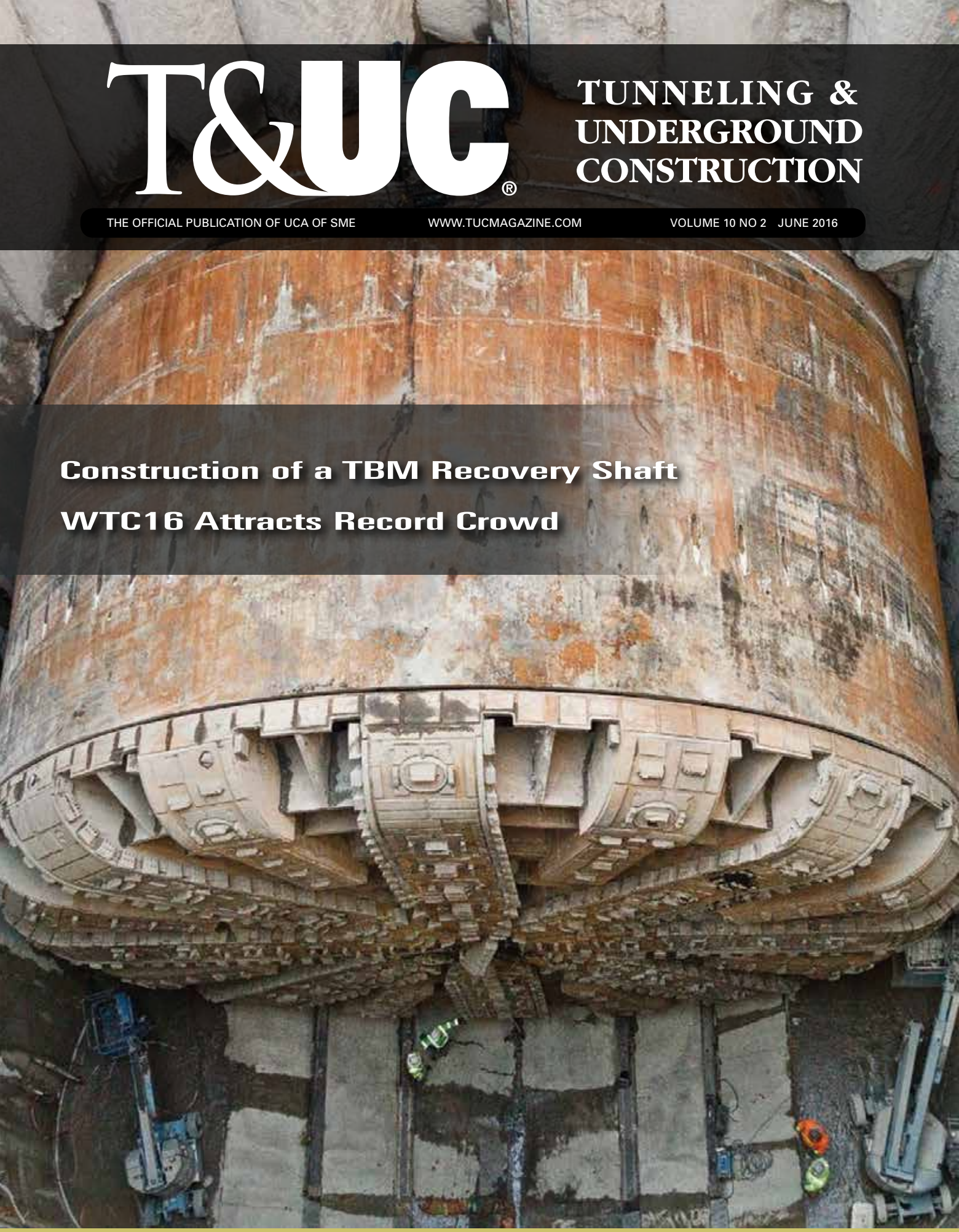
THE OFFICIAL PUBLICATION OF UCA OF SME WWW.TUCMAGAZINE.COM VOLUME 10 NO 2 JUNE 2016



Construction of a TBM Recovery Shaft

WTC16 Attracts Record Crowd

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COVER STORY

In this issue — Bertha, the tunnel boring machine that broke down while boring Seattle's SR99 tunnel. The damage to the machine was bad enough that it needed to be removed for repairs. So a recovery shaft needed to be bored. Details on page 49. The World Tunnel Congress attracted more than 2,300 professionals, page 55.

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CHAIRMAN'S COLUMN

Looking back at 2016, and tunneling toward 2017

First and foremost, let's congratulate everybody for the enormous effort and success of the WTC 2016 event in San Francisco. Many thank yous to the UCA Executive Committee for its strong and unwavering support and commitment to the Congress, to the WTC Organizing Committee, the track chairs, the session chairs and co-chairs, the Scientific Committee and the UCA staff and many others for the thousands of volunteer hours that went into the planning and execution of the event.

Upon last count, more than 2,300 people from around the world attended the event (a new record for attendees), 226 exhibitors had 298 booths, and 353 papers were accepted for podium or poster presentations. I have received comments from many member nations and attendees complimenting us on our planning and execution. Having the event in the Moscone Center under a single roof helped facilitate attendees getting from one session to another session without having to go from building to building and making it quite easy to network with the other attendees and vendors. We were lucky to insist and obtain space that met that criteria and allowed us to shine, and make others realize what could and should be done every year.

We also gave attendance scholarships to more than 50 students to foster additional student growth in the industry. From my discussions with most of the students at the introductory student session, all were very excited about attending and learning more about the varied opportunities within the underground industry and were very appreciative of the scholarships given to them to enable their attendance during the school year. Without the scholarship, none or only a small fraction (locals) of the students would have attended.

We also had several opportunities for the Young Members (under 35) and for the Women Tunnelers to meet and conduct discussions among themselves as groups. I have also received much feedback from members of both groups thanking us for making those events possible with our financial support. We are all very happy to support both groups and enable them to grow and prosper. My thanks and appreciation also to those leaders.

Looking forward, we will continue to support student attendance at RETCs and NATs, the young members and the women tunneling groups. In fact, the UCA executive board has already approved and set aside $50,000 for student scholarships to encourage attendance at next year's RETC event. Further funding for the groups will also be made available for the future events. We must continue to grow our foundations, boundaries and diversify ourselves and the industry. I will continue to provide that leadership to do so.

At the last executive committee meeting, following the WTC 2016, the committee had significant discussions regarding further outreach at the student and educator level. We are in the process of formulating a proposal to provide a one-day session for civil, structural and related fields professors during the summer along with proposed curriculum recommendations for them to use as they build their future programs to expose their students to underground studies and prepare them for future underground job opportunities. Many other discussions are underway to enhance the outreach of the UCA. We also talked about creating new awards next year, including a Lifetime Achievement Award, an Outstanding Educator Award, a UCA

(Continued on page 6)

SAVE the DATE

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The Rapid Excavation and Tunneling Conference (RETC) is the premier international forum for the exchange and dissemination of developments and advances in underground construction. RETC provides innovative solutions to the unique challenges associated with the tunneling industry.

Conference attendance exceeds 1,400 professionals from more than 30 countries. Industry sectors include: construction, mining, geotechnical engineering, exploration, environmental, economics, manufacturing, government, land, water/wastewater and transportation. The conference includes a comprehensive exhibit, short courses and field trips.

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www.retc.org

Topics to Be Covered

- Contracting Practices and Cost
- California Projects
- Design and Planning
- Design/Build Projects
- Difficult Ground
- Drill and Blast
- Environment, Health and Safety
- Future Projects
- Geotechnical Considerations
- Ground Support and Final Lining
- Grouting and Ground Modification
- Hard Rock TBMs
- Large Span Tunnels and Caverns
- Microtunneling and Trenchless Tunneling
- New and Innovative Technologies
- Pressure Face TBM Case Histories
- Pressure Face TBM Technology
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Plan to speed up New York's backup water delivery system approved

New York City Mayor Bill de Blasio said on April 25 that the city would earmark additional money for a third water tunnel in the city that would ensure that clean drinking water could be delivered to Brooklyn and Queens within 48 hours of an emergency shutdown of City Water Tunnel No. 2.

Already, $21 million has been earmarked to disinfect and test the new section of City Water Tunnel No. 3 to prepare it as a backup water source to Tunnel No. 2 by the end of 2017 as part of the city's $82.2 billion executive budget.

Previously, officials said that it would take several months to make even nondrinkable water available, which would have been crippling to the five million residents and the businesses in the area.

The New York Times reported that Tunnel No. 2 is 80 years old, has been in continuous use and has never been shut for inspection. The mayor said the investment would provide "critical redundancy in our system."

Most of the infrastructure for Tunnel No. 3 is in place, except for two shafts that will connect parts of the tunnel in Queens to the current distribution system and future parts of the system. But the tunnel can deliver water without them and already carries water to parts of the Bronx, Manhattan and Queens.

Originally, the plan had been to wait until the shafts were completed before disinfecting the tunnel, a necessary step before it could carry drinking water, Emily Lloyd, the commissioner of the Department of Environmental Protection, said.

But at the mayor's insistence, engineers began devising a way to prepare the tunnel ahead of that work, which Lloyd said would probably be completed in 2025.

"I wish we had thought of it sooner," she said. "But I think it's a really good way to go."

Even now, in the event of an emergency with Tunnel No. 2, the city could deliver water to Brooklyn and Queens through Tunnel No. 3, but it would probably have to be boiled, Lloyd said.

Under the revised plan, residents in those boroughs would have a backup supply of clean water at the ready within about two days, Lloyd said, adding that the details were still being worked out.

Over the past decade, the city has spent about $10 billion to build redundancy into a system that relies on three main tunnels to deliver about 4.1 GL (1.1 billion gal) of water to the city every day.

After reports that money had fallen out of the budget for the shafts for Tunnel No. 3, the mayor reasserted his commitment to complete the $657 million project.

Jim Roberts, who manages the city's water and sewage operations, welcomed the announcement.

"It's always good news when we have more flexibility and more redundancy available to us," he said. ■

Victoria to put up $11 billion to fund Melbourne Metro Rail project

The new Melbourne Metro Rail project will be funded by Victoria.

Victoria's treasurer, Tim Pallas said Victoria wanted $4.5 billion to come from the federal government but that Prime Minister Malcolm Turnbull was only interested in loans. Pallas said the project can no longer wait on the federal government.

9news.com.au reported that the 2016/2017 state budget includes $2.9 billion for the twin rail tunnels under the CBD, with the rest out beyond the forward estimates.

"We just can't wait. We are deadly serious about delivering this project, and we will deliver it, with or without the federal government," Pallas said.

The state government will fund the entire project and hopes to recoup some costs from the private sector, although Pallas said he would welcome future funding from Canberra.

An additional $588 million has been earmarked to extend the South Morang line through to Mernda, with construction set to start next year.

Trains are due to start running by mid-2019.

The Hurstbridge line will be duplicated between Heidelberg and Rosanna at a cost of $140 million.

The budget also includes $1.3 billion for investment in regional rail and $1.1 billion to rebuild schools.

Of the $1.3 billion dedicated to regional rail, $518 million will be used to duplicate the Ballarat line between Deer Park West and Melton.

The newly built Caroline Springs Station will need to be upgraded before taking its first passenger.

The Australian Industry Group has expressed its support for the new budget announcement.

"What we see in infrastructure spending is something we've called for some time and obviously that's not only going to help businesses, it's going to help small businesses and the community as well," Victorian director Tim Piper said. ■

Proposals for second tunnel for Chesapeake Bay Bridge all top $1 billion

Construction of the proposed second tunnel on the 1,740-m (5,710-ft) long Chesapeake Bay Bridge Tunnel, already listed as a mega-project, looks like it will top $1 billion.

Three design-build proposals for the Chesapeake Bay Bridge-Tunnel are hundreds of millions of dollars higher than estimated and each proposal comes in at more than $1 billion for the Parallel Thimble Shoal project. The lowest proposal is $292 million higher than the $724.4 million estimate, according to Jeff Holland, the bridge-tunnel's executive director.

The Virginian Pilot reported that the proposals are from: Bouygues TP/Traylor/Manson, $1,016,046,800; Archer Western-Vinci Construction Tunnel Builders, $1,071,683,000; Dragados USA and Schiavone Construction, $1,092,000,000.

All three companies proposed a bored tunnel which would be the first of its kind in the area.

The Thimble Shoal tunnel is the opening nearer to Virginia Beach on the 28.3-km (17.6-mile) bridge that connects to the Eastern Shore. A second 1.6-km (1-mile) long tunnel there would help in the event of a crash, increase safety and reduce lane closures for maintenance.

The new Midtown Tunnel and every other transportation tunnel in Hampton Roads has been an "immersed" tunnel that sinks sections of the tunnel to the floor of the body of water.

Last August, the CBBT Commission shortlisted the three firms, plus Skanska-Kiewit-Weeks, the firm that is building the Midtown Tunnel. SKW did not submit a formal proposal, Holland said.

The process calls for accepting the lowest bid that meets technical requirements, Holland said. Since the proposals are higher than expected, they would work to "descope" the project by removing or scaling down parts of it for cost, he said.

The governing body that oversees the CBBT has long intended to expand its two tunnels, but approved the project in May 2013. In 2013, the commission voted to raise tolls to help pay for the project, in addition to bonds and state and federal loans. The toll is $13 for an off-peak trip in a regular vehicle.

The CBBT District is a political subdivision of the Commonwealth and operates as a business entity. The district doesn't use federal, state or local taxes to operate or maintain the bridge. However, the district is tax exempt.

The bay crossing was last expanded in 1999, when a second set of bridges opened. Traffic moves in two lanes in each direction on the bridges, but it merges into single-lane, bidirectional traffic in each of the two underwater portions of the crossing.

Timelines call for construction to begin in 2017 with completion in 2020 or 2021. Expansion of the second underwater section is dependent on cost and timeline of the Thimble Shoal portion but it is tentatively slated for 2040 or later. ■

Canada launches feasibility study for tunnel between Newfoundland and Labrador

An investment of C$750,000 to study the feasibility of a tunnel connecting Newfoundland and Labrador is an investment in a project that could pay off by solving many of the province's persisting problems, according to Premier Dwight Ball.

Some residents questioned the cost of the study and the timing, but Ball said a link between the island and mainland would create new sources of revenue and help diversify the economy — something many say is badly needed to break the province from its cycle of booms and busts.

CBC News in Canada reported that businessman and former N.L. Liberal Party president Danny Dumaresque has been trying to drum up support for a tunnel under the Strait of Belle Isle for years, especially after visiting Norway and seeing how similar projects have been completed there with great success.

"It is, in my view, the number one diversification project we could do in this province," he told *CBC News*. "It will bring hundreds of high paying construction jobs and bring hundreds of thousands of new tourists here, with money to spend.

"That's the kind of province building and nation building that we must undertake in order to be able to change the fundamentals of our economy."

The concern has grown out of the financial crisis that the province is currently contending with. But Dumaresque feels it's important to get the project going as soon as possible.

Dumaresque has said that a public-private partnership could cover the costs of the tunnel. He cited the success of the Confederation Bridge between PEI and New Brunswick and how it was funded in the 1990s.

"I was really stimulated to try and pursue this kind of a project because of the PEI bridge, which was built by 100 percent private money in 1997," he said.

(Continued from page 6)

Crossover tunnel boring machine makes history in Mexico City

On March 29, 2016, North America's first Crossover tunnel boring machine (TBM) broke new ground in Mexico City. The 8.7 m (28.5 ft) diameter Robbins XRE — a cross between a rock TBM and an earth pressure balance (EPB) machine — emerged into an intermediate shaft at Túnel Emisor Poniente (TEP) II.

The machine is undergoing some maintenance before continuing on to bore the final 3.2 km (2 miles) of tunnel. The customized TBM, for a consortium of Aldesem, Proacon, and Recsa, was chosen based on a number of parameters that included challenging ground conditions below an area to the west of downtown Mexico City.

The tunnel path travels through a mountain with cover as high as 170 m (560 ft), through fault zones and in a section with cover as low as 8 m (26.2 ft) above the tunnel crown. Much of the tunnel consists of andesite rock with bands of tuff, and softer material in fault zones as well as an 874 m (2,870 ft) long section in soft ground at the end of the tunnel.

"The geological profile of the project comprises six different lithologies, among them hard rock such as dacite. To get the best operation in both areas required use of dual mode technology such as the crossover TBM," said Enrique del Castillo of contractor Aldesem. The 8.7 m (28.5 ft) diameter Robbins XRE is a design that allows for the TBM to effectively bore in both hard rock and mixed ground.

The machine setup includes a canopy drill and positioner for enhanced ground consolidation, as well as gear reducers to adjust torque and RPM based on ground conditions. The TBM, initially launched in hard rock mode, can be operated in EPB mode later on by switching out the belt conveyor with a screw and converting the cutterhead.

The Robbins crossover machine began its journey in August 2015, and advance rates picked up quickly. Project records were set in January 2016 after the machine achieved a best day of 42.8 m (140 ft) and a best week of 185.1 m (607 ft). By mid-March the machine had bored through the first of the contact zones, a 30-m (100-ft) wide section of fractured and blocky rock. While the excavation through the contact zone was slow going, progress picked up again in the more competent rock. Final breakthrough is expected in autumn 2016.

Once complete, the 5.8 km (3.6 miles) tunnel will supplement an existing and overtaxed wastewater line built in the 1970s. The deep drainage tunnel will serve to prevent recurrent flooding in Valle Dorado, and will benefit the cities of Cuautital Izcalli, Tlalnepantla, and Atizapan de Zaragoza, an area with a total population of 2.1 million people. ■

Chairman's Column: Looking beyond WTC 2016

(Continued from page 2)

Outstanding Educator Award, a UCA Outstanding Individual Award, and a UCA Project of the Year Award. All suggestions/recommendations are welcome from the membership for topics to be discussed at the executive committee meetings or for the awards.

The next event that is on the UCA agenda is the Cutting Edge Conference, which will be held Nov. 6-9 in the Concourse Hotel at the Los Angeles Airport in Los Angeles, CA. The theme of the conference will focus on advances in tunneling technology, which will provide attendees with up-to-date information on the latest trends and techniques used in tunneling projects globally. Following the Cutting Edge Conference, the tunneling community will again meet at the George A. Fox Conference on Jan. 24, 2017 at The Graduate Center of CUNY in New York City. The Fox Conference always sells out so book early as the event provides current information and presentations that are unique to the conference.

Several years ago, the UCA established three strategic goals: 1) to become the primary resource for underground construction information requests; 2) to improve the image of underground construction in the minds of public, public officials and private clients and 3) to improve the effectiveness and efficiency of the underground construction industry. Now that the WTC 2016 event is behind us, let's keep the goals in mind and do what we can together to attain these goals, along with inclusion of more younger and women members.

Lastly, as we are now beyond the WTC 2016 event, let's all continue to work together to enhance the industry and how our industry is looked upon by the general public and the project decision makers. We need them on our side to foster pro-underground solutions in the project decision matrixs.

Thank you again to the entire WTC 2016 team. ■

Artie Silber,
UCA of SME Chairman

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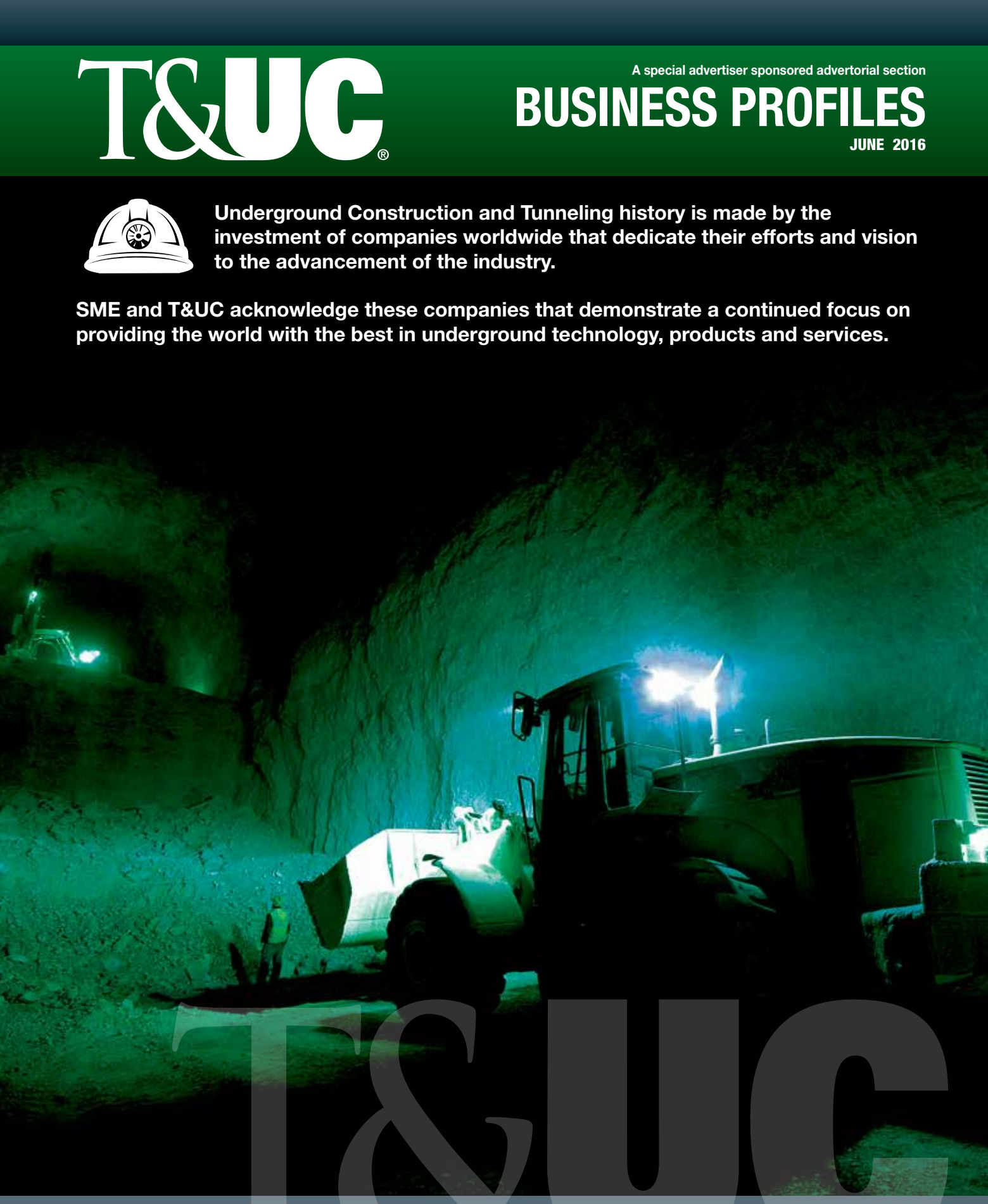

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Seattle, WA
Brightwater Conveyance System
Construction of the Brightwater Conveyance System required surgical jet grouting to facilitate tunneling operations. Utilizing their proprietary jet grouting equipment, Hayward Baker created soilcrete blocks outside of four deep vertical shafts to assist with both TBM and hand-mined tunneling operations. The ground improvements allowed TBMs to be launched or received into and out of the shafts without the risk of water and ground run-in. Overlapping columns to depths of 94 feet compose the soilcrete blocks.

Brightwater Conveyance System

Los Angeles, CA
Lower North Outfall Sewer Rehabilitation Project
Rehabilitation of the 82-year-old Lower North Outfall Sewer included grouting around the outside of the tunnel to densify and strengthen the soil above the tunnel in order to protect the overlying structures from settlement. Hayward Baker performed permeation and fracture grouting through over 3,500 holes from within the tunnel, stabilizing the overlying structures. State-of-the-art survey technology and proprietary grouting instrumentation allowed Hayward Baker to first probe the soil to determine existing conditions, and then observe the soil response during grouting, while monitoring the ground surface in real time.

Los Angeles, CA
Metro Gold Line C800
Construction of twin subway tunnels for the LA Metro's Gold Line would cause ground loss, endangering overlying structures unless the soils surrounding the tunneling zone were treated prior to excavation. Using conventional horizontal drilling to install steel and PVC sleeve port grout pipes, Hayward Baker performed chemical grouting to stabilize soils, and fracture grouting to protect overlying structures. Heave and settlements were monitored by exterior remote robotic total stations and interior wireless tiltmeters.

St. Louis, MO
Baumgartner Tunnel Alignment
Water-bearing rock formations in the path of the Baumgartner Tunnel Alignment needed to be sealed. Unsafe levels of hydrogen sulfide forced the grouting to be performed from the surface in advance of the tunneling operation. Hayward Baker drilled and grouted the water-bearing rock formations along a 1,200-foot-long segment of the proposed 20,000-foot-long, 12-foot-diameter combined sewer tunnel. A total of 40,000 feet of grout holes was drilled to complete the project. Depths of the drill holes were approximately 170 feet from ground surface.

Big Bend Tunnel Improvement
Big Bend, WV
Big Bend rail tunnel, constructed in 1932, required extensive ground and wall improvements over a 1,200 foot stretch due to its age and frequent use. Hayward Baker stabilized the tunnel walls with cement-bentonite structural grout, several rows of rock bolts and dowels, and compaction grout underpinning. Epoxy and cement grouting were utilized to repair an existing fracture of the tunnel liner along the spring line. Hayward Baker also stabilized the invert with compaction grouting at approximately 4,000 locations.

Big Bend Tunnel Improvement

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Delivering liquid nitrogen to the Port Mann off-shore working platform.

Port Mann Water Main: Ground Freezing

Mining of the new, 3,280-ft long Port Mann Water Main was well underway deep below the Fraser River in Vancouver, British Columbia, when an unanticipated mechanical failure occurred in the cutter head, halting mining operations. When initial more conventional approaches to allow access for repair were ruled out, the tunneling contractor contacted Moretrench. Moretrench developed a liquid nitrogen ground freezing solution that would not only allow safe access for inspection and repair but could also be implemented quickly. The remote TBM location, 160 ft below river mud line and 650 feet from the exit shaft, meant that all equipment and materials, including liquid nitrogen storage tanks, had to be ferried to the pile-supported work platform. Pinpoint drilling for freeze pipe installation was critical to ensure freeze build up exactly as designed. After just 12 days of freezing, the freeze was sufficiently formed to allow safe entry into the cutter head for repairs to begin.

High mobility grouting of karstic rock enabled dry excavation of the OARS CSO shafts.

OARS Relief Sewer Phase 2 Shafts: High Mobility Grouting

Drill and blast installation of three deep shafts through highly variable karstic conditions was the challenge facing the design and construction teams for Phase 2 of the CSO project in Columbus, OH. The shafts extended through shale underlain by three distinct strata of karstic limestone. With the water table 20 ft below the surface, and the high hydraulic conductivity of the rock evident from pumping tests, it was estimated that inflows of thousands of gallons per minute could be anticipated during shaft excavation under hydrostatic head of up to 150 ft. Pre-grouting was therefore required. A Moretrench-designed alternate to the original in-shaft staged grouting plan allowed all grouting to be accomplished around the shaft perimeter from the surface. A suite of four, balanced-stable grouts developed by Moretrench catered to the highly variable subsurface conditions. With grouting complete, excavation proceeded with only minimal shaft inflow.

Jet grout cut-off for installation of the Mulry Square vent plant.

Mulry Square Vent Plant: Jet Grouting:

The Mulry Square emergency vent plant is designed to serve a portion of both the 8th and 7th Avenue subway lines in Manhattan, New York. With offsite groundwater drawdown during construction prohibited, a perimeter cut-off was required. This was designed as secant pile walls, with jet grouting specified for closure where the vent plant penetrated the wall of the subway tunnel. Groundwater modeling by Moretrench demonstrated that the jet grouting would need to extend only to a minimum depth of 53 ft to achieve cut-off, rather than the 100 ft originally anticipated, reducing the quantity of secant piling and jet grouting required. Subsequent groundwater monitoring during excavation to full depth within the secant pile/jet grout cut-off structure confirmed the accuracy of the groundwater modelling and offsite drawdown did not exceed the specified limits.

For more on these and other tunneling projects, visit us at:
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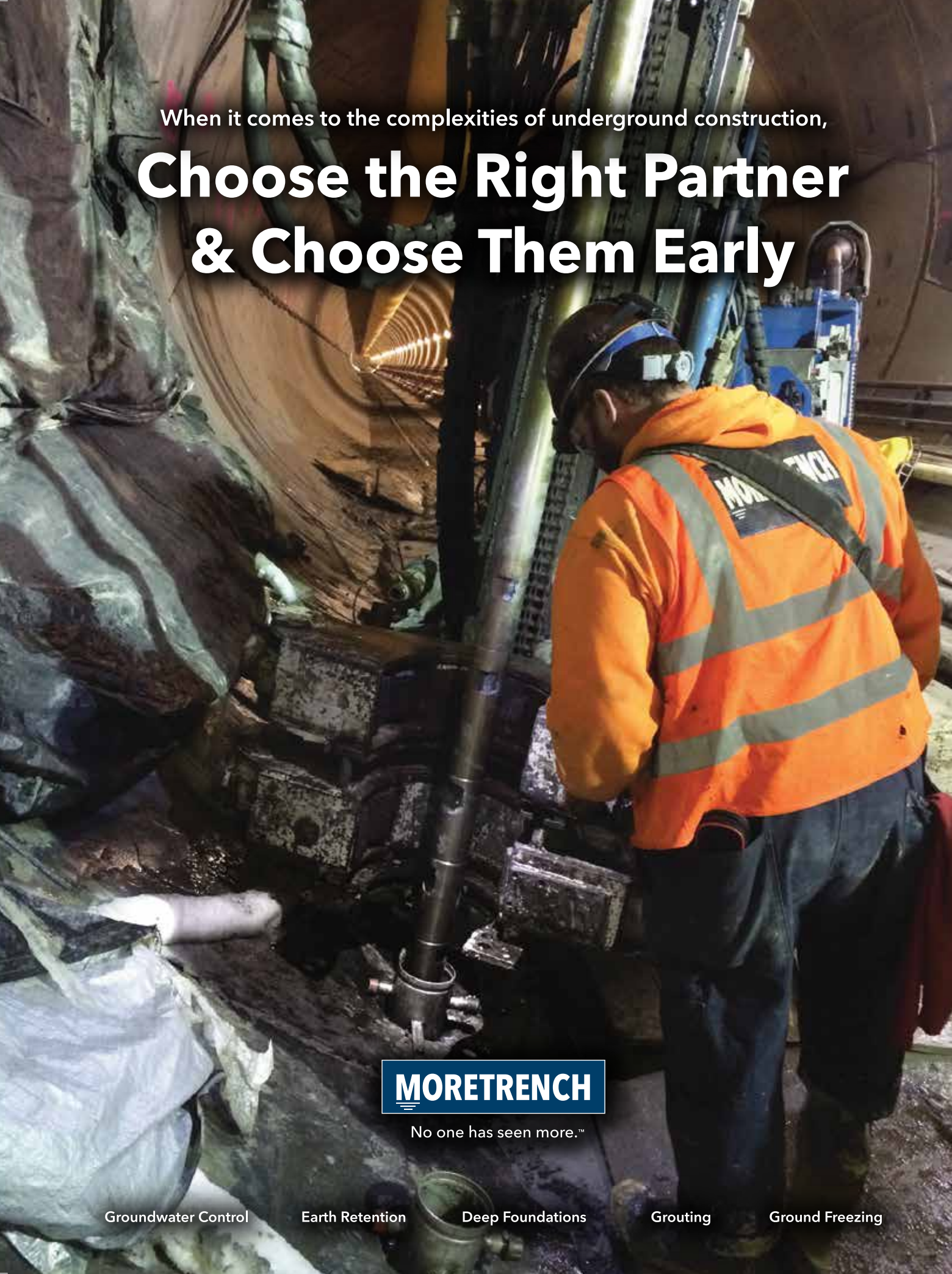
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- Hoists
- Sheaves
- Elevators
- Cages
- Headframes
- Brakeman Cars
- Controls
- Field Services
- Wire Rope NDT

FKC-Lake Shore
1695 Allen Road
Evansville, IN 47710 USA
Telephone: +1-877-554-8600
www.frontierkemper.com
Email: information@frontierkemper.com

CONTROLS
HEADFRAMES
HOISTS
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SKIPS
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WIRE ROPE NDT
VERTICAL BELTS

DESIGN. BUILD. INSTALL. SERVICE.

FKC-Lake Shore serves the underground heavy civil and mining industries throughout North and South America. We offer design-build-install services for innovative hoisting, elevator, and vertical conveyance systems used to transport personnel and material. Our Field Services Division provides routine maintenance, inspections, wire rope NDT, and **24/7 emergency repair** of electrical and mechanical systems.

1.877.554.8600 | information@frontierkemper.com
For more information, visit us at: **www.frontierkemper.com**

FK LAKE SHORE
A DIVISION OF FRONTIER-KEMPER CONSTRUCTORS, INC.

A TutorPerini Company

Sandvik in Tunneling

Sandvik tunneling expertise covers a variety of methods: Drill and blast, mechanical cutting and breaking. The equipment range includes tunneling jumbos, roadheaders and cutting units, bolters and bolts, drilling and cutting tools, hydraulic breakers, loading and hauling equipment, mobile crushers, and financing, parts and consumables, training, technical support, and repair and rebuild service.
The Sandvik DTi series of intelligent tunneling jumbos are fast, accurate and user-friendly. The series is available in four models for excavation of 12–211 m³ cross sections, including face drilling, bolt hole drilling and mechanized long-hole drilling.
Sandvik rock tools offer straight holes, high penetration rate and low costs per meter. As the only supplier with in-house resources for cemented carbide production and R&D as well as drill steel production and R&D, Sandvik can control the whole supply chain from raw material to finished products.
Sandvik roadheaders are extremely powerful, robust rock cutting machines that let you focus on the essential: breaking on through to the other side. These roadheaders are designed to excavate roadways, tunnels and underground chambers without using explosives that can cause harmful vibrations. This is highly valued for both environmental and safety reasons, making roadheaders extremely suitable for underground construction in urban areas.

Research & Development
In order to ensure the best solutions, Sandvik has specialized R&D centers for different fields of rock excavation. Sandvik also works in close cooperation with universities, research institutes and specialist associations everywhere in the world. As results of these R&D projects, Sandvik now offers an energy saving cutting system for roadheaders, a new roadheader type equipped with state-of-the-art profile control and automatic sequence control systems, as well as the DTi jumbos with iSURE® process optimization tool software – just to name a few.
Sandvik Cutting Technology Center runs its own in-house cutting test laboratory, addressing particular customer requirements and offers the latest solutions in mechanical cutting for all kinds of soil and rock. In addition, Sandvik has specialized R&D centers for Drilling Control, Rock Drill and Drilling Tools technologies. Sandvik is also the only manufacturer in the industry owning a unique test mine for practical testing in real life conditions.
Cleaner and safer tunneling

Sandvik focuses on continuously developing novel tunneling methods, making equipment safer, more efficient and more productive, giving results of the highest quality. As a key core value, Sandvik engineers are committed to safety, constantly developing solutions to offer a protective working environment, with efficient ergonomics. All Sandvik production operations are ISO14001 and ISO9001 certified.

Intelligent Solutions
Sandvik iSure® tunneling excavation management tool is designed for the people on site. Revolutionary in its approach - iSure® uses the most critical spot, the blast plane, as basis for the whole planning process. As a result, hole locations and blasting, are optimized. This translates into excellent accuracy, fast process and large-scale savings.
Find out more about Sandvik Tunneling offering on www.understandingunderground.com

Sandvik Construction
300 Technology Court
Smyrna, GA, 30082
Phone: +1-404-589-3800
Email: info.smc-us@sandvik.com
www.construction.sandvik.com

UNDERSTANDING UNDERGROUND

For decades, we've worked with various tunneling projects around the world, creating cutting-edge technology to serve you with the best solution for your application. As the only manufacturer in the business with our own underground R&D center we continue to be the clear forerunner in the tunneling equipment industry.

www.understandingunderground.com

"Sandvik's full support goes even beyond daily routines: They asked us to give our input in the development of the new DTi jumbos. I guess that's why the result meets so well with real job site needs."

Ville Järvinen Project Manager SRV, Finland

Sandvik Construction
1-800-826-7625
info.smc-us@sandvik.com
www.construction.sandvik.com

SANDVIK

Putzmeister Shotcrete Technology, Your Worldwide Partner for Quality and Innovation

Putzmeister Shotcrete Technology provides you with one source for the world's most complete offering of solutions and equipment for sprayed concrete.

Since purchasing Allentown Equipment with its more than 100 years of shotcrete expertise, and combining it with Putzmeister's innovative concrete technologies and experience, Putzmeister Shotcrete Technology can provide world-class support for contractors' needs in the Refractory, Underground, Mortar and Civil industries.

In the early 1900s, Allentown's pioneering technology was first developed for taxidermy purposes when its originator Carl Akeley, a famous hunter and professor, devised a method for spraying plaster onto a wire frame. The outcome was a strong, thick plaster coating that didn't slump from the frame or set before being fully placed. Forty years later, a new process was developed involving the use of pressure tanks to force stiff mortar through a hose. This new wet-process became known as shotcrete - and the rest is history.

"In this day and age, very few companies are able to succeed in business for over 100 years," says Patrick Bridger, president of Putzmeister Shotcrete Technology. "We are very proud of our longevity, and see it as a testament to our reputation for quality, and the value we have brought our customers for more than a century."

Mixkret 4 - Low Profile Concrete Mixer

Since the 1950s, the Allentown name has been synonymous with the process of spraying mortar at high velocity onto surfaces in the refractory, underground, mortar and civil industries. The equipment line has expanded to include a wide range of Gunning Machines, Pre-dampeners, Dosing Pumps, Pumps, Combination Mixer-Pumps, Mixers, Chemical Additive Pumps, Nozzle Carriers, Mortar Machines, Concreting Machines and parts and accessories.

Throughout the years, numerous milestones have been achieved:

- 1900s - Carl Akeley develops method for spraying plaster onto wire frames.
- 1910 - First Cement Gun introduced at New York Concrete Show.
- 1911 - Patents and trademarks issued for the Cement Gun and its Gunite process.
- 1950s - Wet-process shotcrete application developed.
- 1960s - Dry-process rotary gun developed.

SPM 307 Nozzle Carrier

- 1970s - Swing-tube technology used on wet-process shotcrete equipment, making application and use more practical.
- 2007 - Company acquired by Putzmeister America, Inc., resulting in most comprehensive line of sprayed concrete equipment. Name changed from Allentown Equipment to Allentown Shotcrete Technology, Inc.
- 2008 - Allentown becomes exclusive United States distributor of the Sika/Aliva family of wet- and dry-process shotcrete equipment.
- 2009 - Putzmeister America's Special Application Business forms partnership between Allentown, Esser Pipe Technology and Maxon Industries, Inc., creating a comprehensive systems approach for tunnel and mining, dam and power generation, transportation, marine and off shore projects. MacLean Engineering, in partnership with Allentown, develops new self-contained shotcrete spraying machine.
- 2010 - Allentown Celebrates 100th Anniversary.
- 2012 - Allentown Shotcrete Technology, Inc. is re-branded Putzmeister Shotcrete Technology.

With Putzmeister's reputation for excellence and expertise built on our commitment to application-oriented engineering and customer service – put the strength of Putzmeister to work for you. Contact us at (800) 553-3414 or visit PutzmeisterShotcrete.com.

Putzmeister Shotcrete Technology

Putzmeister SHOTCRETE TECHNOLOGY

Telephone: +1-800-553-3414
www.putzmeistershotcrete.com

TK 70

Putzmeister

Trailer-Mounted Concrete/Shotcrete Pump

Built to tackle the toughest structural concrete jobs, the Putzmeister Thom-Katt® TK 70 Trailer-Mounted Concrete/Shotcrete Pump can pump a variety of materials – including the harshest mixes – up to 74 yd^3/hr. Enhanced with premium technologies that improve strength, safety and operation, the TK 70 provides the long-term performance you demand.

At Putzmeister, exceeding your expectations isn't a goal – it's mandatory.

800.884.7210 | PutzmeisterAmerica.com

Leading the Way

Every structure needs a strong foundation and John Malcolm established Malcolm Drilling Co. Inc. (Malcolm) on a strong foundation of hard work, dedication and an unwavering commitment to pursue new technologies. Over the course of 50 years the company has become one of the country's foremost practitioner and authorities in deep foundation, retention systems and ground improvement work, operating the largest fleet of drilling equipment in the country (valued at more than $190 million). Malcolm is committed to reinvesting capital back into the company in the form of state of practice equipment and cutting-edge technology, which allows the company to serve client needs on a broad geographic basis.

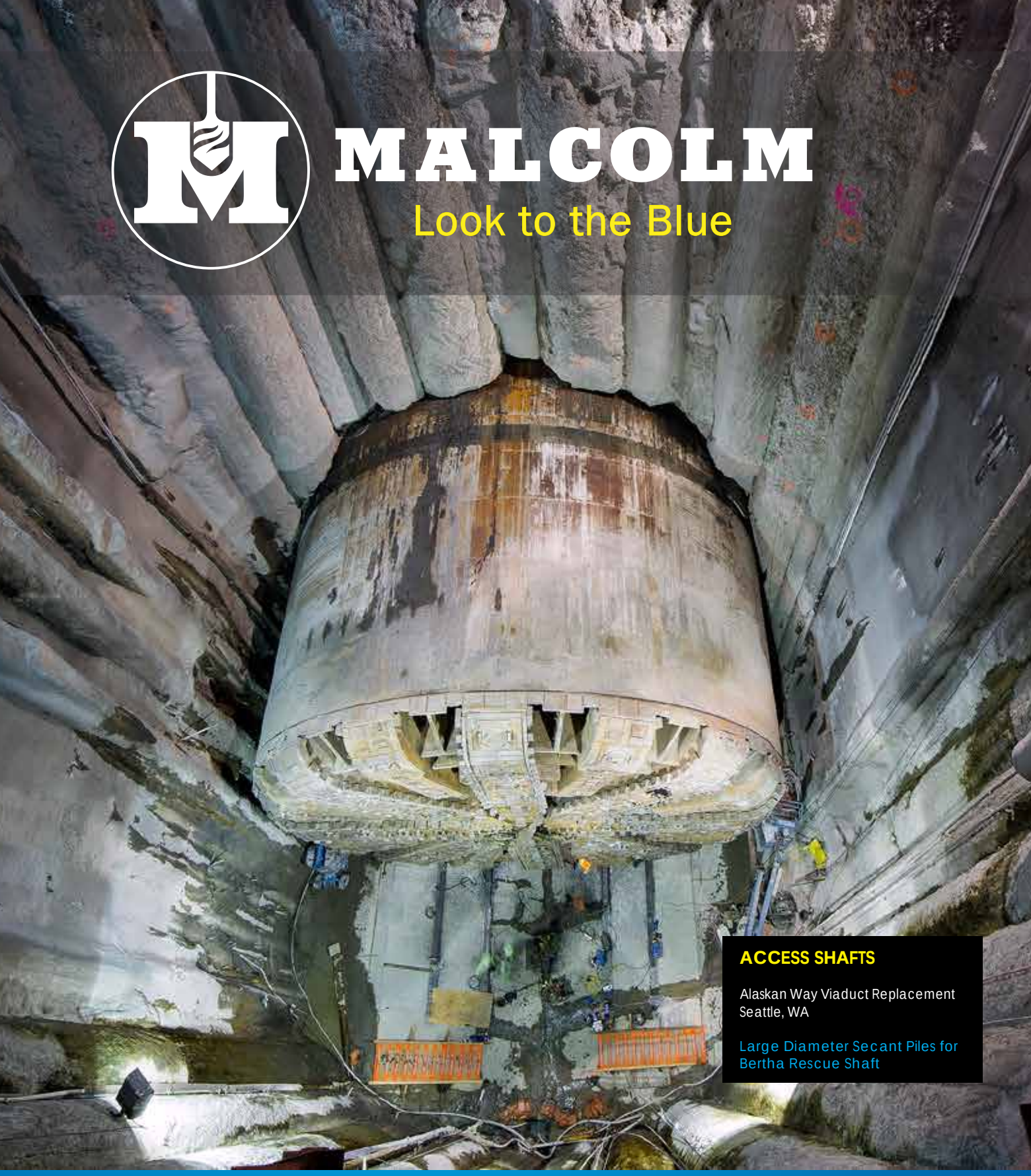
Malcolm's list of core services as it relates to tunneling includes access shafts, excavation support systems, cutoff and secant pile walls, jet grouting, deep soil mixing, cutter soil mixing and dewatering. The company has augmented its construction and engineering expertise along with a strong safety record into an equally impressive resume that represents a significant number of high-profile, highly challenging tunneling projects throughout North America.

Malcolm crews recently completed work on the Alaskan Viaduct Replacement Project (SR 99), in Seattle where we installed the support of excavation (SOE) which incorporates large-diameter secant piles to construct the portal for Bertha, the world's largest tunnel boring machine (TMB).Various ground improvement techniques were used to construct several TBM Safe-Haven's in challenging glacial till with a myriad of undocumented obstructions. At the Port of Miami Tunnel Project in Florida, Malcolm installed the launch and retrieval pit for the TBM incorporating various Soil Cement Mixing techniques for the SOE as well as the break-in and break-out structures in highly permeable limestone. For the New Irvington Tunnel in California, we drilled very deep Secant Piles to construct the access shaft in rock with verticality requirements which until recently were unachievable.

Our large equipment fleet and highly skilled personnel affords Malcolm the unique ability to comply with the most rigorous schedule compression, while delivering a high quality product in the most difficult ground conditions. Our experience facilitates a Design/Build approach to projects and allows for timely collaboration with owners and contractors. We provide these services nationwide through our regional offices. We welcome the opportunity to work with you in developing the most efficient and cost effective solution to your next project.

Look to the Blue

Malcolm Drilling
www.malcolmdrilling.com



MALCOLM

Look to the Blue

ACCESS SHAFTS

Alaskan Way Viaduct Replacement
Seattle, WA

Large Diameter Secant Piles for Bertha Rescue Shaft

Malcolm Drilling has been providing support for our clients for over 50 years. Our innovative technology and extensive equipment fleet uniquely positions Malcolm as a national leader in the deep foundation industry. Find out more about what we can do for you at **Malcolmdrilling.com.**

JENNMAR

JENNMAR is a global, family-owned company that is leading the way in ground control technology for the mining, tunneling and civil construction industries. Since 1972, its mission has been focused on developing and manufacturing quality ground control products. Today, JENNMAR makes a broad range of reliable products, from bolts and beams, to channels and trusses, to resin and rebar. We're proud to make products that make the industries we serve safer and more efficient. And with more than twenty manufacturing plants around the world and a network of affiliates, JENNMAR is uniquely positioned to react to ground control needs anywhere, anytime.

A Single Source Provider
JENNMAR's network of affiliates includes engineering services, resin manufacturing, rolled-steel and drill-steel manufacturing, custom steel fabrication, chemical roof support and sealing products, and even includes staffing solutions and our own trucking company. This ability to provide a complete range of complementary products and services ensures quality, efficiency and availability resulting in reduced costs, reduced lead times and increased customer satisfaction.

JENNMAR Affiliates
JENNMAR Civil
JENNMAR Civil is dedicated to providing products and services to the Civil Construction and Tunneling industries. Products include various types of rock support bolts, anchoring systems and resins to support tunneling, geotechnical, foundation and earth retention projects.

J-LOK
J-LOK manufactures state-of-the-art resin anchorage systems that are designed to complement JENNMAR products and provide an optimum bolt and resin system. J-LOK equipment is among the most technologically advanced in the resin industry.

JENNCHEM
JENNCHEM designs and delivers chemical roof support, rock stabilization and ventilation sealing products to the mining and underground construction industries.

KMS (Keystone Mining Services)
KMS (Keystone Mining Services) is JENNMAR's engineering affiliate that provides advanced engineering services such as structural analysis, numerical and 3-D modeling, as well as conducting research and development of new products.
JENNMAR Specialty Products

JENNMAR Specialty Products is a full-scale steel fabricator specializing in roll-forming coil, sheet and structural beams to provide quality arch and corrugated products. In conjunction with KMS, we can also custom design and fabricate products for a variety of applications.

JM Steel
JM Steel's steel processing facility, located on Nucor Steel's industrial campus near Charleston, SC, has the processing capability and extensive inventory to provide a variety of flat rolled steel products including master coils, slit coils, blanks, beams, sheets, flat bars and panels.

JENNMAR McSweeney
JENNMAR McSweeney is a leading manufacturer of forged drill steel products for the underground mining and civil construction industries, along with a complete line of bolt wrenches, socket accessories, chucks, augers, and other related products.

CSA (Compliance Staffing Agency)
CSA is an energy industry staffing service that provides trained, experienced, drug-screened personnel and can supplement an existing workforce during peak work periods or act as a screening service for potential new hires.

MARJENN Trucking
MARJENN Trucking provides trucking services throughout the eastern and mid-western U.S. to transport raw materials, supplies and finished products between JENNMAR plants, suppliers and customers.

JENNMAR continues to grow, but our focus is always on the customer. We feel it is essential to develop a close working relationship with every customer to understand their unique challenges and ensure superior customer service. JENNMAR's commitment to the customer is guided by three words; SAFETY, SERVICE and INNOVATION that form the foundation and identity of our business. It's who we are.

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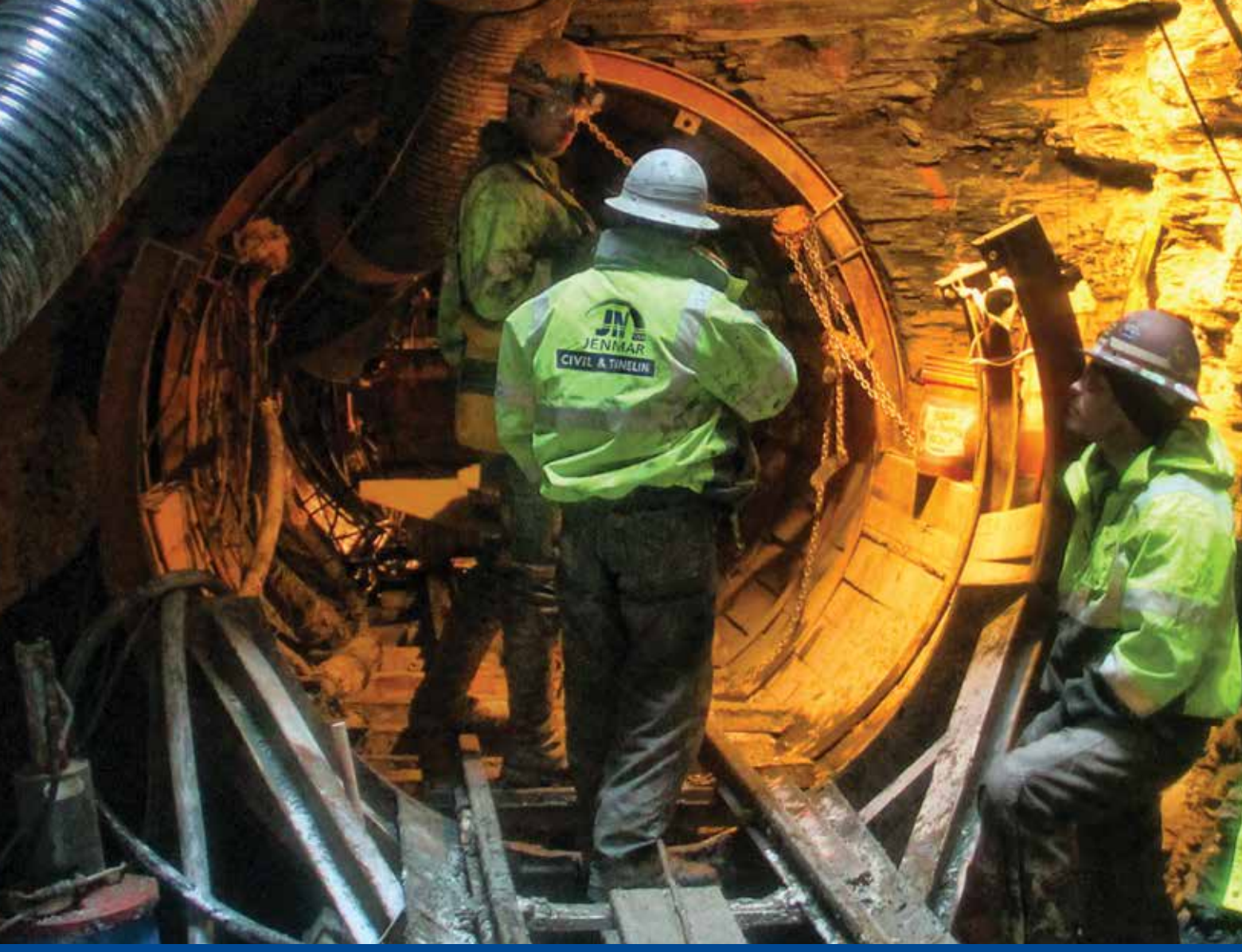


Demanding Conditions Demand JENNMAR.

We've been an innovative leader in ground control for the mining industy for more than forty years. Over the past decade, our growth has led us to make key acquisitions of resources to further enhance our deep commitment to serve the tunneling industry as well. Our rock bolts, anchoring systems, liner plates and resins are backed by experienced engineers and technicians who are with you every step of the way, from initial consultation to qualified instruction and on-going technical support. *And, of course, our customer service is second-to-none. That's something we've always demanded of ourselves.*

JENNMAR CIVIL™

Pittsburgh, PA USA • **412-963-9071** • www.jmcivil.com

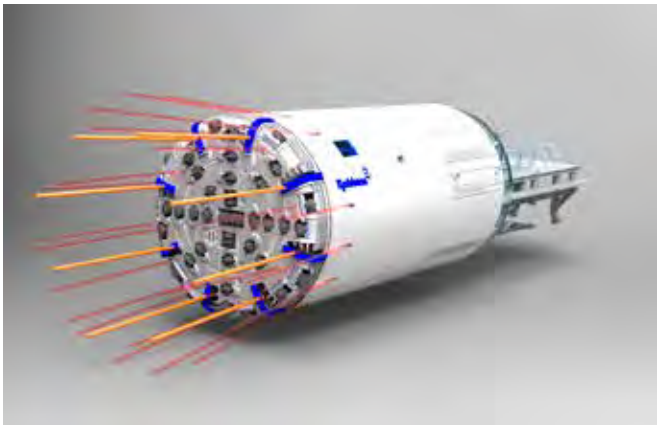
The Robbins Company

Setting the Tunneling Standard
With over 60 years of experience, The Robbins Company is the world's foremost developer and manufacturer of advanced underground construction machinery. Robbins TBMs made swift headway on many worldwide projects in the first half of 2016, and will continue this progress into 2017. Innovative concepts keep expanding the company's scope, from efficient TBM assembly methods to high-performance machine designs resulting in landmark performances in soft ground and hard rock.

Robbins is Focused Forward
Every technological breakthrough Robbins has ever made has been an answer to a client's challenges. From minimizing downtime in mixed geology with Crossover TBMs to maximizing safety and performance with the latest ground investigation solutions, Robbins is committed to keeping even the toughest projects moving forward.

In 2015, Robbins proudly announced its Crossover Series of TBMs, a line of field-tested, rugged Dual Mode-type machines. Today, these customized machines are at work around the world. Crossover TBMs feature aspects of two TBM types, and are ideal for mixed ground conditions that might otherwise require multiple tunneling machines. The first North American Crossover TBM, for the Túnel Emisor Poniente II (TEP II) Project in Mexico City, made an intermediate breakthrough on March 29, 2016 after overcoming challenging ground conditions. The 8.7 m (28.8 ft) dual-mode type machine is an XRE TBM capable of "crossing over" (X) between two modes, rock (R) and EPB (E), and represents the latest in Crossover technology. Designed with field-inspired features including a single-direction cutterhead, multi-speed gearboxes, and improved probe drilling capabilities, the machine has navigated abrasive volcanic rock and fault zones with great success. The success in Mexico is being followed up by the first Crossover TBM to be used in the United States. Currently under assembly, the 9.3 m (30.5 ft) diameter XRE TBM for the Akron Ohio Canal Interceptor Tunnel (OCIT) will be launched in 2017.

In 2016, Robbins introduced its latest package of innovations to help contractors stay a stroke ahead of their TBM in challenging conditions. Difficult Ground Solutions (DGS) is a suite of options available for shielded hard rock and Crossover TBMs that can keep a machine moving in long tunnels, high cover, and tough geological features. From Continuous Advance Shield Design to Water Inrush Control, Robbins is making the impassible no longer impossible. These designs will be featured on a new 6.6 m (21.7 ft) diameter Single Shield TBM for New York City's Rondout West Branch Bypass Tunnel. The customized TBM will be capable of withstanding up to 30 bar water pressure and will utilize enhanced probe drilling and grouting technology able to be employed 60 to 100 m (200 to 330 ft) ahead of the TBM operation.
With major projects currently underway in North America and abroad, Robbins continues to lead the tunneling industry in innovation and partnership. For more information about Robbins and our past and present projects, visit **www.TheRobbinsCompany.com or call +1 (440) 248-3303.**



ONE MACHINE
MANY GEOLOGIES

INTRODUCING THE
ROBBINS CROSSOVER MACHINE

Robbins continues to set the industry standard with the release of the Crossover TBM Series: a line of rugged, field-tested tunnel boring machines. Capable of crossing over between two modes, they are ideal for mixed ground tunnels that, until now, required multiple TBMs. Robbins Crossover TBMs are already underway on projects around the globe.

A SERIES OF
ROBUST MACHINES FOR THE WORLD'S **MOST CHALLENGING PROJECTS**

XRE

Crossover Between Rock/EPB

For excavation in mixed soils with rock

XSE

Crossover Between Slurry/EPB

For excavation in mixed-to-soft ground under water pressure

XRS

Crossover Between Rock/Slurry

For excavation in hard rock and soft water-bearing ground

Robbins

TheRobbinsCompany.com | sales@robbinstbm.com

Local Presence. Global Competence.

DSI Underground Systems (American Commercial Division) offers a complete selection of ground control solutions for the Civil, Mining and Foundation markets. We have been a leader in the underground support business in North America since 1920.

We are a global leader in tunnel and shaft construction, focused on engineered and tailored products to support our customers and industry.

DSI is proud to bring an expanded group of products to the job site:

- **ALWAG** – Support Systems
- **Biomarine** - Tunnel Rescue Equipment
- **Boart** – Probe and Roof Bolting Equipment
- **CBE** – Segment Moulds – Precast Segment Moulds, Related Equipment and Plants
- **ChemGrout** - Grouting Equipment
- **Condat** – Ground Conditioning Chemicals and Lubricants
- **Cooper & Turner** – Bolts and Sockets for Precast Segments
- **DSI** – Steel Ribs, Liner Plates, Lattice Girders, Lagging and Miscellaneous Support Items
- **Dywidag** – Bolts and Accessories including DSI Threadbar, Friction Bolts and Omega Bolts
- **ES Rubber** – Segment Gaskets
- **Geodata** – Monitoring Equipment
- **Hany** – Grouting Systems
- **Montabert** – Excavator Drilling Attachments and Replacement Drifters
- **Promat International** – Fire Protection Products
- **Strata Worldwide** – Safety and Communication Equipment
- **VikOrsta** – CT-Bolts – Double Corrosion Protection
- **Weldgrip** – Fiberglass Bolts and Dowels
- **WIRTH** – Pile Top Rigs

www.dsiunderground.com
502.473.1010

DYWIDAG-SYSTEMS INTERNATIONAL

DSI

DSI Underground Systems, Inc.
American Commercial Division

GROUND CONTROL SOLUTIONS

DSI Tunneling LLC offers a complete selection of ground control solutions. Beginning with steel liner plates installed in the Gratiot Avenue sewer system in Detroit, Michigan in 1920, we are today the leading designers and manufacturers of underground steel supports in North America.

- Steel Ribs, Liner Plates and Lattice Girders
- Dywidag (DSI Bolts and Accessories)
- AkerSolutions Pile Top Drills & Shaft Boring Equipment
- Condat Ground Conditioning Chemicals and Lubricants
- Häny Grouting Systems
- Boart Probe and Anchor Drills
- ES Rubber Segment Gaskets
- VikOrsta CT-Bolts
- Biomarine Tunnel Rescue Equipment
- PBE Communication Equipment
- Strata Worldwide Safety and Communication Equipment
- Promat International Fire Protection
- CBE Concrete Segment Moulds
- Cooper & Turner Segment Connection/ Grouting Accessories
- ALWAG Support Systems

DSI UNDERGROUND

Local Presence.
Global Competence.

DSI TUNNELING LLC

502.473.1010

dsiunderground.com

Surecrete Inc.

Surecrete Inc. specializes in furnishing bagged cementitious materials, mixing and placing equipment, and related accessories to the heavy civil tunnel, geotechnical and mining markets.

Our product lines include Nittetsu SuperFine ultrafine cement, rheology modifiers, admixtures, and a complete selection of packaged wet and dry shotcrete, concrete and grout mixes.

We also represent several major equipment manufacturers focusing on the mixing and placing of shotcrete, concrete and grouts. Surecrete Inc.

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Email: jeff@surecrete.com
For more information, visit our website at www.surecrete.com.

Schnabel Engineering

Schnabel Engineering, formerly Lachel & Associates, specializes in design and construction management services for tunneling and other heavy civil construction projects in the areas of transportation, water and wastewater infrastructure, and hydroelectric power. Our goal is to meet the needs of clients by providing fully integrated management and technical services that are objective, thorough, and effective.

We combine our expertise in the design and construction of underground structures with a keen understanding of nuances and interrelationship of geology, hydrogeology, and geotechnics on underground projects. From inception, through design, risk assessment, estimating, construction, and operations, we provide time-critical answers to difficult questions that help make certain the project comes in on time and within budget.

Founded in 1956, Schnabel has a long history of providing tunnel design services for constructors, owners, and other A/E firms for project across the United States. Some of our recent projects include:

- DC Water Clean Rivers Program, Washington, DC
- Loudon Water Raw Water Supply Tunnel, Leesburg, VA
- East End Crossing Tunnels, Louisville, KY
- Waller Creek Flood Tunnel, Austin, TX

TUNNEL DESIGN SERVICES
Some of our design services for tunnels and underground projects include:

- Feasibility Studies
- Alignment Optimization
- Assessment of Geotechnical Conditions
- Tunnel Initial and Final Support Design
- Numerical Methods for Design
- SEM / NATM
- Cavern Design
- Shaft Design
- Constructability Review and Cost Estimating
- Geotechnical Baseline Reports (GBRs)
- Construction Documents/Design Reports

www.schnabel-eng.com

Schnabel ENGINEERING
formerly Lachel & Associates

- Tunnel Engineering
- Geotechnics
- Constructability and Cost Estimating
- Risk Management
- Construction Engineering
- Construction Management
- Trenchless Technology
- Tunnel Inspection and Rehabilitation

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Parsons

Connecting infrastructure across the globe.

Founded in 1944, Parsons is the premier source for end-to-end design-build engineering capabilities, including expert multidisciplinary planning, all phases of construction and implementation, and maintenance and improvements. The firm employs more than 15,000 professionals around the world who are prepared to meet every technical and management challenge and to persevere until the job is done.

Parsons' tunnel group has contributed to hundreds of domestic and international tunnel projects, including the Caldecott Tunnel improvement project, which involves the construction of a fourth bore through the Berkeley Hills, near Oakland, California; the Washington, D.C., Metro twin-tunnel program, cited by the American Underground Association as one of the most significant tunneling projects in the last 10 years; and the Maliakos Kleidi Motorway Tunnel, in Greece.

Serving the underground engineering and program management needs of a diverse clientele, Parsons lends its expertise to projects such as underground utilities, water storage and transportation tunnels, and underground buildings. The firm has provided advisory services, performed subway construction, and delivered major highway tunnel projects, including the New York Gowanus Expressway and the English Channel Tunnel.

To minimize the risks associated with underground structures, Parsons offers a host of innovative tunneling techniques, like the New Austrian Tunneling Method, top-down construction sequencing, advanced hard-rock and soft-ground tunnel-boring machine technology, single-pass tunnel construction, and advanced tunnel waterproofing systems. Throughout the firm's history, Parsons has worked to provide safer, better, more sustainable ways to travel the world — one project at a time.

Learn more at **www.parsons.com.**

Tensar

Tensar offers a number of underground and surface solutions to support the unique requirements of the mining and tunneling industry.

Below Ground: Compared with metal reinforcement, Tensar mining products can reduce installation and material handling time by up to 75%. Our Mining Systems offer cost-effective solutions for a wide range of underground mine and tunnel applications, including:

- Roof and Rib Control
- Longwall Screens
- Highwall Screens

Above Ground: Tensar® TriAx® Geogrids stabilize soft soils and improve site access roads, haul roads, and staging areas. When compared with an unstabilized aggregate layer, a Mechanically Stabilized Layer (MSL) incorporating TriAx Geogrid can:

- Reduce aggregate requirements up to 60%
- Maintain surface quality to increase operating speeds
- Reduce the frequency of costly and disruptive surface maintenance
- Reduce labor and equipment needs
- Increase design life and bearing capacity

Tensar International Corporation
Telephone: 800-TENSAR-1
www.TensarCorp.com

Premier Pipe Systems Manufacturer for 90 Years

Since 1925, Naylor Pipe Company has been the premier manufacturer of Spiralweld pipe systems.

Naylor Spiralweld is available in diameters from 4" through 96" and wall thickness from 14 Ga. through 1/2" wall. The Spiralweld pipe is complemented with all types of fittings, fabrications to specification, and joint connections, including the exclusive Naylor Wedgelock Coupling, to complete your pipe system.

Naylor Spiral Buttweld pipe features two welds along the spiral seam. This creates a pipe structure in which the weld is as strong or stronger than the parent metal.

The Naylor manufacturing process creates a pipe that maintains an accurate diameter throughout its length. The uniformity of the pipe ends speed connection, whether mechanically coupled or welded.

Uniform wall thickness is assured because tolerances of steel strip are governed by the standards established by the American Iron and Steel Institute. In addition, the pipe is furnished in any required length with a cutting tolerance of plus or minus 1/8". In addition to carbon steel, spiralweld pipe can be formed from many steel grades, including abrasion resistant, weathering (A-588) and stainless.

Every length of Naylor Pipe is inspected and where required hydrostatically tested to applicable ASTM specifications. The pipe is available in lighter weights than other pipe making it possible

to save money, not only on initial cost, but also in transportation, handling and installation. By sizing the diameter of the pipe to the exact requirements, with exact lengths and factory-sized ends, the greatest economies can be realized.

Quotations are immediately available on inquiry.

Naylor Pipe Company
1270 East 92nd Street
Chicago, IL 60619 USA
Tel: 1-773-721-9400 Fax: 1-773-721-9494
Email: sales@naylorpipe.com
www.naylorpipe.com

T&UC

Mining Equipment Ltd.

12-ton explosion proof diesel locomotive pulling 8 cubic meter side-dump muck cars out of the tunnel.

Mining Equipment has been supplying the mining and tunneling industries with top quality rolling stock for more than 30 years. They supply diesel and battery locomotives up to 35 tons. As well as a complete line of non-propelled rolling stock including muck cars, flat cars, personnel cars, segment car and concrete agitator cars.
Recently Mining Equipment has supplied a string of rolling stock including 5th wheel dump muck cars to Stillwater Mining in Montana. The cars will be used to haul muck out of a new TBM mined tunnel.

Another recent project for Mining Equipment was the New Irvington Tunnel in northern California. 12-Ton explosion proof diesel locomotives were supplied as well as a large spread of 5th wheel dump muck cars, flat cars and personnel cars.
Mining Equipment is based in Durango, Colorado. There primary shop is in Farmington, New Mexico. They also have a fabrication facility near Shanghai, China and an office in North Bay, Ontario.
Mining Equipment Ltd.

25-ton diesel locomotive pulling a string of 15 cubic meter capacity roll-over muck cars through a dump at their mine in Papua New Guinea.

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Fax: +1-970-259-5149
www.miningequipmentltd.com

Alpine Equipment

Alpine Equipment is the industry leader in hydraulic rock and concrete grinder attachments, roadheaders, shaft sinkers and soil remediation equipment, with over 40 years of expertise in North America. Our customers range from owner-operators to the largest tunneling firms. Alpine supplies attachments for construction, demolition, excavation, scaling, trenching, mining and tunneling. The rotary cutter heads come in range of sizes to fit on skid steer loaders, backhoes and excavators or any equipment with a hydraulic circuit. With a range of options and customizations, we can get you working more efficiently and with more precision than your current tools. Many of our customers are using the cutter head for concrete scaling projects for highway rehab or shotcrete clean up. The power, flexibility and precision of the Alpine concrete grinder enable this as a highly useful tool in a variety of jobs.

In addition to rotary cutterheads, Alpine also supplies state-of-the-art in situ soil mixing and remediation equipment. Remediation equipment includes mixing attachments and wet or dry amendment delivery systems. With increased Natural Gas production, we have supplied the industry with mixers for solidification of drilling mud, whether on site or in container batches. The power and efficiency of our mixers have yielded significant production increases, allowing you to reduce costs and finish on time.

Contact Alpine Equipment for cutterheads, new & used roadheaders, ITC tunneling machines and soil mixing equipment.

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CDM Smith

CDM Smith provides lasting and integrated solutions in water, environment, transportation, energy and facilities to public and private clients worldwide. As a full-service engineering and construction firm, we deliver exceptional client service, quality results and enduring value across the entire project life cycle. CDM Smith's underground construction staff includes geotechnical, structural, and civil engineers and geologists located worldwide. Our staff has extensive experience in providing the full range of tunnel and geotechnical related services. Our tunnel related work includes planning, feasibility and design, including both 2D and 3D FEM analyses. We offer construction services including construction and program management, inspection and geotechnical instrumentation monitoring and interpretation for soft ground and rock tunnels. Design and construction includes all types of ground modifications including ground freezing, grouting, and dewatering.

Our field equipment includes geotechnical instrumentation and construction data acquisition equipment. Our field personnel are NICET, OSHA and NRC certified. CDM Smith's tunnel services include:

- Shaft Design: Ground Freezing, Slurry Wall and Secant Pile Wall
- Conventional Soft Ground and Rock Tunnel Design, Microtunneling, Pipe Jacking and Directional Drilling
- Evaluation and Rehabilitation of Existing Tunnels
- Ground Investigation, Testing and Evaluations
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Mott MacDonald

Tunnel engineering is one of Mott MacDonald's core services. For a wide-range of public and private clients, we have engineered transportation tunnel solutions for roadway, passenger rail, freight rail, subway, pedestrian, cable and communications projects. Our expertise spans a broad-range of capabilities from the planning and implementation of new facilities to the inspection and rehabilitation of existing facilities.

Our involvement in tunneling began more than a century ago, dating back to our founders' involvement with London's underground road and rail systems in 1902, and Toronto's subway system in 1954. Our association with these clients continues today – a testimony to the trust, confidence, and professional relationship we build with our clients and to the quality of our work.

With more than 75 offices throughout North America, Mott MacDonald offers a full-range of services to handle any size project – from a small inspection assignment to world-class, multi-billion-dollar transit programs.

Our goal is to deliver client projects in an environmentally responsible manner, with value-added design and construction methods – minimizing programmatic risk along the way.

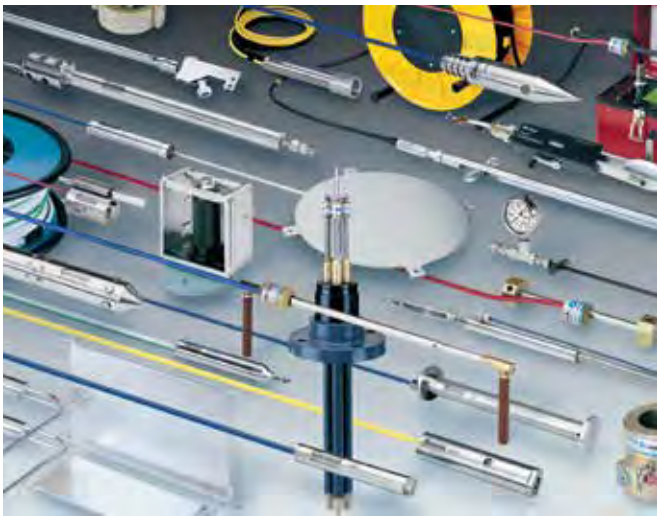
Geokon, Incorporated

Geokon, Incorporated, is a 35 year-old company based in Lebanon, New Hampshire, USA. It operates on a worldwide basis through a network of over 45 agencies for the manufacture and sale of geotechnical instruments. Founded in 1979, Geokon currently has over 100 experienced employees, many of whom have been with the company for over 25 years. Geokon, Inc. has emerged as The World Leader in Vibrating Wire Technology™ and one of the major global instrumentation companies due to our high-quality products, responsive customer service and industry-leading designs.

In addition to almost all major cities in the USA, our instruments have been used in tunnels and subway systems around the world, including those found in Seoul, Taipei, Guangzhou, Istanbul, Hong Kong, Singapore, London and the Channel Tunnel.

Tunnel-specific instruments include NATM-style concrete pressure cells for monitoring stresses in shotcrete linings; convergence meters and tape extensometers to measure tunnel closures; multiple-point borehole extensometers and instrumented rockbolts to monitor the stability of the surrounding ground; piezometers to monitor ground water pressures and displacement gages to measure movements across cracks and joints.

Dataloggers are used to take readings at programmed intervals and transmit real-time data (and any triggered alarm signals) to local stations or to remote readout locations using web-based software.



Geokon's experienced staff is at your disposal to assist in instrument design, selection and installation. For more information please visit www.geokon.com, e-mail us at info@geokon.com or call 1-603-448-1562 and speak to a sales representative.

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The Original Tunneling Pro

Experience, innovation and hard work; it's what makes a Brokk Star. And when it comes to tunneling, August Scalici was the first. Brokk's field sales application expert has been working on large tunneling projects since the 1980s. He was an operator on the first U.S. project ever for a Brokk, a ceiling demo in the Holland Tunnel from New Jersey to New York in 1982. He's come a long way since then, and today he's providing guidance to the Bouygues Civil Works Florida crew digging cross passages on the Port of Miami Tunnel Project with a Brokk 400.

Brokk remote demolition machines not only take people out of harm's way, they also offer diverse attachments that enable operators to complete every piece of the tunneling puzzle, from excavating to beam installation. And Scalici knows how to do it all.

"I'm an operating engineer by trade, and I was one of four operators chosen to work on the Holland Tunnel project," Scalici said. "It was amazing what we could do with a Brokk machine. I remember working eight hours and it feeling like five minutes." After that first Brokk Job, he operated the remote-controlled machines in tunnels for nearly 20 years before joining the Brokk team as a field application specialist. He now works directly with operators, getting to know their projects, determining which Brokk machines and attachments will work best for each job, and training the tunneling teams. With his hands-on experience, he's often able to suggest solutions they may not have thought of before.

That's saying something for tunnelers who measure experience not in years or miles but in high-profile projects. And with Scalici's help, many of them are building their resumes and becoming Brokk Stars themselves.

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Schauenburg

We are pleased to announce the formation of a cooperative Business Alliance between Schauenburg Flexadux Corp (www.schauenburg.us) and Protan AS (www.protan.com) to better serve the Tunnelling and Mining across the United States.
This cooperative approach involves combining the strengths of Protan's years of manufacturing and supply of top quality Tunnel Ventilation PVC Ducting and Technical solutions to the global mining and tunnelling industries with Schauenburg Flexadux's 40 plus years of local US Manufacturing, Supply and customer service to these industries.
The major benefits of this Business Alliance is to combine the 60 plus years of Protan experience in designing and supplying lower friction Ventilation Technology with the dedicated local commitment of Schauenburg Flexadux to supply fast deliveries to meet our customers production requirements.

The major benefits to our valued end-user clients are:

1. Combination of Recognized World Class Ventilation Technology with dedicated local manufacturing , sales, service, and support.
2. Fast response time to design and manufacture of specialty products.
3. Elimination of supply logistics related to long delivery concerns, customs and other import administrative costs.
4. Addresses the fluctuating currency exchange rates.
5. Competitive pricing to address the realities of the US Market Demands.

We look forward to working jointly together with you to provide quality ventilation products and services to assist you to be a profitable leader in the United States mining and tunnelling business.

Please feel free to contact us at any time with any questions.

John Kelleher, P.Eng.
President
Schauenburg Flexadux Corp.

Mark Andersen, P.Eng.
Director N. America
Protan AS

David R. Klug & Associates, Inc.

David R. Klug & Associates, Inc. provides international and national manufacturers representative services to the underground heavy civil and mine construction industries. The company specializes in the coordination of specialty products, equipment and services for soft ground, conventional and NATM tunneling practices. Expertise is offered in the supply of various componentry used in the manufacture of one pass precast segmental tunnel linings inclusive of EPDM gaskets, plastic and steel connectors, grout lifitng assemblies, steel fiber reinforcement and precision steel casting moulds. For conventional and NATM tunneling practices the company offers prefabricated welded wire fabric and rebar reinforcing panels in conjunction with concrete final lining forming systems for highway, rail, subway and water tunnel applications.

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Northwest Laborers-Employers Training Trust

**Northwest Laborers-Employers Training Trust –
Safety and Hazard Awareness for Tunnels (SHAFT) program**

The Safety and Hazard Awareness for Tunnels (SHAFT) program seeks to provide comprehensive safety training for both new and experienced tunnel professionals.

The curriculum (developed by the Northwest Laborers-Employers Training Trust with input from a team of industry experts and stakeholders) is comprised of a blend of classroom discussion and interactive use of materials and mockups. Classes focus on tunnel safety, rail, and utilities.

The training facility, located in Elma, Washington, features a TBM mockup, loci, and access to 1,400' of 12' diameter tunnel – providing students with a unique educational experience.

Northwest Laborers-Employers Training Trust
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www.nwlett.org

Brookville

BROOKVILLE 27-Ton MSHA Permissible Locomotives Boosting Safe Work Environment at Major Los Angeles Tunneling Project

Brookville Equipment Corporation (BROOKVILLE) recently shipped three 27-ton MSHA-permissible tunneling locomotives to the Walsh-Shea Corridor Constructors for use on the Crenshaw/LAX Transit Corridor Tunnel Project in Los Angeles. By design, the locomotives reduce the risk of explosion due to geological conditions that may host the presence of methane and other combustible gases. Cal-OSHA has classified the tunnel drives on this project "gassy", mandating the use of MSHA permissible locomotives.

The 27-ton locomotives' special safety features include air start, an enclosed engine block, an exhaust filtration system, wiring and piping guards, and an intake flame arrestor, among other upgrades, to fully comply with MSHA's permissibility requirements. Featuring an 8.3L Cummins six-cylinder diesel engine and four-speed transmission, the 185-horsepower locomotives operate on 36-inch rail gauge underground for Walsh-Shea Corridor Constructors .

"BROOKVILLE was selected based on past performance, simplicity of operation and diagnostics, their ability to communicate locally with MSHA, and knowing we would be dealing with the good people of Brookville, PA, U.S.A," said Walsh-Shea Corridor Constructors Tunnel Construction Manager David Girard, P.E.

Bradshaw Offers Innovative Tunnel Engineering and Construction Technology

Bradshaw Construction Corporation strives to apply the most appropriate tunneling technology to each project based on its purpose, subsurface conditions and surface restrictions. The company's management team is proud of its ability to construct any type of tunnel in any soil condition both above and below the water table. From small hand mined, wood-box and liner plate tunnels to large NATM shotcrete-lined tunnels; from small pilot tube guided auger bores to large rib-and-board shield and tunnel boring machine (TBM) tunnels; from conventional pipe jacking to slurry microtunneling (MTBM) to earth pressure balance (EPB) TBM tunnels; and from hand mined drill and blast to rock tunnel boring machines (TBMs), Bradshaw Construction has a solution.
For your next project, let our knowledgeable staff of tunnel engineers and construction professionals create the most cost effective, safest, and highest quality solution for your unique tunneling needs.

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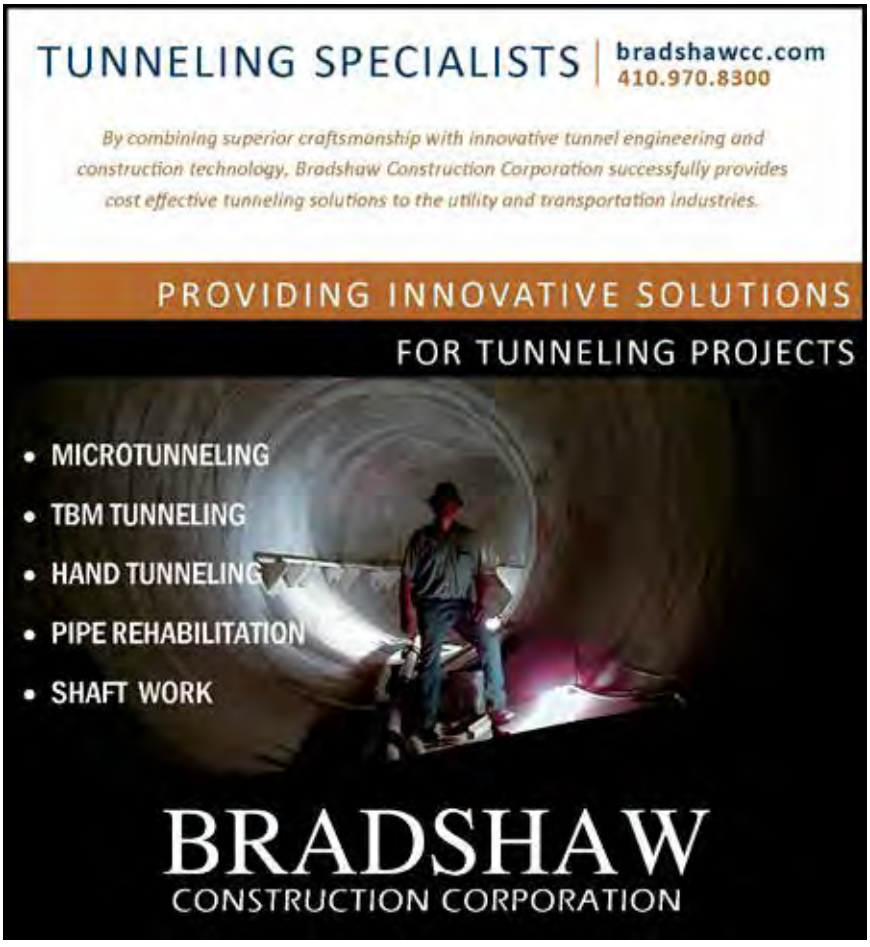

ABC Industries, Inc.

The most extreme tunneling and underground construction sites demand the most dependable, durable ventilation equipment available today. Since 1926, ABC Industries, Inc. has been a leading provider of high quality, customized ducting solutions to many of the largest mine and tunnel operations in North America and around the world. ABC's complete line of MineVent® and TruOval MineVent® layflat blower tubing, MineDuct® wire-reinforced exhaust ducting, RigiDuct® filament-wound fiberglass ducting, brattice, fly pads, blast curtains, fans, and accessories offer underground professionals a complete solution for ventilation products. As tunneling and underground construction continue to evolve, ABC proactively collaborates with industry professionals to engineer unique, high quality ventilation products to exceed the industry's needs tomorrow and beyond.

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www.abc-industries.net

Atlas Copco Innovation

Atlas Copco innovation never stops

Founded in 1873 as AB Atlas, the company manufactured its first drill in 1898. Continuous innovation followed, and in 1936 Atlas introduced a one-man rock drill that could be equipped with a pneumatic pusher leg. This became the basis for the "Swedish method," a modern and lighter drilling technology. In the same year, the company pioneered the use of "down-the-hole" drilling. And in 1937, Atlas manufactured a rock shovel loader for the mining industry. The Atlas Copco legacy continued to grow and innovation on all product lines continues today.

The Swedish Method

The Atlas Copco mining product range includes:

- Exploration drilling equipment
- Rock reinforcement equipment
- Raiseboring equipment
- Face drilling rigs and scalers
- Underground loading and hauling vehicles
- Rock drilling tools, hammers, bits
- Blast hole drilling rigs
- Large rotary and DTH blast hole rigs
- Grouting and shotcrete
- Air compressors, generators

McMillen Jacobs Associates

New Year, New Outlook

After successfully working together for several years and gaining an understanding of each other's cultures and talents, drivers and missions, McMillen and Jacobs Associates agreed to merge in late 2014. Jacobs Associates brings 60 years of serving the heavy civil underground industry, while McMillen brings an integrated design-build delivery to the water supply and hydropower industries. By merging, we can contribute to projects at the planning stage, develop a design, and self-perform construction. Clients benefit because we understand project drivers at all stages and can provide cost-effective alternatives. We are small enough to remain focused on service and quality rather than profit centers and internal bureaucracy, but large enough to offer expanded services and a deeper bench of technical expertise. As the industry we serve continues to change and evolve, so must we. As you learn more about the capabilities of our new firm, we are confident that you will agree.

Daniel N. Adams
President

McMillen Jacobs Associates
800.842.3794
www.mcmjac.com

HIC Fibers is selling direct in North and South America

HIC Fibers, Inc. has opened offices in Los Angeles, California for North America and Lima, Peru for Central and South America.

This marks the first time that HIC Corp. based in Korea, has opened offices with the intention of selling direct to the end user in lieu of selling strictly through distributors.

HIC Fibers has the exclusive technology and rich know-how in manufacturing of steel fibers. HIC Fibers can provide you a steel fiber of your choice in length, diameter and package.

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Dā-mite Rock Splitting Mortar from the Daigh Company, Inc.

Daigh Co. is the supplier of Dā-mite Rock Splitting Mortar. Dā-mite is used to fracture rock and concrete in "no-blast" conditions. Dā-mite is an ideal and effective tool for fracturing mass rock, boulders, trench rock, dimensional stone, concrete and reinforced concrete. "Dā-mite is mixed with water and placed in the appropriately placed predrilled holes, where it sets and expands, fracturing the rock/concrete". No license required. There are four grades of Dā-mite, providing enough versatility to be utilized in drilled hole diameters from 1 in. to 2 ¾ in.

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Announcing Doctor Mole Incorporated

Dr. Gary S. Brierley started operating as an independent consultant under the corporate name of Doctor Mole Incorporated (DMI) on January 1, 2013. Doctor Mole Incorporated is a one-stop-shopping-center for the design of all types of underground openings in all types of ground conditions. DMI can help clients meet their underground design and construction needs. No job is too small and it is our intention to help owners, designers, contractors, geotechnical engineers, and developers create successful underground projects from start to finish. Based in Denver, Colorado, DMI is strategically located and available to help with projects across the United States. Give us a call at 303.797.1728 or visit us on the web at www.drmoleinc.com.

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For more information contact:

Gary Brierley

gbrierley@drmoleinc.com or 303.797.1728

The Heintzmann Group

The Heintzmann Group, which has been in business approximately 165 years, manufactures support systems in the tunneling and mining industries. In the last decade, we have greatly expanded our line of products, as well as our regions of service. We currently have offices located in Virginia, West Virginia, Alabama, Colorado, and Illinois. Our range of products and services include but are not limited to standing supports, pumpable roof support, arches, square sets, pre-stressing devices, heat treated beams, polyurethane grout injection, shaft rings, lattice girders, two flange liner plates and four flange liner plates. The goal of the Heintzmann Group is to provide resources to make

the tunneling and mining environments safer and to achieve the highest level of customer satisfaction by providing our customers with a variety of support options.

The Heintzmann Group
Telephone: +1-276-964-7413
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ILF Consultants, Inc.

ILF USA specializes in tunnel and underground engineering, foundation and retaining systems for permanent and temporary works, and construction engineering services throughout North America.

Our team can assist clients with engineering solutions in energy, water, infrastructure, and natural resources markets, applying cutting edge technology and providing services including; project consulting, engineering design and planning, pre-bid services, construction management, project management, and risk management/claim avoidance and mitigation.

ILF USA has expertise in design-build, P3's, and conventional contract delivery methods. Depending on the requirements, we can serve as an owners engineer or as a construction engineer for contractors. For more information contact James Morrison at (231) 944-9732.

ILF Consultants, Inc.
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FEATURE ARTICLE

Construction of the SR-99 recovery shaft

FIG. 1

Site layout/access constraints - Note existing SR-99 behind work area, and pile-supported structure above Puget Sound in foreground, just out of view.

Mining on Seattle's SR99 tunnel began in July of 2013. Initial mining progressed slowly through a 4.5 m (14.9-ft) thick fiber-reinforced concrete headwall before immediately entering the first of three planned safe havens. Once through the headwall and safe haven the machine would move through roughly 122 lineal m (400 ft) of jet grout improved soil at a rate of slightly more than 1.6 m/d (5.3 ftpd). It was anticipated that once mining has passed through the improved area, "Bertha" – now the world's second largest tunnel boring machine (TBM), would be moving at a rate of almost 11 m/d (36 ftpd). By the end of October 2013, Bertha had mined roughly 131 m (430 ft), averaging 1.4 m/d (4.7 ftpd), and had begun mining within native soils. By the start of December 2013, tunneling had reached the 244 m (800 ft) mark and Bertha was averaging 3.6 m/d (11.9 ftpd), achieving as much as 12.8 m (42 ft) of progress on given days. Unfortunately, on Dec. 6th, 2013, Bertha began to stumble and all progress quickly came to a halt.

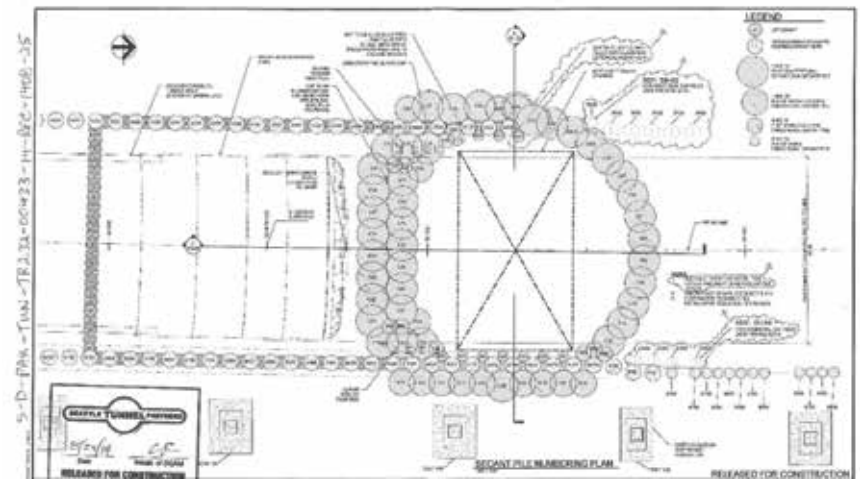
Initial reports stated an obstruction had stopped Bertha in her tracks. The preliminary investigation involved installation of 10 deep dewatering wells to reduce the hydrostatic pressure within the ground around the TBM, to allow the contractor's personnel to inspect the cutter head from within and also to investigate for the presence of obstructions at the face of the cutter head. During inspection, the contractor's crews found fragments of steel pipe entangled in the cutter head. The steel was apparently from an abandoned 254 mm (0.9 in.) diameter monitoring well casing, previously installed by the Washington State Department of Transportation (WSDOT) to monitor groundwater conditions for the

John Starcevich, Lance Rasband and Richard Hanke

John Starcevich, member UCA of SME, is chief engineer and **Lance Rasband** and **Richard Hanke**, are project manager and ground improvement project manager Malcolm Drilling Co, email jstarevich@malcolmdrilling.com.

FIG. 2

Access/recovery shaft layout - Note existing SR-99 footings, near bottom edge of drawing.

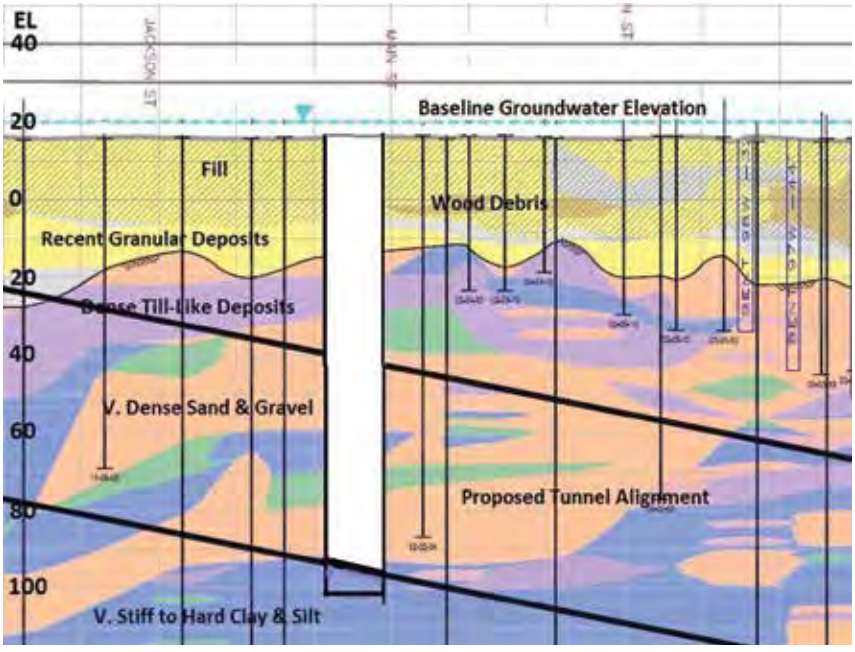


design and planning of this tunnel project. After the steel was removed from the cutter head and cleared from Bertha's path, she attempted to move forward but was only able to generate a slow crawl.

The contractor elected to further investigate the soil located immediately in front of the TBM. At the contractor's request, Malcolm Drilling Co. mobilized a Davey Drill 725 duplex rotary drill to install 18, 152 mm (6 in.) diameter probe holes on 1.5 m (4.11 in.) centers across the face of the cutter head. Of the 18 holes drilled, six obstructions were found at depths between 17 to 24 m (55.9 to 78.8 ft) located between the top of the cutter head to near spring line). Small fragments of steel were found in several of these holes, and the drill casing was not able to be advanced beyond the obstruction. Malcolm Drilling Co. was then directed to drill 1.5 m (4.11 in.) diameter holes in four locations where the obstructions were encountered, to facilitate their removal. However, after these additional, larger exploratory holes were drilled, no additional steel fragments, nor obvious signs of apparent obstructions were encountered. All additional exploratory work was completed by late February 2014, and the alignment was then thought to be clear and ready for Bertha to continue moving forward. However, once the TBM was cleared to resume mining, and the cutter head started turning again, a much larger issue was discovered. The machine's main bearing had been damaged so severely upon encountering the obstructions, it would need to be completely replaced. This would require a monumental effort, with the fast-track design and construction of a structure more than 36.6-m (120-ft) deep and more than 24 m (78.8 ft) in diameter; that would provide access to the TBM and allow the disassembly and removal of the entire cutter head.

FIG. 3

Access/recovery shaft subsurface conditions.



Site constraints

Malcolm Drilling Co. was solicited to help with preliminary design and constructability of the access shaft required for the repair of the machine. Several obstacles had to be overcome in designing an access shaft that would work for this project. The primary constraint was space and access (Fig. 1). With the Puget Sound approximately 30.5 m (100 ft) to the west and the deteriorating Alaskan Way Viaduct (SR-99) immediately to the east within feet of the proposed access shaft location, there were severe "at grade" access restrictions. Also, previously installed under the main tunneling contract, 1.5 m (4.11 ft) diameter tangent piles, spaced 0.46 m (1.6 ft) from each other, ran along the east and west of the tunnel alignment. These piles were required for settlement mitigation during tunneling and to protect the existing viaduct. In

addition, a very high water table, only 2.4 m (7.11 ft) below grade, needed to be cut off. And last, but not least, were the schedule implications for building something effective and quickly enough to get this major project back on track.

Rescue shaft desgin

Exact reasons for Bertha's lack of progress has been the subject of much speculation, however one indisputable fact remained; the full cutter head and inner workings needed to be removed to facilitate a complete repair of the TBM. To accomplish this, a recovery shaft needed to be designed and installed immediately in front of the TBM to allow it to enter the shaft and provide access for repairs.

Having extensive experience with secant pile compression rings, Malcolm Drilling Co. recommended a circular access shaft comprised of over-lapping secant piles, which would provide excavation support, groundwater cut-off, and eliminate the need for horizontal anchors or braces thereby maximizing space for removal of the cutter head. The original design included 2.13 m (10.3 ft) diameter secant piles in a circular ring with jet grouting between the originally placed tangent piles. Moreover, jet grouting continued across the back of the machine to provide water cut-off for internal maintenance of the machine, as well as controlling water when the machine enters the access shaft.

Designed by Brierley and Associates, this option was put out to bid to select drilling contractors. Upon initial review of the design, Malcolm Drilling Co. suggested an alternate option; to install 3-m (9.84-ft) diameter drilled secant piles, thus requiring fewer secants and reducing the anticipated schedule. Once awarded the work, Malcolm Drilling Co. worked closely with Brierley in finalizing the design with the capabilities that could be brought to the project (Fig. 2).

Subsurface conditions

The south Seattle waterfront sits upon reclaimed

FIG. 4

Access/recovery shaft construction — confined work site.

lands comprised of decades of undocumented fills, debris, and various organic deposits. Within the upper reaches of the soil profile, numerous timber piles and railroad ties from buried trestles can be expected. The various fill deposits overlie soft and loose marine sediments that lie on top of glacial till at depths of 12 to 27 m (39 to 88 ft).

The complex glacial stratigraphy controls the nature of the groundwater flow. The permeabilities vary by orders of magnitude in adjacent stratigraphic units. Consequently, there are multiple perched groundwater-bearing layers and multiple piezometric surfaces along the proposed tunnel alignment.

Groundwater movement is governed by hydraulic

FIG. 5

Access/recovery shaft dewatering – Horizontal drain layout.

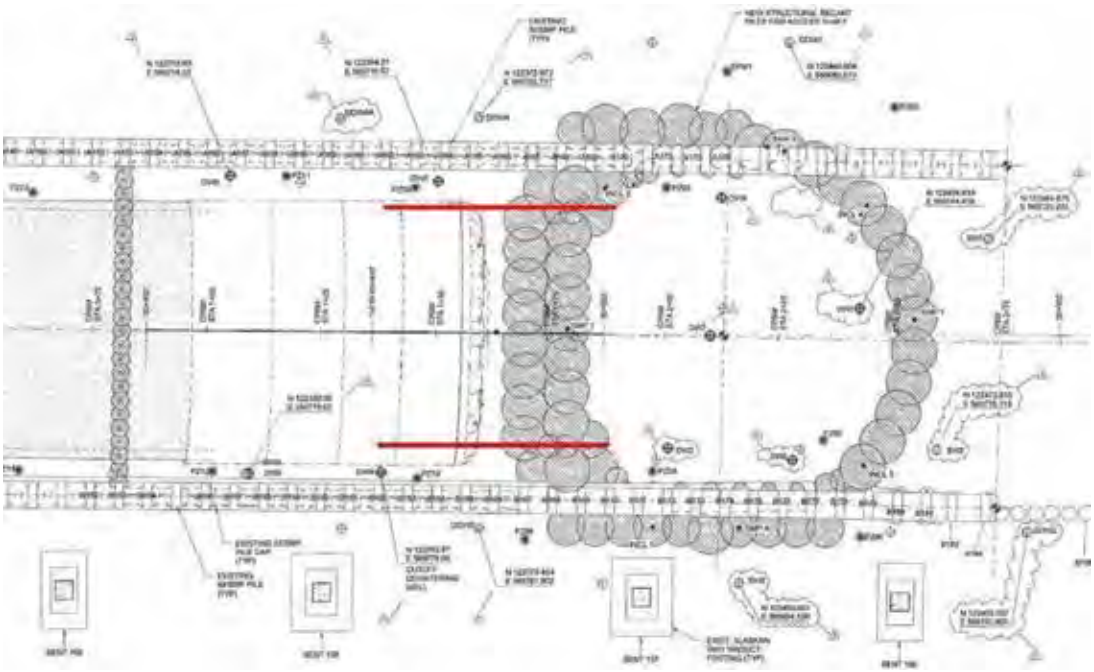


FIG. 6

Access/recovery shaft dewatering – Horizontal drain installation from within shaft.

gradients, which may increase, or decrease with depth; downward gradients typical of upland areas, and upward gradients often observed in water-bearing units close to discharge points. Soil borings near the south portal, with multiple piezometers installed, indicated multiple piezometric surfaces with variations in groundwater levels of up to 3 m (9.84 ft); some indicated artesian pressures of up to 1.5 (4.11 ft) meters above the ground surface (Fig. 3). Tidal influence was also observed to affect the groundwater level within the area of the recovery shaft, with groundwater levels observed as shallow as 1.5 m (4.11 ft) below grade.

Consistent with the known subsurface conditions at this reach of the tunnel alignment, there was an abundance of wood debris within the upper fill zone. Relic deposits of wood, pulp and decayed organic matter would be routinely encountered in vast areas where little to no natural granular soils were detected.

Additional geotechnical investigation within the vicinity of the recovery shaft revealed a deep aquifer with direct communication to, and encompassing, the silt deposit that constitutes a majority of the soil plug within and beneath the proposed access shaft. In addition, the presence of several large voids were confirmed, some that required more than 420 m^3 (459 cuft) of CDF to fill, and some that had been previously filled with large crushed rock by the contractor.

Drilled secant piles

The original design for the TBM launch pit included two parallel rows of drilled shafts, one to the east, and one to the west, of the proposed tunnel alignment. They were designed to prevent lateral soil movement adjacent to the tunnel, and mitigate potential surface settlement; they were referred to as South End Settlement Mitigation Plan (SESMP) piles. Please note, for the purpose of this discussion, the authors will use the terms "drilled shaft" and "pile" interchangeably, to refer to the deep foundation and earth support elements used to construct both the recovery shaft and the original TBM launch pit. To incorporate the existing SESMP piles into the access shaft, smaller 1-m (3.3-ft) diameter drilled shafts were constructed parallel to, and along the interior face of the existing SESMP piles. These drilled shafts help create a continuous outer wall along both the east and west sides of the access shaft, and to provide additional bearing capacity for the cap beams, required for support of the gantry crane. The work was completed with a Bauer BG-50 installing drilled shafts up to 40 m (131 ft) in depth. Once again there was difficulty with maintaining verticality that was specified to be within 152 mm at 40 m (5.9 in. at 131 ft), as checked with a SoniCaliper. The difficulty was a result of the concrete over-break of the existing SESMP piles (drilled shafts) and field adjustments had to be made to accommodate these issues. It was clear that the actual installation of the drilled shafts required to construct the access/recovery shaft was going to be significantly more challenging than designing it. Additionally, far more obstacles than anyone could have imagined during the planning and design phase were encountered. However, having the designer's field representative on-site full-time provided the opportunity to quickly address challenges as they arose, allowing the project to move forward as quickly and efficiently as possible.

After the completion of the drilled shaft work, other equipment was mobilized to begin the large diameter work. Two spreads of equipment and crews began work

in mid-June with Liebherr dig cranes and Leffer oscillators and rotators to start the 2.5 m and 3 m (8.2 ft and 9.11) diameter secant piles included in the final Brierley design (Fig. 2). The work proved to be very difficult due to sequencing and the tight work areas on the job site (Fig. 4). The greatest assets to the project were the two Leffer rotators. These machines proved to be the most efficient at installing the piles on location, maintaining verticality, and with the highest rate of advancement as opposed to just using casing oscillators for advancement. In the end, the shaft work was complete be the end of August 2014, leaving only the remaining grouting and dewatering work to be constructed.

FIG. 7

Success – "Bertha" within the Access/Recovery shaft.

Jet grouting

Jet grouting was an integral part of the overall access/recovery shaft design. Jet grouting was required outside of the recovery shaft to provide a level of groundwater control at the machine "break-in," the location the TBM will bore into the recovery shaft. The SESMP piles, constructed previously, as part of the work for the original launch of the TBM, were located on both the east and west sides of the tunnel alignment, and were enhanced with jet grouting to act as cutoff walls, (Fig. 2). These SESMP piles consisted of 1.5 m (4 ft) outside diameter drilled shafts, installed in two parallel lines, one to the east and one to the west of the proposed tunnel alignment. These drilled shafts were spaced approximately 1.9 m (6.3 ft) center to center, creating a gap of about 0.4 m (1.3 ft), requiring jet grouting to enclose the gap and provide groundwater cutoff. A transverse line of jet grout columns placed in secant fashion tied the two east/west cutoff walls together and encapsulated the TBM cutter head with the recovery shaft that was yet to be constructed.

Jet grouting between the existing SESMP piles would have been extremely difficult, if not impossible, due to the large amount of concrete over-break resulting from the poor soil conditions. Accordingly, each proposed jet grout column was pre-drilled with 152 mm (5.9 in.) tooling, clearing a space for the jet grout monitor and casing to reach the designed depth. Upon completion of jet grouting along the SESMP pile lines, jet grouting efforts continued with construction of a transverse grout curtain, or cutoff wall, behind the TBM tail shield. The purpose of the cutoff wall was to control groundwater during the critical phase of shaft "break-in," as the TBM enters the access/recovery shaft.

SESMP piles were located only on the east and west walls of the access shaft. The soil between them needed to be grouted in order to create a complete and continuous wall to withstand the extreme loads required throughout the various stages of the work. However, continued dewatering, pressurizing of the TBM heading, and work within the tunnel horizon caused soil loss and changes to the subsurface conditions. This was first observed when a 420 m^3 (459 cuft) sinkhole appeared in front of Bertha shortly after she first stopped. This fact was further evidenced by removal of vast quantities of TBM soil conditioner during drilled shaft excavation, at horizontal distances greater than 24 m (78 ft) to the north east of the TBM cutter face. A dynamic environment materially different than the rest of the project site had been created over a very short time. Consequently, during drilled shaft construction sink holes manifested to existing grade, requiring evacuation of all heavy drilling equipment while the safety and stability of the working platform was assessed. After mass excavation and earthwork, a large volume of quarry spalls was imported to the site to create a safe and stable working platform, or mattress, for staging the drilling equipment. Subsequently, during the following drilled secant work, quarry spalls were carried

deeper into the soil profile with each tooling penetration. As a result, the combined presence of a quarry spall mattress at grade along with quarry spalls throughout the vertical soil profile created an environment that was not conducive to jet grouting methods. As an alternative to jet grouting methods Malcolm Drilling Co. mobilized two Foremost DR-24 vertical drill rigs to drill out and flush these confined spaces with high strength cement grout in hopes to treat the areas needed for the shoring design.

Dewatering

Once the grouting work was completed the installation of the remaining dewatering wells commenced in addition to further geotechnical investigations and installation of instrumentation. The geotechnical investigation showed that the silt plug in the bottom of the excavation, previously assumed impermeable and to function as an aquiclude, actually had vertical silty sand seams thereby raising concern that the shaft bottom had potential to heave. This new obstacle was overcome by enhancing the current dewatering design. The current design was limited to eight wells at 47 m (154 ft) in depth. To eliminate this potential bottom heave condition, eight more wells, four at 47 m (154 ft) in depth and four more at 62.5 m (205 ft) in depth, were installed to depressurize the bottom plug for the final state of the excavation.

Prior to advancing the TBM into the access/recovery shaft, Malcolm was asked to install two horizontal drains, from within the access shaft, to relieve hydrostatic pressure behind the secant pile wall. The 15.25-m (50-ft) long drains were installed working from on top of the upper horizontal surface of the concrete cradle that was constructed in the bottom of the shaft to support Bertha upon entry, (Fig. 6). The horizontal drains were comprised of 7.6 m (24.11 ft) of pre-pack PVC well screen, and 7.6 m (24.11 ft) of solid PVC pipe. The pre-pack well screen consists of a 152 mm (5.9 in.) diameter outer and 51 mm (2 in.) diameter inner slotted PVC well screen with filter sand in the annular space. One drain was located on each side of the TBM, at roughly the lower quarter-points of the tunnel, extending parallel with the alignment (Fig. 5). An approximately 305 mm (12 in.) diameter hole was drilled through the secants and a 254 mm (10 in.) diameter pipe with a blow-out preventer (BOP) was installed at each location. The drains were installed within a 203 mm (8 in.) diameter borehole and equipped with a PVC ball valve to control flow.

Once the hydrostatic pressure surrounding the TBM was reduced to Elevation -85 (ft), essentially the elevation at which the horizontal drains were installed, the tunnel crew was given the approval to advance the damaged TBM forward, into the recovery shaft. However, prior to advancing into the recovery shaft, the perimeter of the anticipated penetration through the wall (of the recovery shaft) was pre-split with a long-reach, excavator-mounted hydraulic concrete breaker to minimize the efforts of the TBM.

TABLE 1

Construction summary. MacIcolm Drilling Co. installed the following work to the complete the access shaft.

NO.	
17	1 m (3.28 ft) diameter drilled shafts 40 m (131 ft) deep.
14	1.5 m (4.92 ft) diameter drilled shafts 40 m (131 ft) deep.
16	2.5 m (8.2 ft) diameter drilled shafts 40 m (131 ft) deep.
25	3 m (9.84 ft) diameter drilled shafts 40 m (131 ft) deep.
16	Dewatering wells up to 62.5 m (205 ft) deep
2	Horizontal drains 152 mm (5.9 in.) diameter by 15.25 m (0.6 in.) long
1,951 m (6,400 ft) of jet grout column	

Summary

The work to create this access/recovery shaft was a monumental effort requiring precise coordination from the best in all disciplines and utilization of the most state-of-the-art foundation drilling equipment. There were many obstacles to overcome, as is the case in most emergency jobs, which required problem-solving "on the fly" to accomplish this monumental task within the extremely limited time available.

A broad range of geotechnical construction techniques were required for the construction of the TBM recovery shaft on the SR 99 tunnel. Difficult ground conditions along with a condensed work schedule contributed to the complexity of the work. Moreover, a highly "dynamic" underground environment created by TBM operation and maintenance, site preparation work and maintenance, and dewatering, added unforeseen challenges. State-of-the-art specialty foundation equipment was mobilized, which worked concurrently with Leffer casing rotators and oscillators, and Liebherr duty cycle dig cranes. Other applications included various jet grouting and dewatering scopes completed both at grade and from within the shaft excavation. This work tested the capabilities of existing equipment, pushing them to (and beyond) their previous benchmarks, and in doing so has defined new limits for secant shaft construction.

At the current time, repairs to "Bertha" are complete, she has been reassembled within the recovery shaft, and has advanced a few feet, to allow for evaluation of her recent repairs and ensure no further repairs are required. The present schedule calls for her to re-commence mining operations within the coming days and potentially complete the 2.4 km drive by January 2017. ■

FEATURE ARTICLE

WTC 2016 attracts more than 2,300 professionals from around the world

During WTC 2016, the ITA 73-member Council held its General Assembly.

The International Tunnelling and Underground Space Association (ITA) held its 42nd General Assembly along with the 2016 World Tunnel Congress (WTC) April 22-28 in San Francisco, CA. The event was co-organized by the Underground Construction Association of SME (UCA). This was the first time the event has been held in the United States in 20 years.

As cities demonstrate strong needs in tunnels and underground spaces for public transportation, subway stations, hydroelectric infrastructures and other underground infrastructure needs, the WTC 2016 provided the 2,319 attendees from around the world a unique occasion to discover the latest state-of-the art innovations in urban planning and underground construction projects in the United States and worldwide.

The Congress, held in lieu of the UCA's North American Tunneling Conference, included an exhibit that attracted 226 exhibitors in 298 booths. The exhibit had on display the latest in technical equipment and services from some of the largest and best companies in the international tunneling industry. The exhibit hall was also the place where participants were able to interact with the authors of the 168 posters and receive answers to various topics directly concerning civil engineers: innovative procurement processes, cost and risk management, contractual methods, BIM technologies and examples of innovative underground infrastructures built worldwide. And the technical program included 353 technical presentations – 185 podium and 168 posters.

What is ITA?

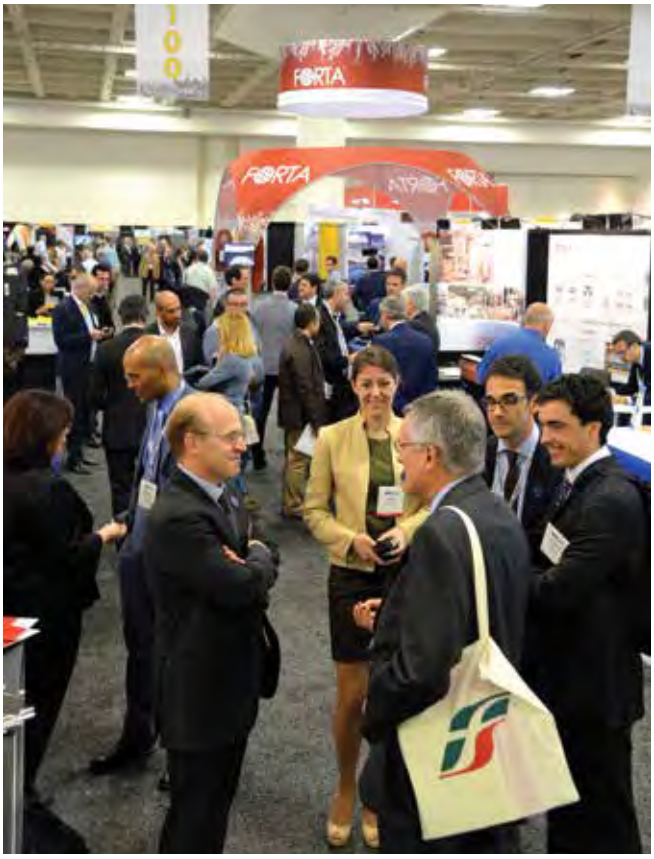
ITA-AITES is a nonprofit, nongovernmental organization that promotes greater use of underground space as a key instrument in sustainable development. Established in 1974 and based in Lausanne, Switzerland, ITA-AITES is made up thousands of professionals involved in the tunnel and underground space industry, including engineers, project owners, town planners, architects, industrial designers, companies specialized in public works and major structures, suppliers of construction site facilities and equipment, lawyers, politicians, researchers and academics, economists, financial experts and other stakeholders.

ITA-AITES consists of 73 member nations and 300 affiliated members, including 15 major sponsors and 60 donors. The association is run by an executive council made up of 15 members elected by the 73 member nations, each representing a different dimension of the tunnel community.

One of

by Steve Kral, Editor

The accompanying exhibit at WTC 2016 included 226 exhibiting companies in 298 booths.



the great strengths of ITA-AITES lies in the synergy created by its 20,000 international experts. These experts from internationally renowned universities and the tunnel industry share their experience at conferences and meetings organized by ITA or its member nations. Researchers share the latest scientific studies with the professionals in the industrial sector of tunnels and underground space. Conversely, industry players keep the researchers abreast of the new cutting-edge technologies in the sector and the fieldwork being carried out.

ITA technical program

This year, participants gathered around several strategic questions raised by countries: How are cities coping with climate change pressures, a few months after the COP21 negotiations in Paris? How could they improve their networks of mobility and, at the same time, develop green and pedestrian areas above ground? What will the urban planning of the future be? What is the future of material freight? In what way can high technologies in tunnels and underground spaces contribute to the development of smart cities? The international tunneling industry has many responses to address these challenges, and the ITA, along with the UCA of SME, offered the attendees a large panel of several high profile technical sessions and poster presentations to address these questions.

Pauli Arenram, chair of the Committee on New Technologies within the ITA, expressed his satisfaction regarding the value of the exchanges "New digital technologies have definitely reached the tunneling industry," he said. "There is a growing need for safer and more reliable systems that communicate, deal with and report large data in an actionable format to the stakeholders from the investigation phase of tunneling projects, during the construction and the tunnel operation phase. These ITA tech sessions were a great opportunity to find precious answers to the questions and challenges of our industry."

One session was dedicated to the recent exploitation of the Internet of Things (IoT) by the tunneling industry. A representative of SIGMA Connectivity offered an interesting perspective of the future IoT developments. He pointed out that two strategic shifts would greatly influence the tunneling industry: the connection of digital technologies with industrial products and logistics and the development of easy-to-use IoT enablers that will drive higher volumes of data and considerably reduce the costs of this revolutionary technology.

Another session was held by the ITA Committee for Underground Space (ITACUS). The discussions focused on the international urban agenda, in which the United Nations (U.N.), through their Habitat Program, takes a part. As other U.N .consultative members involved in urban development, the ITACUS, through the World Urban Campaign, is in charge of proposing new solutions to imagine sustainable cities. Through this open session, the ITACUS developed new insights about the role that underground freight networks could take. The Hyperloop technologies were also discussed, as well as CargoCheck Systems, in order to help stakeholders in port areas become aware of the relevance of urban underground freight systems. "During the session, we also heard a presentation on the possibilities of mixed-use tunnels and the implications this could have," Han Admiraal, chair of ITACUS, said.

Rather than building a tunnel for just one use, the future could bring urban network providers underground spaces to be used by multiple parties. Urban system integrators would bring these parties together to ensure that the underground space is used in an efficient way. In the future, metro systems will not only move people, they will also be able to move cargo and to carry cables that are essential to modern societies. Furthermore, they could be producing energy for the city beneath which they operate, he said.

UCA of SME technical program

In addition to the ITA technical programming, the UCA also provided WTC attendees its own program. Proceedings from the UCA program are available from UCA of SME, www.smenet.org. Here is a sampling.

Performance of macro synthetic fiber-reinforced tunnel lining. Macro synthetic fiber-reinforced concrete or shotcrete is seen by many design engineers as offering a viable alternative to steel reinforcement in tunnel linings. The technology is now commonplace for primary and permanent ground support in mining and civil tunnel applications. The use of macro synthetic fiber offers innovate solutions, yielding robust and sustainable tunnel lining designs.

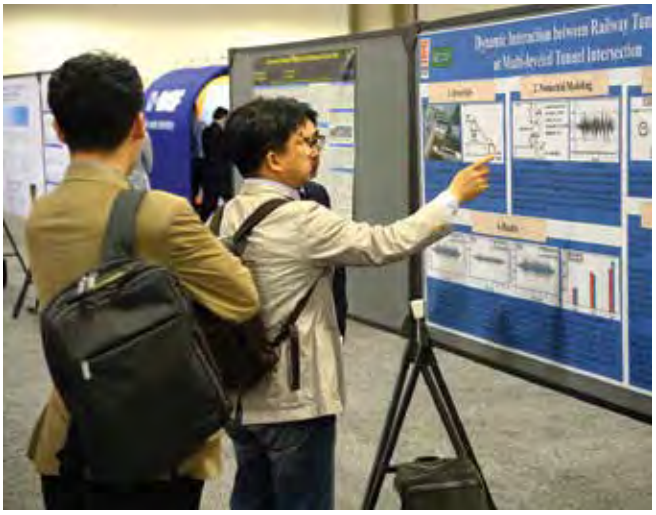
Detailed fire safety design of subways for arson – initiated design fires – innovation, coordination and implementation. To protect public safety in the event of a deliberate fire attack, underground rail authorities are increasingly considering the need to design for arson-initiated fire scenarios. Where typical design for fires for modern rolling stock means a peak fire size is reached after 12 minutes, an arson-initiated fir reaches its peak in two to three minutes. The authors presented the innovations required to successfully incorporate this requirement on a recent design-build project.

The Norsborg metro depot – Case study of a modern urban development in Stockholm. Construction of large facilities underground in urban areas has many advantages. The Norsborg metro depot will be the largest and most modern underground metro depot in northern Europe. This depot has been built in hard rock in an urban area with small impact on the environment and residents. This paper describes how it is possible to build underground facilities in a cost-efficient way and take care of the challenges that come with locating a permanent working place underground.

Squeezing ground: Conditions and lessons learned at the New Irvington Tunnel. Excavation and initial support of the New Irvington Tunnel presented significant challenges including rapidly changing ground conditions, heavy ground loads and squeezing. Such behaviors were anticipated from historic tunneling records of the adjacent existing Irvington Tunnel. Extensive site investigation provided a clearer understanding of their actual extent and causes and has resulted from convergence measurements, observations of ground behavior, initial support monitoring and detailed geologic mapping. Time-dependent movements, documented hours to months after excavation in clay-rich rock and moderately to intensely fractured rock identified squeezing areas, allowed classification by currently used predictive methods and added to the list of lessons learned in tunneling in such ground.

An advanced shaft construction method to install 10 ventilation shafts, as applied in the Naples metro project. This paper deals with an innovative mechanized method to bore and simultaneously line circular shafts, adopted in the Naples metro project for the installation of 10 vertical shafts for ventilation purposes. With this method, the excavation of shafts is carried out under a positive head of stabilizing fluid by a milling machine, temporarily set at the bottom of a permanent lining made of precast segment rings.

There were plenty of social activities at WTC 2016 (top), and attendees were able to listen to poster sessions in the exhibit hall (bottom).



A case history: Convergence in a shear zone at Devil's Slide. During the excavation of the northbound tunnel of the Devil's Slide Tunnel project, deformation (convergence) was measured after passing through fault zone B. The tunnel convergence was not symmetrical, but was larger on the left side of the profile. It was determined that a shear zone nearly parallel with the tunnel drive was contributing to the uneven deformation. This paper discusses how it was determined that the shear zone existed and how multipoint borehole extensometers were used to verify that a significant amount of the deformation was occurring due to movement along the shear zone as the excavation advanced. The paper also considers the methods that were used to ultimately control and stabilize the deformation. ■

Coming Events

Tunneling Fundamentals, Practice and Innovations
June 20-23. 2016
The Colorado School of Mines, Golden, CO
website: csmspace.com/events/tunneling

Cutting Edge: Advances in Tunneling Technology
Nov. 6-9, 2016
The Concourse Hotel at Los Angeles Airport, Los Angeles, CA, USA
website: smenet.org/full-calendar

2017 George A. Fox Conference
Jan. 24, 2017
Graduate Center City University of New York
365 Fifth Ave. New York, NY, USA
website: smenet.org/full-calendar

2017 RETC
June 4-7, 2017
Hyatt Grand Manchester, San Diego, CA
1 Market Place, San Diego, CA 92101
website: smenet.org/full-calendar

For additional information contact: Meetings Department, SME, phone 800-763-3132, 303-948-4200, fax 303-979-4361, email sme@smenet.org, http://www.smenet.org/full-calendar

UCA awards WTC scholarships

The mission of UCA of SME is to promote the responsible development and use of underground space and facilities, and to provide critical industry and technical knowledge, educational and professional development opportunities for practitioners around the world.

During the WTC 2016 conference, the UCA of SME Young Members Committee presented 47 scholarships totaling $70,000 in cash and benefits to promising college students who desire to develop their skills and are seeking a career in the underground construction and tunneling industry. Scholarships included full registration to the WTC 2016 conference, attendance at the welcoming reception and special networking events, plus a one-year student membership to the UCA of SME.

Attendance Scholarships were presented to 43 recipients who received travel assistance to the conference in addition to their registration and membership fees. Travel assistance included airfare, lodging, transportation and meals up to $1,000.

Thank you note

Juan Jose Monsalve, Universidad Nacional de Colombia – Medellin, expressed his thanks for his attendance scholarship in a letter to SME.

"I have learned in my life that you have to take advantage of each opportunity you have. I have also learned that you have to thank all people that help you, in one way or another to make your dreams reality. That's the reason why I would like to thank SME and the UCA of the SME through the UCA Young Members group for the opportunity they gave me to attend the World Tunnel Congress in San Francisco. This has been one of my best life experiences, since it gave me the opportunity to be involved with an industry for which I am really passionate. I would also like to acknowledge Mona Vandervoort (SME staff); she is such a lovely person and a great friend of mine."

Conference scholarships

Additionally, four Conference Scholarships of $5,000 each were presented to Michael Kennedy, University of California, Berkeley, Yuanli Wu, Colorado School of Mines, Maxwell Engen, Colorado School of Mines and Adam Reinbold, Colorado School of Mines.


WU

YUANLI WU is pursuing a Ph.D. at the Colorado School of Mines (CSM) in the Department of Civil and Environmental Engineering. She is the president for the UCA of SME Student Chapter at CSM. Her Ph.D. research focuses on soil conditioning in earth pressure balance-tunnel boring machine tunneling, especially the experimental investigation of the soil-foam interaction behavior under pressure. She received her bachelor's and master's degrees from the China University of Geosciences.

MAX ENGEN received a bachelor's degree in civil engineering from the University of Minnesota-Duluth and is pursuing a master's degree in underground construction and tunneling from the Colorado School of Mines. While finishing his degree, Engen is employed as a field engineer with J.F. Shea Construction working for the Shea-Kiewit joint venture on the Indianapolis Deep Rock tunnel system in Indianapolis, IN.


ENGEN

ADAM REINBOLD had more than six years of industry experience in heavy civil construction and geotechnical consulting before he enrolled in the Colorado School of Mines' Underground Construction & Tunneling program. His passion for tunneling, particularly urban tunneling, was piqued by attending tunneling


REINBOLD

Juan Jose Monsalve helped out in the book store during the WTC.

WORLD TUNNEL CONGRESS

short courses at the Colorado School of Mines and the UCA of SME Cutting Edge Conference in Denver, CO. Reinbold is a licensed P.E. in Utah and Texas. He began full-time employment with Traylor Bros. in its Long Beach, CA office in May 2016 and will complete his master's degree in Underground Construction & Tunneling in December 2016. His goal is to continue to develop his technical knowledge base as a tunnel engineer with special interest in large subway/metro rail or water/wastewater projects. Eventually he desires to expand into project management and/or business development roles.

MICHAEL H. KENNEDY is a graduate student in civil/geotechnical engineering at the University of California, Berkeley. He received a B.S. in civil engineering, summa cum laude, from California Polytechnic State University. Kennedy


KENNEDY

has worked as an intern and field technician for Construction Testing and Engineering in Sacramento, CA and for Schlumpberger Consulting Engineers in Mount Shasta, CA. He is a member of the Engineers Without Borders Malawi Team and the Society of Civil Engi-

PERSONAL NEWS


WU

LUCY WU, PE, has joined HNTB Corp. as senior tunnel and geotechnical engineer based in the firm's Oakland, CA office. In her new position, she is working as a geotechnical project engineer for the California High-Speed Rail project from San Francisco to San Jose and Merced. She has previously worked on the Transbay Transit Center and the BART Warm Springs Extension. Wu will also be involved in preliminary engineering and design preparation of the tunnels through the Pacheco Pass.

JACOB SWANSON has joined Avanti International as its Midwest regional mangager. Swanson has more than 10 years of experience in injection grouting for BDA & Associates and Structural Group — including


SWANSON

Structural Specialty Contracting and Pullman. As an expert injection specialist of acrylics, polyurethane and cementitious grouts, his past responsibilities have included the positions of crew chief, project manager, and liaison for engineers and owners. ■

NEW MEDIA

World Tunnel Congress 2016 proceedings

2016, USB thumb drive available from SME, 12999 E. Adam Aircraft Cir., Englewood, CO 80112, USA, www.smenet.org/store, email books@smenet.org, phone 303-948-4225, 800-763-3132, , ISBN: 978-0-87335-424-0, 312 papers, $159; SME member $129, student member $99.

Written by international experts in their field, the *World Tunnel Congress 2016 Proceedings* is a collection of technical and academic papers presented at the World Tunnel Congress April 22-28, 2016 in San Francisco, CA, USA. The collection of papers addresses all relevant tunneling topics, including:

- Safety in design and construction.
- SEM and caverns.
- Underground support — controlling the ground.
- Tunneling advances through innovation.
- Case histories and difficult ground.
- Instrumentation and monitoring.
- Complex projects in rock and related technology.
- Tunnel interactions with ground and structures.
- Soft ground — TBMs and microtunneling.
- Planning, finance, and site investigations.
- Risk management and contracting practices.
- Ground improvement and shafts and more. ■

NEW PRODUCTS

ABC Industries celebrates 90 years

ABC Industries, a leading manufacturer of industrial ventilation and fabric products, is celebrating its 90th anniversary in 2016. What began with a single product has transformed into a robust line of industrial ventilation products and high-quality industrial textile fabrics.

Demanding mine and tunnel ventilation applications require high-quality, reliable ducting that performs in extreme underground conditions. MineDuct wire-reinforced ducting is made of premium PVC fabric for positive and negative pressure applications. Durable sewn construction and heavy-duty wear strips allow MineDuct to withstand continuous use in the harshest environments. ABC's RipStop substrate technology makes maintenance quick and easy by preventing tears from expanding.

MineVent's collapsible, lay-flat blower ducting (positive pressure) features 100 percent welded construction that eliminates air loss and weakening associated with conventional sewn ducting. Standard and custom-end finishes provide numerous installation possibilities. MineVent with RipStop prevents small tears from expanding into gaping holes.

ABC also offers a variety of made-to-order curtains and temporary stoppings for mine and tunnel applications using brattice fabrics.

www.abc-industries.net

MineDuct — wire reinforced.

Brattice fabric blast curtain.

MineVent — inflated.

Sandvik DT912D offers intelligent efficiency to underground excavation

Sandvik Construction is introducing a new tunneling jumbo — the DT912D. Designed especially for limestone applications, the high-reach, single-boom jumbo is completely self-contained.

It is powered with a fuel-efficient and environmentally friendly Cummins Tier 4 final diesel engine and equipped with onboard compressor and 1,000-L (265-gal) water tank for air-mist flushing. The new, intelligent, state-of-the-art control system brings high quality and increased productivity to both tunneling and underground mine production.

The DT912D is designed for fast and accurate drifting and production drilling of 12 to 125 m² (130 to 1,345 sq ft) cross sections and features a 25-kW (33.5-hp), high-frequency RD525 rock drill. The DT912D offers rapid, safe and balanced tramming thanks to its powerful, 4-wheel-drive center-articulated carrier. ■

http://construction.sandvik.com

In addition to face drilling, the versatile boom can be used for crosscutting, bolt-hole drilling and extension drilling.

COMPILED BY JONATHAN KLUG, DAVID R. KLUG & ASSOCIATES

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Gateway Tunnel	Amtrak	Newark	NJ	Subway	14,600	24.5	2018	Under study
2nd Ave. Phase 2-4	NYC-MTA	New York	NY	Subway	105,600	20	2017-22	Under study
Water Tunnel #3 bypass tunnel	NYC-DEP	New York	NY	Water	20,000	22	2015	Kiewit - Shea JV awarded
Water Tunnel #3 Stage 3 Kensico	NYC-DEP	New York	NY	Water	84,000	20	2017	Under study
Cross Harbor Freight Tunnel	NYC Reg. Develop. Authority	New York	NY	Highway	25,000	30	2018	Under study
South Conveyance Tunnel	City of Hartford	Hartford	CT	CSO	16,000	26	2016	Kenny/Obayashi low bid
Amtrak B& P Tunnel	Amtrak	Baltimore	MD	Rail	10,000	30	2018	Under design
Purple Line - Plymouth Tunnel	MD Transit Administration	Baltimore	MD	Subway	1,000	30x40	2016	P.L. Transit Const. low bid
Thimble Shoal Parallel Tunnel	Chesapeake Bay Bridge and Tunnel Dist.	Chesapeake	VA	Highway	5,700	45	2016	Bouygues/ Trylor/Mason low bidder
Northeast Boundary Tunnel	DC Water and Sewer Authority	Washington	DC	CSO	17,500	23	2017	Prequal underway
US Highway 17 drainage tunnel	City of Charleston	Charleston	SC	CSO	8,420	12	2016	Jay Dee Contractors low bidder
Bellwood Tunnel Phase 2	City of Atlanta	Atlanta	GA	Water	21,000	12	2016	Under design
Olentangy Relief Sewer Tunnel	City of Columbus	Columbus	OH	Sewer	58,000	14	2016	Under design
Blacklick Creek San. Interceptor Tunnel	City of Columbus	Columbus	OH	Sewer	24,000	10	2015	Michels/Jay Dee low bid
Alum Creek Relief Tunnel Phase 1 Phase 2	City of Columbus	Columbus	OH	Sewer	 30,000 21,000	 18 14	 2016 2017	 Under design Under design
Doan Valley Storage Tunnel	NEORSD	Cleveland	OH	CSO	9,700	17	2017	Under design
Westerly Main Storage Tunnel	NEORSD	Cleveland	OH	CSO	12,300	24	2020	Under design
Shoreline Storage Tunnel	NEORSD	Cleveland	OH	CSO	16,100	21	2021	Under design
Southerly Storage Tunnel	NEORSD	Cleveland	OH	CSO	17,600	23	2024	Under design
ALCOSAN Ohio River Tunnel Allegheny River Tunnel Monongahela Tunnel	Allegheny Co. Sanitary Authority	Pittsburgh	PA	CSO	 10,000 41,700 53,900	 14 14 14	 2019 2020 2021	 Under design Under design Under design
Lower Pogues Run	Indianapolis DPW	Indianapolis	IN	CSO	9,000	18	2016	Shea/Kiewit award pending
White River Tunnel	Indianapolis DPW	Indianapolis	IN	CSO	28,000	18	2016	Shea/Kiewit award pending
Three Rivers Protection/Overflow	City of Fort Wayne	Fort Wayne	IN	CSO	26,400	12	2016	Prequals underway

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
St. Louis CSO Expan.	St. Louis MSD	St. Louis	MO	CSO	47,500	30	2016+	Under design
KCMO Overflow Control Program	City of Kansas City, MO	Kansas City	MO	CSO	62,000	14	2016	Under design
Mill Creek Peaks Branch Tunnel	City of Dallas	Dallas	TX	CSO	5,500	26	2014	Odebrecht low bid
Bellevue Tunnel - E330	Sound Transit	Seattle	WA	Transit	2,000	40x30	2015	Atkinson awarded
Ballard to Wallingford	Seattle Public Utilites	Seattle	WA	CSO	14,250	14	2018	Under design
L.A. Metro Regional Connector	Los Angeles MTA	Los Angeles	CA	Subway	20,000	20	2014	Skanska-Traylor JV Awarded
L.A. Metro Westside Extension Phase 1 Phase 2 Phase 3	Los Angeles MTA	Los Angeles	CA	Subway	 42,000 26,500 26,500	 20 20 20	 2014 2016 2017	Skanska/Traylor, Shea awarded Bid date 06/01/16 Under design
Speulvada Pass Corridor	Los Angeles MTA	Los Angeles	CA	High/Trans.	55,500	60	2017	Under study
Northeast Interceptor Sewer 2A	LA Dept. of Water and Power	Los Angeles	CA	Sewer	18,500	18	2018	RFQ under way
River Supply Conduit - Unit 7	LA Dept. of Water and Power	Los Angeles	CA	Water	13,500	18	2017	Under design
JWPCP Effluent Outfall Tunnel project	Sanitation Districts of LA	Los Angeles	CA	Sewer	37,000	18	2017	Under design
Freeway 710 Tunnel	CALTRANS	Long Beach	CA	Highway	26,400	38	2018	Under design
BDCP Tunnel #1 BDCP Tunnel # 2	Bay Delta Conservation Plan	Sacramento	CA	Water	26,000 369,600	29 35	2018 2019	Under design Under design
SVRT BART	Santa Clara Valley Trans Authority	San Jose	CA	Subway	22,700	20	2017	Redesign activated
Silicon Valley Clean Water Tunnel	Silicon Valley Clean Water	Silicon Valley	CA	CSO	17,500	13	2017	Under design
Coxwell Bypass Tunnel program	City of Toronto	Toronto	ON	CSO	35,000	12	2017	Advertise 3Q 2017
Keswick Effluent Outfall Tunnel	City of Toronto	Toronto	ON	CSO	11,600	23	2018	Under design
Yonge St. Extension	Toronto Transit Commission	Toronto	ON	Subway	15,000	18	2019	Under study
Scarborough Rapid Transit Extension	Toronto Transit Commission	Toronto	ON	Subway	25,000	18	2018	Under design/ delayed
Taylor Massey Tunnel	City of Toronto	Toronto	ON	CSO	20,000	15	2019	Under design
Inner Harbour West Tunnel	City of Toronto	Toronto	ON	CSO	18,400	19	2021	Under design
CSS - East-West	City of Ottawa	Ottawa	ON	CSO	14,400	10	2016	Dragado/R.W. Tomlinson low bid
Second Narrows Tunnel	City of Vancouver	Vancouver	BC	CSO	3,600	14	2013	Under design
UBC Line project	Trans Link	Vancouver	BC	Subway	12,000	18	2015	Under design
Annacis Island Outfall	City of Vancouver	Vancouver	BC	Water	8,000	10	2017	Under design
Northern Gateway Clore Tunnel Hoult Tunnel	Enbridge Northern	Kitimat	BC	 Oil Oil	 23,000 23,000	 20 20	 2014 2014	 Under design Under design

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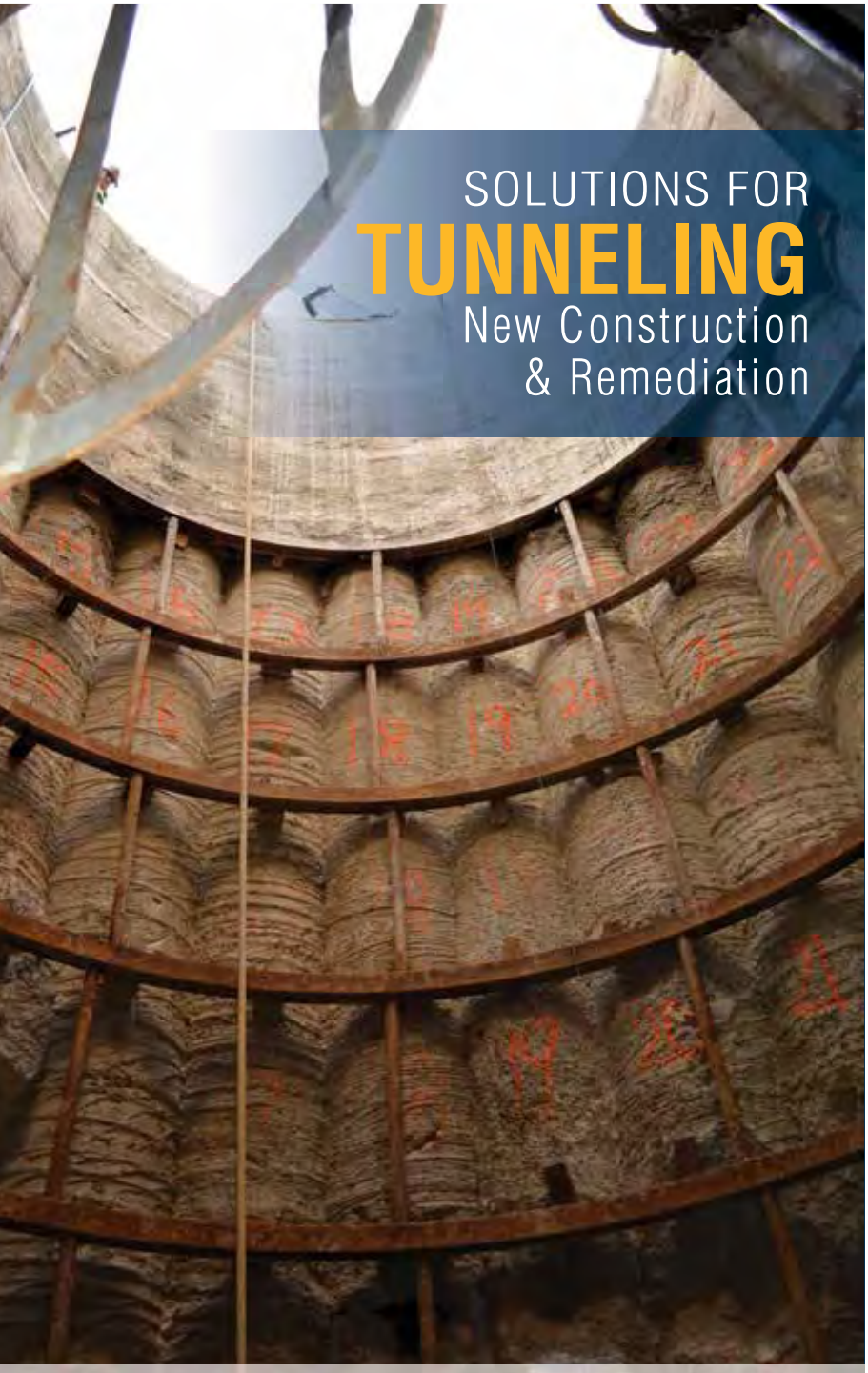

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