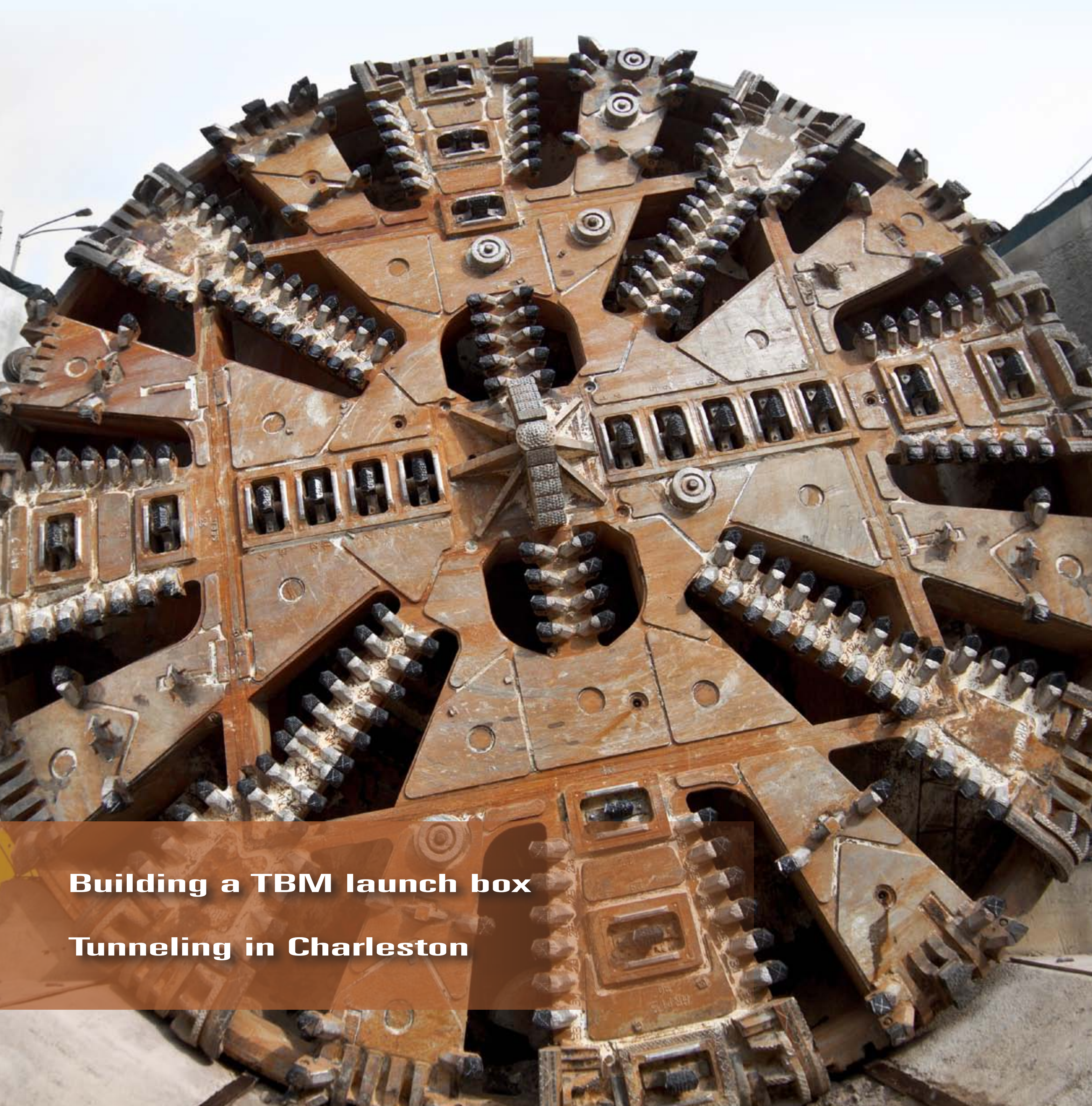
T&UC

TUNNELING & UNDERGROUND CONSTRUCTION

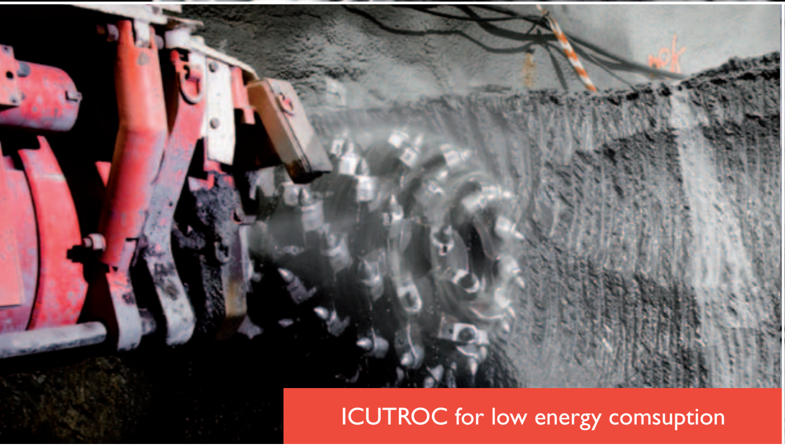
THE OFFICIAL PUBLICATION OF UCA OF SME | WWW.TUCMAGAZINE.COM | VOLUME 7 NO 1 MARCH 2013



Building a TBM launch box

Tunneling in Charleston

Special Editorial Section from the publisher of *Mining Engineering*



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COVER STORY

IN THIS ISSUE — The proposed Second Street Avenue Subway will be a new two-track subway line running from 125th Street and Park Avenue. Geologic conditions and existing buildings made building a TBM launch box challenging, page 50. Charleston, SC is one of the first cities to build separate sanitary and storm water drainage infrastructure. Replacing it requires innovative thinking, page 56.

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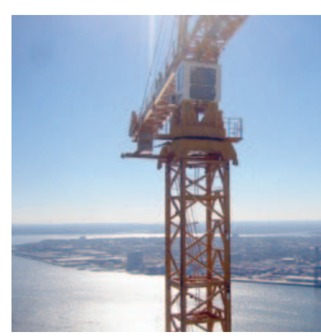

DEPARTMENTS

CHAIRMAN'S COLUMN

Spring is in the air, and it's time to prepare for industry conferences

By the time this issue of *T&UC* goes to press, most of us should be seeing some signs of spring, which means another busy season is getting under way in our industry.

Spring and summer are also known for our industry's annual conferences. These conferences provide a great opportunity for those in the underground construction and tunneling industry to catch up with many friends and business partners, and also learn about the latest progress and technology that is available to help in all aspects of our business. And, no matter what your interest or expertise, these conferences can help share the best knowledge with all of the growth and change in our industry.

Many of you had the chance to enjoy another very successful George A. Fox Conference in New York City in January. I also hope that many of you had the chance to attend the SME Annual Meeting in Denver, CO in February and stop in for some of the great presentations during the UCA sessions.

If you missed the Fox Conference, you may not have heard about the short video presentation that the UCA has put together to help introduce people to a career in the underground industry.

I encourage you to check it out at http://uca.smenet.org/Jobs/ and use it to help spread the word of the need to recruit quality people in all aspects of our business.

This year, I am especially looking forward to the World Tunneling Conference (WTC). The conference will be held May 31 through June 7 in Geneva, Switzerland. This is the year that the UCA will compete for selection and the honor to host the WTC in 2016 in San Francisco, CA. If successful, we will combine the North American Tunneling conference with the WTC for what will be a premier industry event in one of the best cities in the world. Please do everything you can to help bring this prestigious event back to our country.

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2013 is also the rotation year for bauma, the premier world equipment expo held in Germany. It is a little late to be starting your plans to attend this huge exposition, held in April. However, if you have not ever been there, I recommend it, as a single place to be educated about everything related to the latest equipment technology. Every supplier is in one place, and there are many demonstrations that result in hands-on experiences.

And, if that is not enough opportunity for you to catch up on the latest, we have the biennial Rapid Excavation and Tunneling Conference (RETC) June 23-26 in Washington D.C. This conference promises to be another excellent gathering of vendors and technical presentations that cover many of the past years' challenges and accomplishments and also looks into our future opportunities.

If you have not already signed up to attend RETC, you can now by going to http://www.retc.org/ to get all of the latest information.

Jeffrey Petersen,
UCA of SME Chairman

Florida reaches agreement with Port of Miami tunnel firm over unanticipated work

The Florida Department of Transportation (FDOT) will pay multinational company Miami Access Tunnel (MAT) $58.5 million for extra work the company has performed on the $1 billion Port of Miami Tunnel.

The two sides settled a dispute over how much the state must pay the firm for unanticipated work, which included the reinforcement of the porous limestone subsoil with grout so the tunnel boring operation would be more stable.

The amount is less than MAT had sought: $67.5 million. The money will come from the project's contingency reserve fund.

The settlement closes a chapter on an issue that marred the early stages of the project in July 2011. Details of the settlement were contained in a lengthy Jan. 14 memo from FDOT Miami District 6 secretary Gus Pego to Miami-Dade Mayor Carlos Gimenez, *ElNuevo Herald.com* reported.

As workers prepared to start boring the tunnel from the MacArthur Causeway to the port, MAT asked FDOT and its partners — Miami-Dade County and the city of Miami — to provide additional money from a contingency fund to cover expenses linked to the extra grouting.

On July 19, 2011, 13 days after MAT requested the money, FDOT rejected the request on the grounds that its assessment of subsoil conditions was incorrect.

MAT insisted that geological conditions that its experts found in the bay were different from what FDOT had previously found.

"A preliminary review of the notices by FDOT experts indicates that a changed geological condition does not exist and therefore the concessionaire is not entitled to accessing the reserve [fund]," FDOT said on July 19, 2011.

Company executives took the matter to a mediation panel set up under the project's agreement. MAT insisted that the limestone its experts found under Biscayne Bay was extremely porous, and that the many gaps in the rock needed to be filled with grout. They also said this meant the $45-million tunnel boring machine (TBM) had to be modified. MAT also requested an additional $27 million to cover costs of modifying the TBM, a request FDOT rejected as well.

The Technical Disputes Resolution Board ruled in favor of MAT on the grouting issue and in favor of FDOT on costs to modify the TBM.

The board ruled that the modifications to the TBM were not "compensable" but that the grouting costs were because they were "necessary."

After the ruling, MAT and FDOT negotiated the settlement down to $58.5 million. At one point, Pego's memo said, MAT indicated that the amount could go as high as $149 million, and that the project could sustain a three-month delay.

Under the settlement, Pego wrote, no delays are foreseen.

Pego assured Gimenez that the dispute and settlement did not delay the work. "The project schedule remains on track for opening to traffic in May 2014," Pego said. ■

New York City plans $1 billion tunnel to fix leaks in aqueducts

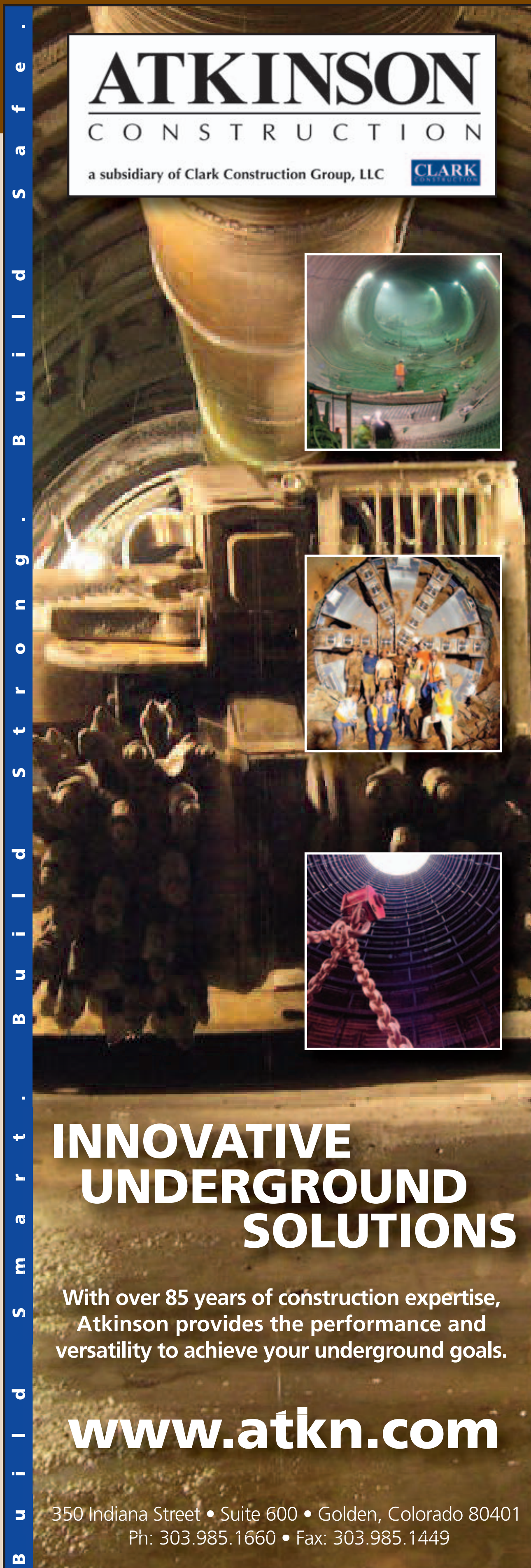
The Environmental Department (DEP) of New York City said it will begin building a 5-km (3-mile) tunnel in the Hudson Valley to fix leaks in one of the city's aqueducts. The cost of the fix is roughly $1 billion, the *Examiner.com* reported.

A portion of the aqueduct leaks between 56.7 and 132 ML/d (15 and 35 million gal/day) of water of the more than 1.9 GL (500 million gallons) that passes through it daily, said DEP. The department has been monitoring the leaks since the 1990s. Years of study, it says, show that cracking and leaks occur in a section of the tunnel that passes through limestone.

"Repairing the leaks in the Roundout-West Branch Tunnel remains DEP's top priority for construction in our water supply system," said Carter Strickland, commissioner of the Department of Environmental Protection.

The Roundout-West Branch Tunnel is a section of the Delaware Aqueduct, which is 136-km- (85-miles-) long, draws from four reservoirs and provides 50 to 80 percent of the city's daily water demand, according to Riverkeeper and DEP. It also serves about a million residents of Orange, Putnam, Ulster and Westchester counties in lower New York.

The bypass tunnel, to be built so construction can be done on the aqueduct, will cross under the Hudson River from the town of Newburgh in Orange County to the town of Wappinger in Dutchess County, the DEP says. The shafts for the bypass tunnel will be 274 and 213 m (900 and 700 ft) deep in Newburgh and Wappinger respectively. ■



Fifth TBM begins work at Crossrails project

The fifth tunnel boring machine (TBM) to be used on Britain's Crossrail project began tunneling under the River Thames from the project's Plumstead portal in January.

The TBM, named Sophia, will drill at an average rate of around 100 m/w (300 ft/week), installing precast concrete segments as rings to form the tunnel lining as it goes.

Unlike the TBMs currently in operation, Sophia is specially equipped to handle the chalk, flint and wet ground conditions in southeast London.

As part of the tunneling process, the excavated soils will be pumped out as liquid slurry to a special treatment plant at Plumstead. The slurry will be separated into sand, gravel, water and chalk. The chalk will come out in 'cakes' or slabs of filtered chalk particles.

"The launch of Sophia, Crossrail's fifth tunneling machine, demonstrates the great progress the project is making, stimulating the economy, generating thousands of jobs during construction and delivering huge transport improvements to people living in southeast London," said Stephen Hammond, Crossrail Minister.

In other news from the Crossrail project, work on a new station at Custom House also began in January.

The Crossrail station, which will be built on the site of the former North London Line station, will include a new ticket hall and an interchange with the Docklands Light Railway (DLR).

The new station will be largely manufactured off site at a state-of-the-art Laing O'Rourke facility near Sheffield.

The sections will then be transported to Custom House and re-assembled to reduce disruption to DLR services.

Jeff Clegg, Crossrail area director East said: "When Crossrail opens, up to 12 trains an hour will link Custom House with central London and beyond, improving access between the Royal Docks and London's key employment areas as well as supporting wider regeneration."

The new line will also reduce journey times for many of the four million annual visitors to the nearby ExCeL London.

Across the whole Crossrail project, eight tunneling machines will construct 21 km (13 miles) of twin tunnels under London. The Crossrail route will pass through 37 stations and run 118 km (73 miles) from Maidenhead and Heathrow in the west, to Shenfield and Abbey Wood in the east. ■

Herrenknecht receives 18 orders from India

About a third of India's population lives in large urban areas and the number is growing. More than 30 cities in India have more than a million residents and, at the same time, India is one of the world's largest economies. Today, and in the future, there is correspondingly high demand for improved infrastructure in the areas of transportation and supply.

In recent months, Herrenknecht has received a total of 18 orders from India for tunnel boring machines (TBM) in the large diameter range. Almost without exception, these are for projects for the expansion of metro networks in the Indian cities of Delhi, Bangalore, Chennai and Kolkata. The earth pressure balance (EPB) shields (6,350 mm – 6,600 mm or 20.8 ft - 21.6 ft) are being used to create a total of 71 km (44 miles) of tunnels for efficient mass transit systems.

In March 2012, the Italian-Thai Development Public Co. Ltd. began tunneling with the first two of four Herrenknecht machines for the metro in Kolkata. In May and July, the first intermediate openings took place. In Delhi, two TBMs began work on behalf of Pratibha Industries Ltd. in March and April. On July 26, one of the two TBMs completed its first intermediate breakthrough.

In previous projects, Indian tunnel builders have already successfully drilled about 30 km (18.8 miles) of metro tunnels in Delhi and New Delhi using Herrenknecht technology. In Chennai, a total of eight TBMs are currently being prepared for the excavation of more than 38 km (23.6 miles) of tunnels for new metro lines.

Record rates of advance in the Veligonda project

The distribution of clean drinking water is also a major issue in Indian infrastructure expansion. In some cases, large distances need to be covered. In the eastern area of the state of Andhra Pradesh (Southeast India), there is a major shortage of water due to low rainfall. There are plans to remedy this by piping water from the Srisailam Dam on the River Krishna over a distance of about 100 km (62 miles). Part of the construction project is the Veligonda tunnel with a length of 18 km (11.2 miles), which is being built by the Nuzivveedu Swathi Coastal Consortium. Here, a double shield TBM (7,900 mm or 26 ft) from Herrenknecht is in use. From October 2008 to June 2012, it completed more than 7 km (4.3 miles) of the underground water pipeline. In February 2012, the best rates of advance ever known in Indian tunnel building were achieved: 525 m (1,722 ft) of drilled and secured tunnel in 29 days.

On the other side of the subcontinent, in the 13 million metropolis of Mumbai on the west coast, the existing water supply network is being elaborately renewed and expanded. A total of three hard rock specialists from Herrenknecht (gripper TBMs, 2,800 mm – 6,230 mm or 9.2 ft - 20.4 ft) drilled or are drilling more than 16 km (10 miles) of drinking water tunnels for the largest city in India. ■

Robbins main beam TBM to be used again

On Nov. 27, 2012, a 6.2-m (20.2-ft) diameter Robbins hard rock cutterhead arrived in Indianapolis, IN. The arrival at the staging site was timed with a ceremony that included the city's mayor and local officials, marking the assembly progress of the large main beam tunnel boring machine (TBM).

Once launched from a 76-m- (250-ft-) deep shaft, the machine will embark on a 12.2-km- (7.5-mile-) long wastewater tunnel for the Shea/Kiewit joint venture.

The contractor-owned Robbins machine was refurbished and redesigned in Cleveland, OH and Mt. Pleasant, PA facilities following its most recent excavation at New York City's Second Avenue Subway.

Its latest rebuild was complex, according to Dave Girard, senior engineer for J.F. Shea Construction. "We retrofitted a machine built in 1976 with the latest technology — in particular, variable frequency drive motors." Other new components include the back-loading cutterhead with 48 cm (19-in.) disc cutters and rescue chamber.

Despite the complexities of the redesign, the machine is scheduled to be launched from a deep shaft in early 2013, proceeding toward the Belmont wastewater treatment plant in what is expected to be competent limestone and dolomite rock. Robbins continuous conveyors, including a horizontal and vertical conveyor, will aid in muck removal on the long drive.

Once complete, the tunnel will be lined with unreinforced concrete, making the finished diameter 5.5 m (18 ft). Cleaner water is the ultimate goal of the city's new Deep Rock Tunnel Connector (DRTC), along with four shorter tunnels that will be added on afterwards. The DRTC will convey up to 2.1 million m^3 (550 million gal) of combined sewer overflows daily to the Southport advanced water treatment plant.

A Robbins main beam TBM is preparing to excavate the Indianapolis DRT for JV contractor Shea/Kiewit.

By 2025, the network of five tunnels will total more than 40 km (25 miles), and will reduce wastewater overflow into the White River, Fall Creek, Pogues Run and Pleasant Run waterways by 95 percent or more. ■

California project pitched to farmers

California Gov. Jerry Brown took his plans for a $14-billion tunnel project that would reshape the state's water delivery system from the Sacramento-San Joaquin Delta to Southern California to one of the largest agricultural shows on the West Coast.

Brown addressed hundreds of farmers where he promised a crowd of about 500 at the Colusa Farm Show's annual breakfast that he would protect their water.

The stakes are partly personal for the governor, who retains an interest in 2,700 acres of ranch land in Colusa County settled by his grandfather.

"I said we're going to protect that land, and I promise you today that I'm going to protect the water on that land and the water in this county and everywhere else in this state," he told a crowd.

He vowed to return and speak more with community members as his water proposal is developed. But he also said the 100-year-old levees protecting the Sacramento River delta would not withstand a natural disaster, such as an earthquake or sea level increases.

Farmers in the delta region and upriver from where the tunnels will be located are concerned about their water supply if the governor's proposal succeeds.

Brown says the tunnels are needed to ensure that water deliveries continue to southern California cities and Central Valley farmers into the future. Many farmers and Republican lawmakers want more water storage in northern California.

Brown told reporters that he would weigh all the options but did not intend to violate any of the historic water protections farmers have won, dating back to the 1800s. ■

Guest Comment

Risk and reward: Assessing the merits and opportunity consequences of alternative delivery in underground construction

Seattle's Alaskan Way Tunnel, DC Water's Clean Rivers Program and the Port of Miami Tunnel are examples of tunnel projects being delivered through alternative delivery methods, underscoring an emerging trend in the underground construction industry. As the owners of these projects will attest, alternative delivery methods offer a host of benefits. But, to experience those benefits, owners must understand and accept the corresponding consequences.

Merits

The primary reasons public sector owners choose design-build delivery method are:

- **Single point of contact.** Under design-build, the owner contracts with the builder who, in turn, hires the designer. The arrangement streamlines communications, improves project integration, provides design innovations and avoids potential conflicts inherent in the traditional design-bid-build model.
- **Risk.** Under the design-build approach, higher risk is assigned to the contractor. The owner avoids dealing with disputes concerning changed conditions, conflicting design requirements and third party approvals.
- **Speed.** Design-build overlaps critical-path activities of design, procurement and construction, collapsing the project timeline and producing the facility faster.
- **Lower cost.** Design-build provides the opportunity of a potential lower overall project cost due to innovative approaches, predefined risk sharing and accelerated schedule.
- **Funding.** When P3 is used, a funding element is provided that allows cash-strapped owners to deliver critical infrastructure projects decades earlier than the traditional procurement methods would.

Opportunity consequences

To experience such compelling benefits, however, owners must be prepared to relinquish a certain amount of control in two primary areas:

- **Day-to-day management.** The advantage of design-build is the synergy between the designer and the contractor, working collaboratively to develop best solutions possible. If owners attempt to exert too much control over that relationship — by issuing prescriptive-based specifications, for example — they will sabotage the benefits associated with this delivery method. Therefore, design-build is most effective when owners provide performance-based criteria and specifications that allow the design-build team to determine how best to meet those goals. Often, this is where cost- and time-saving innovations occur.
- **Risk management.** In alternative delivery, risk should be allocated to the party best suited to manage it, again requiring owners to relinquish some control. However, an owner cannot assign risks without knowing what they are and to what degree they are likely to occur. Conversely, contractors cannot bid on an underground project rife with unknowns without arming themselves with contingencies.

A detailed geotechnical baseline report (GBR) can paint a realistic picture of the risks and tame those contingencies. Based on a quantitative analysis and a realistic GBR values, owners can strategically assign risks to the party best suited to manage or mitigate them. And contractors can make informed budget decisions.

The selection of the traditional design-bid-build versus the design-build delivery methods should be structured for success. Initial goal-setting sessions and value analyses can help owners identify the optimal delivery method for their specific projects. Understanding the merits and consequences of the project delivery method before entering the market is critical if the project is to succeed.

For more information about alternative delivery method, download HNTB's white papers at http://news.hntb.com/white-papers. ■

Nasri Munfah

Nasri Munfah, member UCA of SME, is chairman of tunnel services for HNTB Corp., email nmunfah@hntb.com.

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BUSINESS PROFILES

A special advertiser sponsored advertorial section

DECEMBER 2012

Underground Construction and Tunneling history is made by the investment of companies worldwide that dedicate their efforts and vision to the advancement of the industry.

SME and T&UC acknowledge these companies that demonstrate a continued focus on providing the world with the best in underground technology, products and services.

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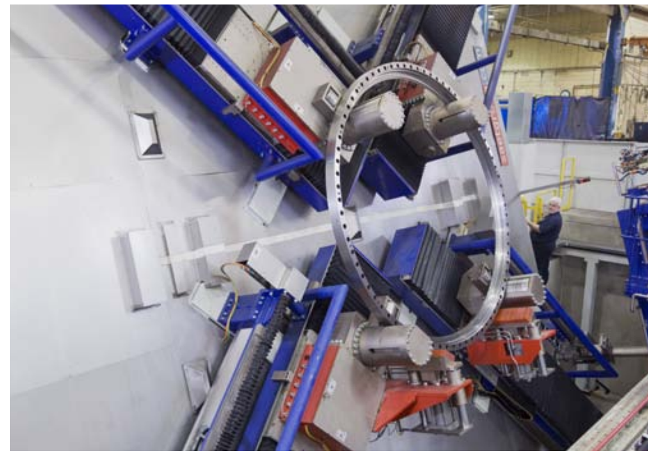
Messinger Bearings is one of an elite few companies in the world capable of producing large, custom-designed bearings for tunnel boring machines (TBMs). Messinger is addressing the challenge from end users who require new or repaired bearings of this size delivered in a reasonable timeframe.

TBM Bearing Customers Have an Option

Based in Philadelphia, Messinger Bearings was established in 1912 as a designer and manufacturer of large, heavy duty rolling element bearings. Today, Messinger focuses on providing large diameter custom bearings for unique applications, including those for TBM equipment. Messinger can manufacture new bearings to 25 ft in diameter, as well as repair them. In fact, Messinger is one of the few bearing manufacturers in the United States capable of turning and heat-treating bearings of this size completely in-house using a new state-of-the-art CNC vertical boring mill along with new induction heat treat capabilities.

New or Rebuild? Your Choice

Deliveries for 3-row TBM main bearings have been a recurring challenge for TBM customers. Messinger is committed to supporting its customers in its core business, that is, large heavy-duty custom bearings for specialty applications in limited quantities. In addition, Messinger maintains a repair and service department that



is capable of rebuilding old bearings at a fraction of the cost of new.

For example, a TBM project was recently under way and the spare bearing was found to have a broken outer race. In addition to manufacturing a new outer race, Messinger was able to repair the entire bearing in more than enough time to have it on site when needed. Considerable savings were realized, not only with the repair itself but also by limiting downtime.

This is but one example of the problem-solving attention TBM customers routinely receive from Messinger Bearings -- to enable superior machine performance through expert bearing solutions.

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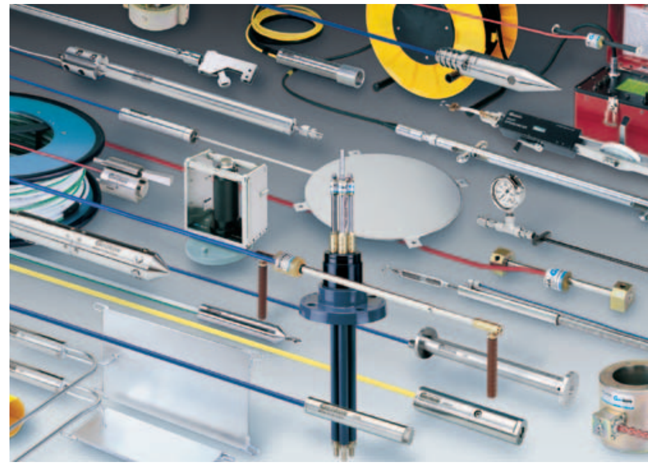
Geokon, Incorporated, is a company based in Lebanon, New Hampshire, USA. It operates on a worldwide basis through a network of over 45 agencies for the manufacture and sale of geotechnical instruments. The company was founded in 1979 and currently has over 100 experienced employees, many of whom have 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.



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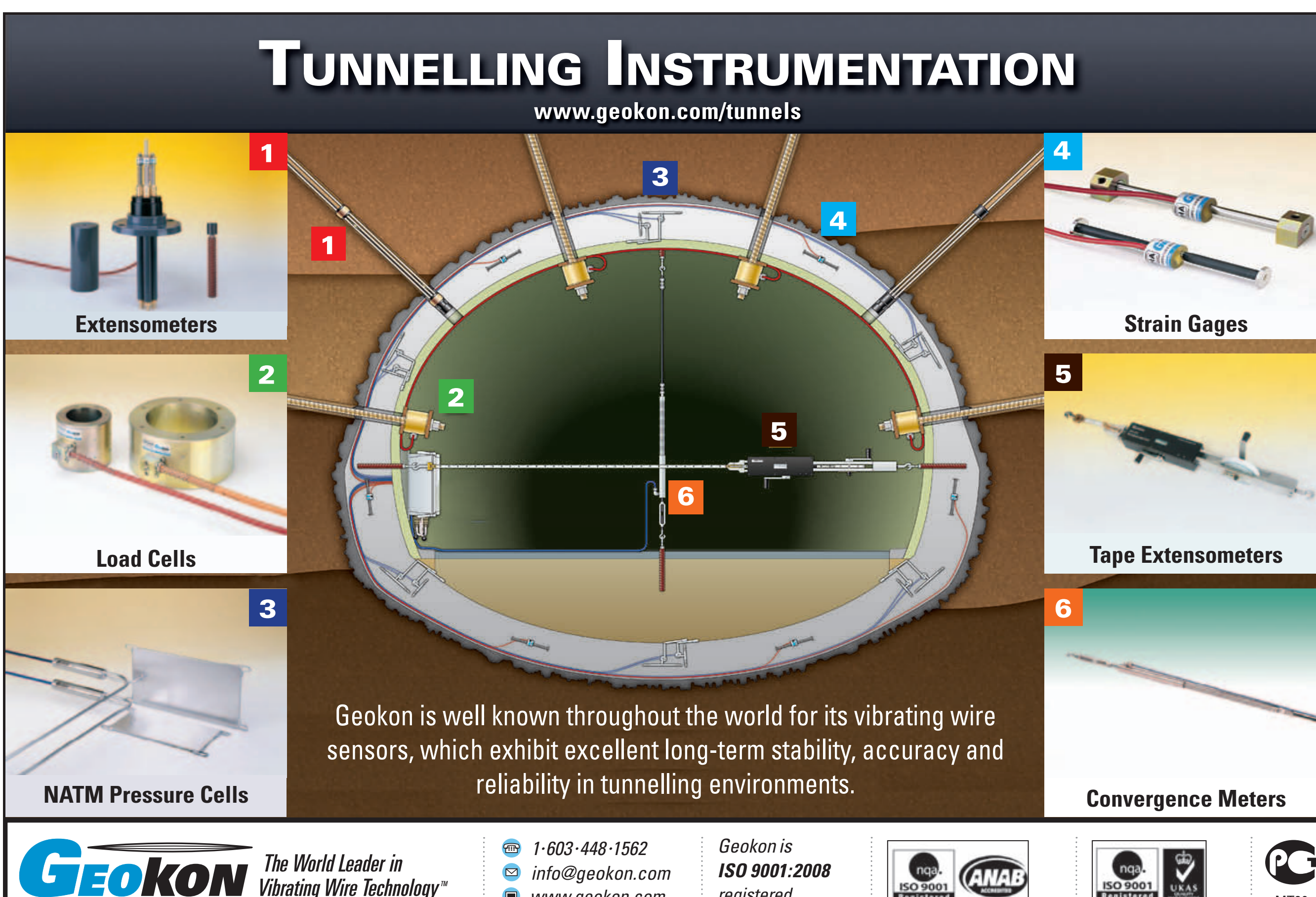
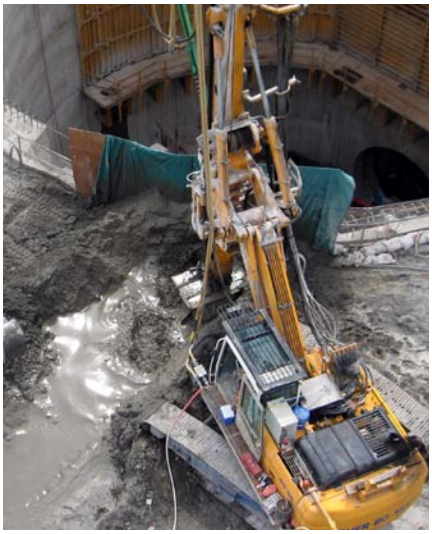


North America's Leader in Geotechnical Construction

Hayward Baker handles geotechnical challenges both large and small. Our extensive experience with the full range of ground modification techniques has been applied to hundreds of tunneling projects. Commonly applied tunneling services include earth retention, underpinning, waterproofing, soil improvement, and ground stabilization.

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 handmined 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.

Lower North Outfall Sewer

River Supply Conduit Unit 4
Los Angeles, CA

Ground subsidence above a 108-inch-diameter tunnel for a water supply line required compaction grouting (low-mobility) to densify disturbed soil and control settlement. Hayward Baker drilled over 180 grout holes between 10 and 23 ft deep, and pumped over 350 cy of low-mobility grout over a 600-ft length of the tunnel. All work was completed safely even though a portion was within a major city intersection.

River Supply Conduit Unit 4

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-ft long segment of the proposed 20,000-ft long, 12-ft diameter combined sewer tunnel. A total of 40,000 ft of grout holes was drilled to complete the project. Depths of the grout holes were approximately 170 ft from ground surface.

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Atlas Copco – A 140 Year Heritage of Innovation and Service

Founded in 1873 as AB Atlas, the company manufactured its first drill driven by compressed air in 1898. More innovation was soon to follow, as Atlas manufactured its first piston air compressor in 1904, and its first portable air compressor in 1905. Today, Atlas Copco is the world's leading manufacturer of air power equipment.

Continuing to create the legacy it boasts of today, in 1936 Atlas introduced a one-man pneumatic rock drill that was light, strong and efficient, and 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" (DTH) drilling. And in 1937, Atlas manufactured a rock shovel loader, driven by compressed air, for the mining industry.

During the '50s and '60s, Atlas Copco designed and launched its first mobile rig for underground drilling, and the workhorse Simba 22 production drill rig for underground mining. In the 1970s, Atlas Copco introduced a series of pneumatic rubber-tired shovel loaders that became the market leader in small to medium mines, and in 1989 Atlas purchased U.S.-based Wagner Mining Equipment to be able to offer a full range of loaders and underground trucks. The '80s also saw the introduction of the Swellex rock reinforcement system, which still commands a leading position in rock bolting today.

And in 2012, Atlas Copco acquired the underground products of GIA Industri AB. Therefore, in addition to its previously existing range of equipment, Atlas Copco can now offer electric haultrucks, locomotives, rail mounted shuttle cars, charging and service trucks, Häggloader continuous loaders, and complete ventilation systems.

Atlas Copco has continued to innovate, and to add more and more products to its mining portfolio. Today, the Atlas Copco Mining & Rock Excavation product range includes:

- Blast hole drilling rigs
- Exploration drilling equipment
- Ground engineering equipment
- Rock reinforcement equipment
- Large rotary and DTH blast hole rigs
- Portable and stationary compressors
- Raiseboring equipment
- Rock drills and drilling tools
- Underground vehicles
- … and more!

Atlas Copco has an impressive 140-year heritage of innovation and service. But rather than rest on their laurels, they continue to develop new ways for their mining customers to work more safely and more productively.

Learn more at www.atlascopco.us.

Atlas Copco
www.atlascopco.us

SwedVent

More power. Less noise.

Introducing our new underground ventilation system

- Featuring high pressure fans, flexible ducting and control systems
- Air delivered 3 to 200 cubic meters (106 to 7,063 cubic feet) per second
- Silencers for noise reduction

Another important part of the overall package is system design. Our design takes into account system pressure, total leakage, motor load, airflow and other safety considerations and energy consumption.

800-732-6762
www.atlascopco.us

Sustainable Productivity

Atlas Copco

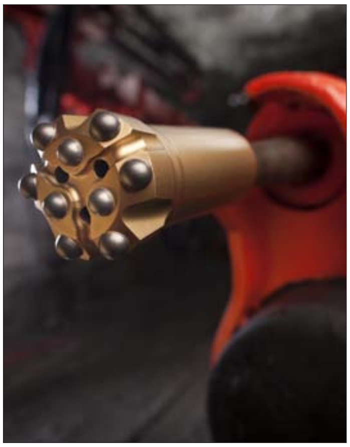
Sandvik in Tunneling

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 m^3 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

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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.

Telephone: +1-814-466-7134
Email: info@alpinecutters.com
www.alpinecutters.com

Connecting infrastructure across the globe

Founded in 1944, Parsons, an employee-owned engineering, construction, technical, and management services firm, conquers the toughest logistical challenges to deliver design, design-build, program and construction management, professional services, and innovative alternative delivery solutions to private industrial customers and federal, regional, and local government agencies worldwide. Parsons is a leader in diverse fields, with a focus on the infrastructure, environmental, and defense/security markets. The firm employs 11,500 professionals around the world who are prepared to meet every technical and management challenge, no matter when or where, and to persevere until the job is done.

Parsons has been combining strong forward thinking with cutting-edge technology to improve the way people connect with the world since the firm's inception, striking a balance between big ideas and the technical ability to bring them to life. Thanks to Parsons' global network of resources, it has the power to combine state-of-the-art technology with unparalleled quality and control, all supported by an unwavering commitment to safety on all projects, under any conditions. Throughout its history, Parsons has provided transportation services on projects of all sizes and complexities. From the world's largest airports to iconic bridges and the most widely recognized tunnels, the firm has the scope, resources, people, and experience to deliver world-class performance on schedule and within budget.

Parsons is the premier source for end-to-end design-build transportation engineering capabilities, including expert multidisciplinary planning, all phases of construction and implementation, and maintenance and improvements. Its Tunnel Division has contributed to 250 international tunnel projects, including the Caldecott Tunnel improvement project, which involves the construction of a fourth bore through the Berkeley Hills, near Oakland, California, and 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.

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. Parsons offers a host of innovative tunneling techniques, like the New Austrian Tunneling Method, top-down tunneling, advanced hard-rock and soft-ground tunnel-boring machine technology, single-pass tunnel construction, and advanced tunnel waterproofing systems, to minimize the risks associated with underground structures. 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.

Parsons
www.parsons.com

South Cobb Tunnel CM — Cobb County, Georgia

Caldecott Tunnel Improvement Project — Alameda and Contra Costa Counties, California

Lake Mead Tap Intake Tunnel and Underground Pump Station — Greater Las Vegas Region, Nevada

Moretrench

Moretrench, headquartered in Rockaway, New Jersey, is a full-service geotechnical contractor specializing in design/build and turnkey solutions for challenging construction requirements and subsurface conditions. The company's wide range of services includes construction dewatering and groundwater control; ground/water treatment; mass and peripheral ground freezing; jet, permeation, compaction, compensation and fracture grouting systems; cut-off and containment systems; earth retention and excavation support systems; underpinning and foundation support; deep foundations; environmental remediation, including landfill gas and leachate systems; and specialized civil and mechanical construction. These services are available nationwide through full service offices in New Jersey, New York, Tampa and Orlando, Florida, Massachusetts, Pennsylvania, Delaware, Maryland, Wisconsin and Iowa.

For unanticipated problems such as abrupt building settlement, retention wall movement, high-volume groundwater inflow, contaminated water supplies, gaps in "bathub" excavation support, under-dam seepage and sinkholes, Moretrench offers a 24-hour emergency response service.

Moretrench is a member of the USGBC (United States Green Building Council) which oversees the Leadership in Energy and Environmental Design (LEED) Green Building Rating System, developed by the USGBC to provide standards for environmentally sustainable construction.

Moretrench
Telephone: +1-800-394-MORE
www.moretrench.com

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.

SPM 307 Nozzle Carrier

- 1960s - Dry-process rotary gun developed.
- 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


SPM 500
Dulles Corridor Metrorail

The New Standard for Tunneling

With 60 years of experience, The Robbins Company is the world's foremost developer and manufacturer of advanced, underground construction machinery. In 2013, Robbins TBMs are making swift headway on a variety of projects worldwide. Innovative concepts continue to expand the company's scope, from efficient TBM assembly methods to high-performance machine designs resulting in landmark performances through both soft ground and hard rock.

Total Supply Company

Robbins is a total supply company, offering everything from cutters and stacker conveyors to knowledgeable field personnel and technical support. Robbins' time-saving Onsite First Time Assembly (OFTA) method was first used at Canada's Niagara Tunnel Project in 2006 and continues to be successfully carried out on multiple projects and with all types of TBMs. The method results in significant time savings and cost reductions for the contractor, all by initially assembling the TBM at the jobsite rather than in a manufacturing facility. The method

has been used most recently for Vietnam's remote Thuong Kon Tum Hydroelectric Project, nearly 90 km (55 mi) from Ho Chi Minh. Components for the 4.5 m (14.8 ft) diameter Main Beam TBM were transported on 95 km (59 mi) of dirt roads to achieve the successful assembly.

Robbins' field service personnel bring years of engineering experience to each project. In mid-2013, personnel will help guide the transport of large TBM components through San Francisco, California's narrow and steep city streets. The team will then oversee the onsite assembly of two 6.3 m (20.7 ft) diameter Robbins EPBs in dense urban surroundings for the city's Central Subway project.

Continued Success in Hard Rock and Soft Ground

Robbins EPBs continue to show their reliability and robustness, even in some of the world's most difficult ground conditions. In Autumn 2012, Mexico's largest infrastructure project, the 62 km (39 mi) long Emisor Oriente Wastewater Tunnel, achieved a TBM milestone. The first of three Robbins 8.93 m (29.3 ft) EPBs completed the critical Lot 1 portion of the tunnel in challenging mixed ground conditions after rescuing a Herrenknecht EPB that was stalled.

In Austin, Texas, USA, a 3.25 m (10.7 ft) Robbins TBM is flying through limestone rock at average rates of 55 m (180 ft) per day, with several days over 60 m (200 ft). The Main Beam machine and a refurbished 3.0 m (9.8 ft) Double Shield TBM are successfully boring the Jollyville Transmission Main, a new water tunnel, with minimal impact below the Balcones Canyonlands wildlife refuge.

Robbins innovations will continue to advance into 2013, with major hard rock and mixed ground projects underway across North America—from mine access tunneling in Montana to a deep rock sewer bore in Indianapolis, Indiana. For further information on tunneling projects and groundbreaking R&D, visit www.TheRobbinsCompany.com or call +1 (440) 248-3303.

The Robbins Company
Telephone: +1-440-248-3303
www.TheRobbinsCompany.com

New York Blower

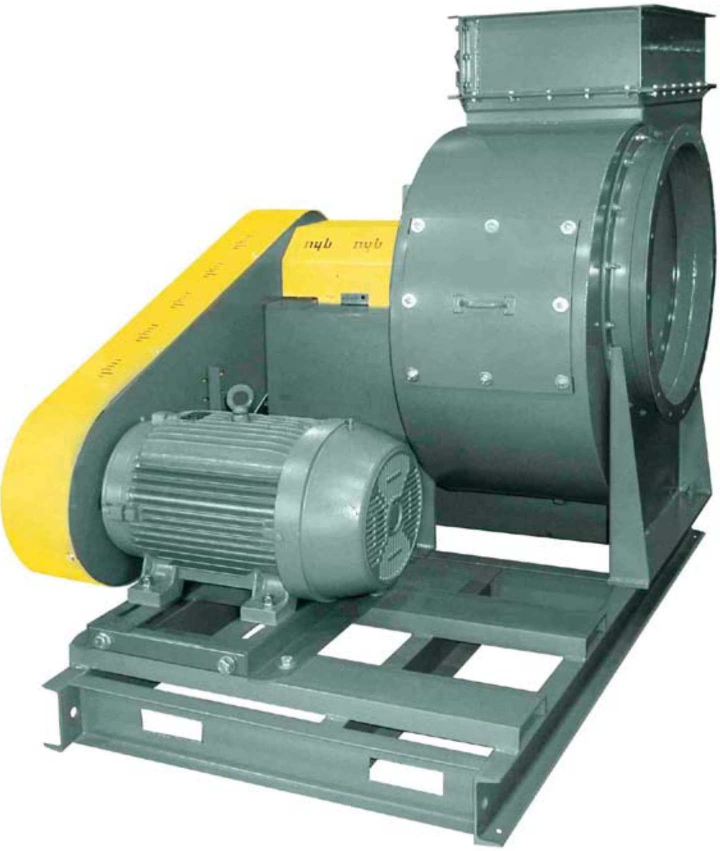
The New York Blower Company is a world leader in manufacturing premium-quality, engineered fans and blowers for the industrial marketplace. At the New York Blower we carry the most complete product line in the industry. Our product range is unparalleled, and includes a comprehensive offering that covers the spectrum from pre-engineered OEM products and high-temperature fans, to highly engineered process fans for the mining and tunnel markets. And the commitment to product innovation doesn't stop there. We create special fan designs, customized for your unique mining applications. We respond to your lead-time requirements with delivery flexibility, unmatched in our business. That's why New York Blower always has the right answer, even for the most demanding operations.

Durable fan structures are designed for long life in the harshest and most demanding industrial applications. Both deep shaft and mining operations use a variety of New York Blower fans. Non-sparking below-ground applications use both axial and centrifugal designs for ventilation and safety exhaust-and-supply systems. Quarry trucks and draglines require cooling fans for the large DC traction motors. Crushing and grinding phases of ore processing use many types of New York Blower fans in environmental and ventilating systems. Some ore processing goes into a wet cycle where spray dryers and particle sizing systems direct products to chemical and food industries. New York Blower offers fans for all of these applications.

New York Blower has the experience, knowledge, and technology to produce what engineers and machine designers agree to be the most durable and efficient industrial fans and blowers. Today New York Blower has a worldwide presence with over 200 representatives, partners, and licensees established around the globe. We have maintained an AMCA-registered laboratory that allows us to meet the highest standard in product development and product performance testing. All of our products undergo extensive air performance, sound and quality assurance testing prior to release to the market. So when it comes time to choose the best possible air-movement solution for your construction needs, trust the industry leader.

More information about The New York Blower Company can be obtained at our website,www.nyb.com, or calling 1-800-208-7918.

New York Blower
Telephone: +1-800-208-7918
www.nyb.com



Tensar International Corporation

Tensar International Corporation (Tensar) offers a number of solutions to support the unique requirements of mining and tunneling construction. Tensar® Mining Systems include a family of polymeric grid products.

Made from high-strength, corrosion-resistant polymers, these geosynthetic reinforcement products are lightweight and easy to handle; this allows for safe, quick and easy installation, resulting in significantly fewer back, hand and facial injuries. Compared with metal reinforcement products, Tensar mining products can reduce installation and material handling time up to 75%.

Our Mining Systems offer cost-effective solutions for a wide range of underground mine and tunnel applications, including:

- Rib Control (Tensar® TriAx® and BX Mining Grid)
- Roof Control (Tensar® TriAx® and Tensar® UX3340 Roof Mats)
- Longwall Screens (Minex™ Rock Mesh)
- Highwall Screens (Tensar® TriAx® Mining Grid)
- Road Reinforcement (Spectra® Roadway Improvement System)

Tensar International Corporation
Telephone: +1-888-826-0715
www.tensarcorp.com

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.

Brokk, Inc.
1144 Village Way
Monroe, WA 98272 USA
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Email: info@brokkinc.com
www.brokk.com

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.

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.

Mining Equipment Ltd.
Telephone: +1-970-259-0412
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www.miningequipmentltd.com

Antraquip Corporation

Antraquip Corp. has established itself as a leading designer, manufacturer and supplier of roadheaders, hydraulic rock grinders (roadheader attachments), shaft sinkers, specialty tracked machines with a variety of boom options, and tunnel support systems. The newest addition to the Antraquip product line are diamond tipped rock saw attachments for excavators designed to cut hard rock and reinforced concrete for specialty applications. Antraquip machines, built to the highest technical standards, are being used all over the world in a variety of civil engineering and mining projects.

Antraquip offers not only standard roadheaders in the 12 to 75 ton weight classes but is proud to offer project oriented engineering solutions. Some of the recent projects have included AQM roadheaders equipped with customized drilling attachments and fully automated remote control operation. Antraquip also provides various tunnel support products including lattice girders, steel sets, and arch canopy systems which they have supplied to some of the highest profile projects in North America in recent years.

In addition to offering project consultations, innovative rock cutting solutions and tunnel support systems, Antraquip recognizes the importance of after sales service. Their commitment to offering the best service and technical support is carried out by highly proficient and experienced service technicians and reinforced with the largest roadheader parts inventory in North America. Innovation, reliablility and experience offered by Antraquip, continues to make them your reliable partner for any tunnel or mining project.

Antraquip Corporation
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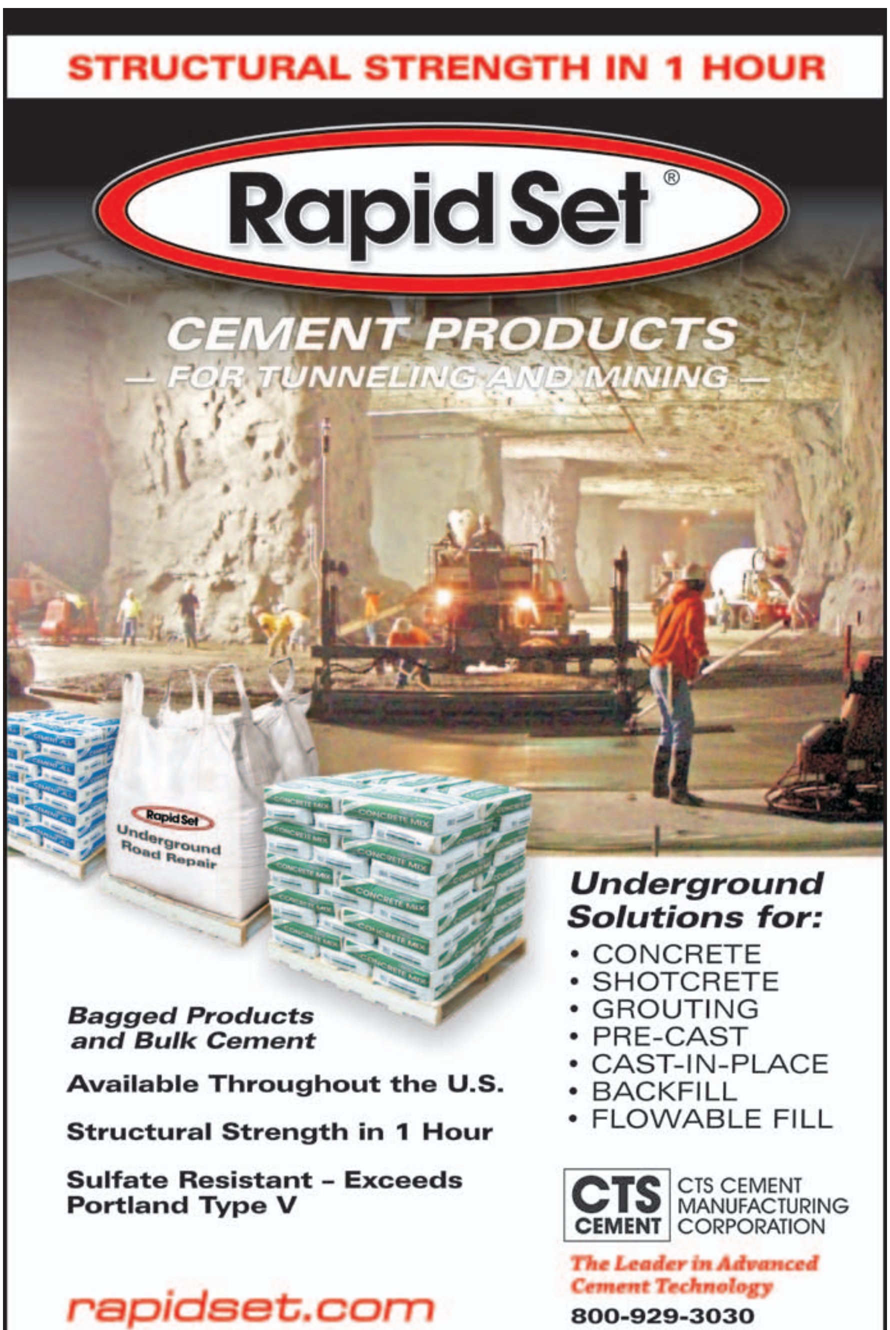
www.antraquip.net

Rapid Set® Cement Products for Tunneling and Mining



CTS Cement Manufacturing Corporation is the largest manufacturer of Rapid Set® fast-setting hydraulic cement, well known for its versatility and high performance. Rapid Set® products are used for underground roadway repair, shotcrete, grout, cribbing for long- wall mining- mostly coal mining, and the precast concrete tunnel segment industry. Rapid Set® cement is not only a more durable alternative to portland cement on many projects, but its rapid-setting properties also make it an ideal solution for today's schedule- and budget-driven projects.

Rapid Set® cement offers reduced shrinkage and superior resistance to chemical attack. It achieves strength much faster and many installations can be put into service in as little time as one hour. Rapid Set® cement reaches typical compressive strengths in a few hours that an equivalent portland cement mix would require one month to achieve. In fact, Rapid Set® cement is a high performance binder that outperforms portland cement-based products consistently. Durability, versatility, speed and ease-of-use along with cost benefits are just some of the many benefits Rapid Set® cement offers.

Headquartered in Cypress, California, CTS manufactures Rapid Set® in the United States. Rapid Set® is distributed through a network of distributors and dealers throughout the United States and Canada. To learn more about Rapid Set® cement, visit www.ctscement.com or call 800-929-3030.

CTS Cement Manufacturing Corp.
Telephone: +1-800-929-3030
www.ctscement.com

Rapid Set®
Construction Cement Products

New TruOval® MineVent® Layflat Blower Ducting

ABC Industries, Inc. has launched its new TruOval® MineVent® line of layflat blower ducting for the mine, tunnel, and underground construction industries. TruOval®'s patent-pending design reduces air flow friction and maximizes head room without compromising air flow output.

TruOval® is engineered with suspension cables spaced intermittently through the ducting to maintain the ducting's oval shape. By utilizing an internal cable suspension system and eliminating the fabric divider typically seen in oval layflat ducting, TruOval® minimizes the amount of air flow friction and maximizes the ventilation system's efficiency. Its oval shape also allows for more headroom in confined spaces and accommodates higher profile underground equipment.

TruOval's® welded construction reduces air loss, weakening, and premature failure associated with

conventional sewn ducting. The durable RipStop substrate prevents small tears from becoming major holes. All TruOval® MineVent® fabrics have been tested and approved by the Mine Safety and Health Administration Standards (MSHA).

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www.abc-industries.net

CDM Smith

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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.

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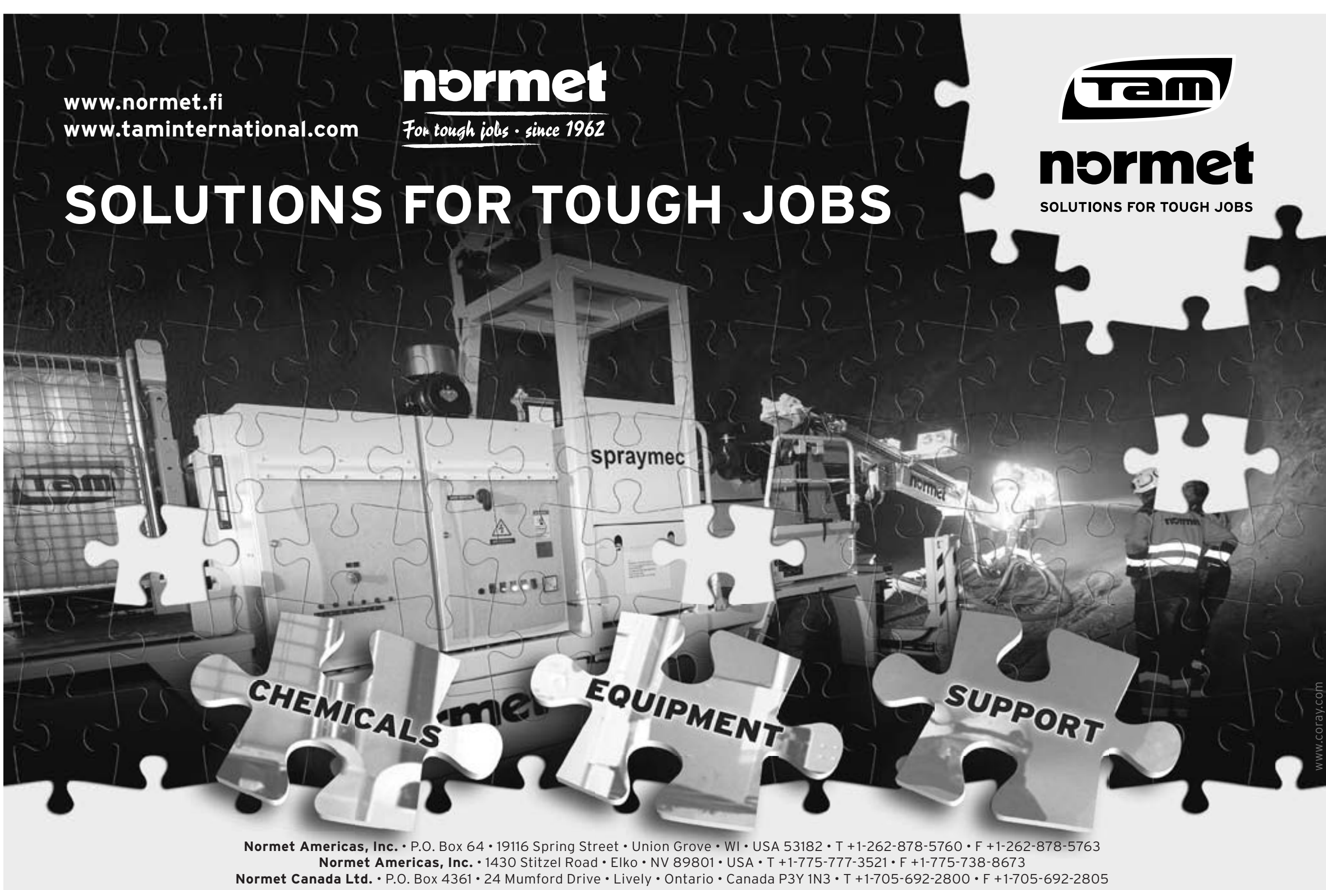

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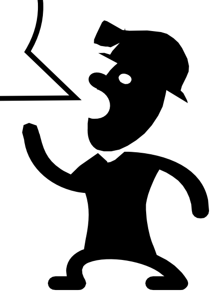

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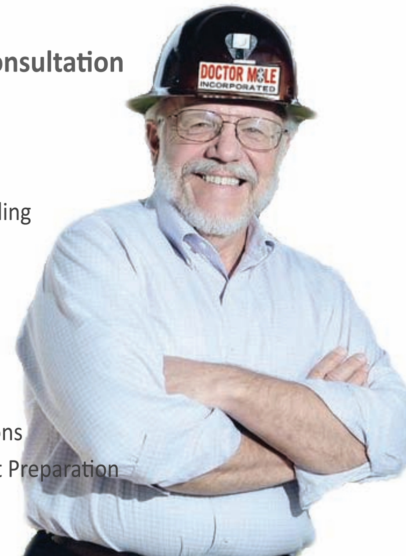

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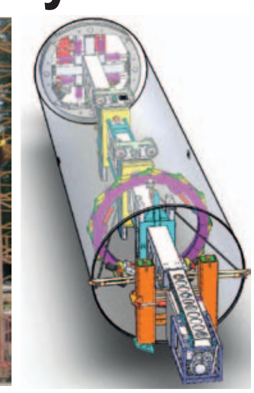

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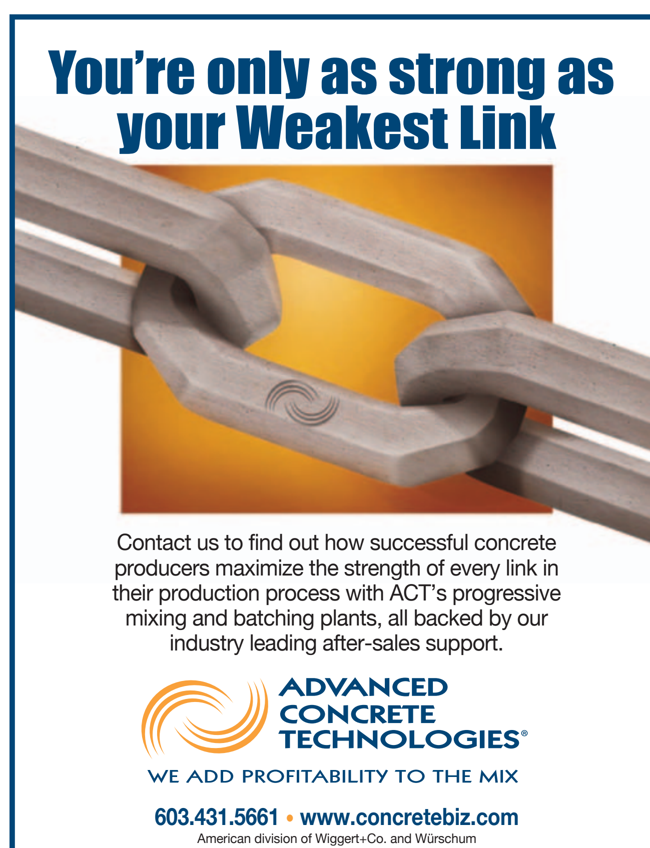

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FEATURE ARTICLE

Construction of a TBM launch box in a complex urban environment

The proposed Second Avenue Subway is a new two-track subway line running from 125th Street and Park Avenue at the north, east along 125th Street to Second Avenue and south along Second Avenue to the Financial District in lower Manhattan, NY with 16 new stations and 13.6 km (8.5 miles) of track. The project has been broken into four construction phases. The initial Phase 1 operating segment includes three new stations (96th, 86th and 72nd Street stations) with a connection to the existing Broadway line at the 63rd Street Station at Lexington Avenue. Rehabilitation of the 63rd Street Station is also included in the scope of Phase 1. Subsequent phases extend service north and west to 125th Street (Phase 2), south to Houston Street (Phase 3) and finally to Hanover Square (Phase 4). The DMJM Harris/Arup Joint Venture (DHAJV) prepared the Contract Documents MTA for Phase 1. Parsons Brinckerhoff is providing the MTA with construction inspection services for Contract C-26002.

In April 2007, NYCT awarded first Phase 1 for $337 million to S3 Tunnel Constructors, a tri-venture comprised of Skanska USA Civil, Schiavone and Shea. Contract C26002 is for the construction of the tunnel boring machine (TBM) launch box and the mining of the TBM tunnels from 92nd Street to 63rd Street. The major part of the contract is to construct a shaft, commonly referred to as the launch box, from East 92nd Street to East 95th Street having dimensions of 244-m- (800-ft-) long by 18.9-m- (62-ft-) wide and a depth of 19.8 m (65 ft), including more than 91,000 m^3 (119,000 cu yd) of soil and rock contained within its walls. The launch box will ultimately become the southern half of the 96th Street Station. The focus here is geological conditions at the launch box and existing structures along the launch box. These geologic conditions and existing structures had a major influence on the selection and design of the support of excavation system (SOE), the SOE bracing system, construction staging, the ground movements, dewatering and other challenges of constructing the launch box (Fig. 1).

Vincent Tirolo Jr., Thomas Maxwell and Anil Parikh

Vincent Tirolo Jr., member SME, and **Thomas Maxwell** are consultant and project executive, Skanska USA Civil NE, Whitestone, NY and **Anil Parikh** is project manager MTA Capital Construction, New York, NY, email Vincent.Tirolo@skanska.com.

FIG. 1

Plan view of the TBM launch box at Second Avenue.

Geological conditions

Ground behavior in the area the launch box is domnated by two formations. One is the varved silts and clays deposited when Lake Flushing formed during the terminal moraine of the Wisconsin ice sheet. In these environments, different processes of deposition occur during cyclical periods of advance and recession of the ice sheet causing prior deposits to be reworked and new materials to be deposited. Parsons (1973) describes the materials deposited in Lake Flushing as "varved silts and clays." The "varves" consist of alternating layers of reddish brown sandy silt, silt and clay with sandy silt and silt predominating. However, within the launch box, the fine sand did not form distinct visible "varves" but, rather, were distributed within a silt matrix. Overlying the glacial deposits is a layer of manmade fill material. North of East 92nd Street, organic silt deposits can be found between the fill and the glacial deposits. These were formed by postglacial streams and creeks in marshy or swampy lowland areas.

The thickness of this stratum in the launch box varied from zero south of East 93rd Street to more than 31 m (100 ft) at East 95th Street. Immediately above the varved silts and clays is a silty sand/sand stratum. Above the silty sand/sand unengineered fill. A thin layer of organic silt, less than 1.5 m (5 ft), was encountered at some locations immediately below the fill stratum. Ground water was generally encountered within 3 m (10 ft) to 3.7 m (12 ft) of the ground surface.

The other formation that strongly influences ground behavior at the launch box is the bedrock located below the varved silt and clay stratum. The bedrock consists of the Manhattan schist, calcareous rocks of the Inwood marble and Fordham gneiss. Manhattan schists are typically crystalline variations of essentially quartz and mica composition with quartz and feldspar rich zones, garnetiferous biotite and muscovite mica schist, quartz-hornblende-mica-garnet schists, and chlorite schists. The rock mass contains regularly spaced faults, fault clusters and shear zones associated with the major Manhattanville Fault.

The top of bedrock slopes down from 3 m (10 ft) deep below ground surface at the south end of the launch box at East 92nd street to more than 61 m (200 ft) deep below ground surface at the north end of the launch box at east 95th street. The typical RQD value for the rock mass is 60 to 100 percent and joints are closely to moderately spaced but occur in widely to very widely spaced clusters.

The rock is generally folded across the launch box and plunges to the southwest at about 10° to 15°. The rock strike is generally northeast to southwest, subparallel to the tunnel alignment, and the dip 45° to 90° to the east. A number of these steeply dipping features faults, shears and fracture zones exposed during excavation of rock within the launch box required rock bolt, straps, wire mesh and other rock supports.

The stratigraphy south of East 94th Street is summarized in Table 1.

Construction staging, utility constraints and building protection

The area of Manhattan where the launch box is located is primarily residential. The buildings adjacent to the launch box vary from new 20- to 30-story high-rise apartment buildings supported on drilled caissons to rock to three-, four- and five-story 100-year-old unreinforced masonry structures supported on shallow spread footings. Prior to construction, most of these older structures were classified as fragile. Permissible thresholds of settlement, angular distortion and horizontal movement of these fragile buildings were very restrictive. For example, the limiting value of settlement was as 10 mm (0.4 in). In addition, it was required to maintain ground water levels under these foundations during preconstruction. The number and location of these fragile structures mandated the SOE for the launch box be a rigid watertight system. The contract documents required that north of East 93rd Street the SOE be permanent slurry wall construction. South of East 93rd Street, where the top of rock rises above the new subway invert, the SOE steps back and changes to a temporary secant wall.

The street and sidewalks are major utility, pedestrian and traffic corridors. Therefore, the first aspect of the work involves modifying the layout of Second Avenue to allow for an active construction zone and to begin relocating utilities within the alignment of the secant and slurry walls.

The dense web of preexisting utilities that existed within the top 4.6 m (15 ft) of the launch box consisted not only of service lines to each of the adjacent buildings for the four city blocks, but also held the immense trunk lines that fed the rest of the city's grid. The utility network underneath Second Avenue has been constantly changed and added to during the last 100 years. The major theme for this substantial utility relocation was to reroute all the utilities feeding the buildings to either side of the launch box and to build new major utility mains to connect to the city trunk lines that will be hung temporarily under the decking system for the duration of the project (Fig. 2).

Buildings located adjacent to the launch box must be protected during construction. However, construction activities adjacent to these structures involve unavoidable risks due to the fact that relocation of the utilities adjacent to sensitive buildings on shallow foundations involves risk. One of these relocated utilities, a sewer line up to 1,067 mm (42 in.) in diameter, required pile supports. Although these piles where drilled rather than driven, pile installation adjacent to sensitive structures again involves risk. How these risks and other risks associated with construction of the launch box were mitigated will be discussed later.

FIG. 2

Relocation of utilities adjacent to the west side of Second Avenue.

TABLE 1

Soil stratigraphy at the launch box.

	Stratum Elevation (NYCT Datum)	
Stratum	West side	East side
Fill	+117 to +90	+117 to +90
Organics	+90 to +86	+90 to + 86
Silty sand	+86 to +80	+86 to +78
Silt/clay	+80 to +35	+78 to +25
Till/decomposed rock	None	+25 to +1
Top of rock	+35	+1

FIG. 3

Rock anchor supports of secant pile core beam.

FIG. 4

Launch box, starter tunnels, TBM assembly.

FIG. 5

Permanent slurry wall downstage bracing.

Launch box — south segment

The south segment of the launch box is located from East 92nd Street to East 93rd Street where the depth of the rock is at or above the future station invert slab. The launch box excavation depth varies from 18.3 m (60 ft) to 19.8 m (65 ft) and the width of excavation is 20 m (66 ft), and both soil and rock are excavated. The future station box will be constructed by tradition bottom-up "upstage" method. Permanent cast-in-place concrete walls and slabs will be constructed within the excavation in a different contract. The "downstage" analysis involved the careful location of bracing levels to both facilitate tunnel boring machine (TBM) operations and accommodate future formwork and concrete placement for the future station.

Support of excavation

To protect adjacent buildings, it was necessary to minimize ground movements behind the SOE during downstage excavation within the launch box. Therefore, a rigid and impervious SOE temporary secant pile system was selected for the SOE. The temporary secant pile walls are constructed using secant pile's with diameters of 1,180-mm (3.875 ft), placed on 920-mm (3-ft) centers with 266 mm (10.5 in.) of overlap. The overlap is based on the vertical installation tolerance of the individual secant piles. Assuming a worst case scenario, this overlap minimizes the risk of the secant piles not having at least a 100-mm (4-in.) overlap at their base. The overlap is necessary to maintain the water-tightness of the SOE. The wall extends from ground surface 600-mm (2-ft) into rock. Typically, the secondary piles are reinforced with W760 (W30) steel core beams and the primary piles are unreinforced. In one 12-m (40-ft) long zone where the top of rock was deepest, W760 (W30) steel core beams are installed in both the primary and secondary piles.

The secant pile walls are laterally supported by one to three levels of temporary cross-lot 920 mm (36-in.) or 610-mm (24-in.) diameter pipe struts spaced 6-m (20-ft) center to center. The top level of bracing doubled as bracing and as a traffic decking. Therefore, for the upper bracing level only, W760 (W36) wide flange sections were used in lieu of 920-mm (36-in.) pipe sections. The W36 decking/bracing members were placed at 3-m (10-ft) centers. The wales were single or double W660 (W36) members.

Rock was excavated below the base of the secant wall. At the south end of the secant wall SOE, the exposed rock face below the secant wall was 14-m (45-ft) high. Site restrictions, limited the setback of the secant wall from the face. As discussed previously, the strike of the rock paralleled the tunnel (and launch box) and the rock dipped steeply to the east. Therefore, to reduce the risk of losing shallow rock wedges forming below the secant wall, the lowest secant pile SOE bracing levels consisted of 46-mm (1.75-in.) 1,030 MPa (Grade 150) Dywidag rock anchors. Each secant pile core beam was anchored. The working load on these anchors ranged from 270 kN (60 kips) to 760 kN (170 kips). The rock anchors were placed at a shallow angle, between

20° and 30°, to reduce their vertical component.

Below the rock anchor, the rock face is supported by 3.6-m (12-ft) long swellex rock bolts installed in a 1.8-m x 1.8-m (6-ft x 6-ft) staggered grid. In some locations, rock straps, wire mesh and shotcrete was also used to provide additional rock support (Fig. 3).

Rock removal

Rock at the launch box is excavated by controlled blasting. In order to limit vibration effects to existing buildings adjacent to the launch box, line drilling with 120-mm (4.75-in.) diameter holes placed at 230-mm (9-in.) centers was carried along the perimeter of the launch box prior to any blasting. Typical blasting occurred in maximum lifts of 915 mm (3 ft) with blast holes spacing on 0.5-m x 0.5-m (18-in. x 18-in.) centers. Prior to the start of blasting, three test blasts were made and buildings and other existing structures were monitored for peak participle velocities (ppv) in mm/second and air blast pressures (dB).

The project limits were that the ppv for structures classified as fragile/sensitive/historic has threshold values of 8-mm/sec (0.3-in./sec) and limiting values of 13-mm/sec (0.5-in./sec). Nonfragile/sensitive/historic structures have threshold values of 40-mm/sec (1.5-in./sec) and limiting values of 50 mm/sec (1.92 in./sec). The airblast overpressure limit is 133 dB. Fourteen building were monitored during the test at either the basement or fifth floor level. The maximum ppv measured during the test blast was 0.0831 in./sec and the maximum airblast overpressure was 120.2 dB.

Occasionally during excavation ppv reached threshold levels and even limiting values. At those times, blasting was suspende and excavation was only permitted using by hoe-ramming and rock splitters. The blasting procedures and blasting mat placement was modified and blasting resumed. The partially restrained (not rigid) slurry wall, the secant wall and the soil mass between the rock and the building foundations reduced transmission of vibrations from the launch box to the buildings. Airblast pressures were reduced by the blast mats, concrete decking panels and an air pressure relief opening. It is also a standard procedure to blast toward a free face to increase blasting efficiency. The free face in the launch box was in the northern direction, the buildings were east and west. This also reduced vibrations toward the buildings and reduced air overpressures.

In addition to the launch box rock excavation, two starter tunnels are constructed by blasting to accommodate the TBM. The starter tunnels are 12-m (40-ft) deep, and the crown of the starter tunnels are grouted and are supported by steel spiling at 0.6-m (2-ft) centers (Fig. 4).

Launch box — north segment

The north segment of the launch box is located between East 93rd and East 95th Streets. The excavation depth varies from 16.8-m (55-ft) to 18.5-m (60-ft) and the width of excavation is 17.5-m (57-ft). Since the depth of the rock is below the future station invert slab, it was possible to use reinforced concrete slurry walls as both the SOE and as the permanent sidewalls of the station box. The 1,067-mm (42-in.) thick slurry walls are supported by three levels of temporary bracing during excavation similar to the secant pile SOE. The top level of bracing again doubled as a bracing level and as a traffic decking. Therefore, for the upper bracing level only, W760 (W36) wide flange sections were used in lieu of 920-mm (36-in.) diameter pipe sections. The W36 decking/bracing members were placed at 3-m (10-ft) centers. The wales were single or double W660 (W36) members. The bracing of the northernmost portion of the north segment consisted of cast-in-place concrete slabs that also served as equipment platforms.

As in the secant wall section, the SOE must be both rigid and watertight. Therefore, where the rock is less then 12 m (40 ft) below the invert slab, the slurry wall is keyed 0.3 m (1 ft) into rock. Where the rock is deeper, the slurry wall is constructed with a toe embedment of 12 m (40 ft)

FIG. 6

Slurry wall cage installation.

FIG. 7

Installation of water stop.

FIG. 8

Excavators supported on crane mats excavating "bull's liver."

below the invert slab. The embedment depth is designed to maintain the lateral wall toe stability during the excavation and to maintain excavation base stability due to water seepage from below the wall (Fig. 5).

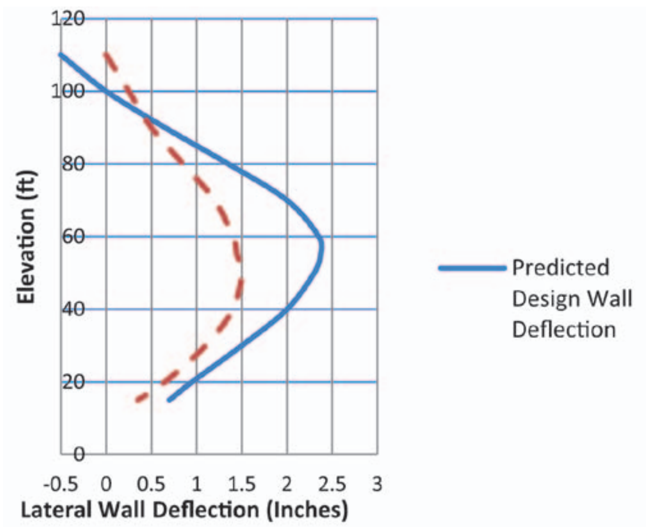
Slurry wall construction

The slurry walls are excavated 18 m to more than 31 m (60 ft to more than 100 ft) deep into the ground. First, guide walls, spaced 1,145-mm (45-in.) apart, are constructed to align the excavation bucket. The slurry fills the trench to within 1.2-m (4-ft) of the ground surface. The slurry is used to support the trenchwalls during a clam bucket excavation of the wall panel in the soil along the perimeter of the shaft, supported by slurry mixture. The slurry panels are 6-m (20-ft) long but are excavated in 3-m (10-ft) "bites." Once excavated, a large rebar cage (some up to 29-m long by 3 m wide or 95 ft long by 10 ft wide) is lifted by crawler cranes (Liebherr 885/855) and placed within the trench. Tremie concrete is then placed into the slurry-filled trench from the bottom, displacing all of the slurry as it rises. The wall panel was constructed with Leffer stop ends, with permanent water stops left in place between the slurry wall panels (Figs. 6 and 7).

Both polymer and bentonite slurries were used during slurry panel excavation. The polymer slurry has a lower density and viscosity than bentonite slurry. In the nonplastic silts encountered on the project site, bentonite slurry was generally more effective in reducing overbreak during excavation of the panels.

FIG. 9

Design and measured wall deflection launch box.



Excavation and dewatering

As discussed previously, the soils at the site are primarily varved silts and clays deposited when Lake Flushing formed during the terminal moraine of the Wisconsin ice sheet. Historically, these soils have been classified as "bull's liver." However, at the project site, fine sand varves traditionally found in these soils were minimal. Therefore, the soil behaved as medium-dense, saturated, nonplastic silt with natural moisture contents greater than its liquid limit. Shearing these soils during excavation results in the soil dilating and developing negative pore pressures. To relieve these pore pressures, water will flow up toward the point of shear. The upward flow of water reduces effective stress (similar to a piping condition) and, thus, bearing capacity. Vibrations transmitted into the ground from the excavators crawlers triggered for "shearing" the soil columns. The highest vibration shear strains are directly under the crane mats. This resulted in difficult excavation of these soils.

To allow excavation in the soils, it was important to reduce the soils' water content. It was also necessary to provide pressure relief of the layers below subgrade. Ejectors are well suited for pumping the low yields expected from each well while applying vacuum to the soils. Ejector wells were drilled from within the excavation support system to a depth of 1.5 m (5 ft) below the bottom of the excavation support or the top or rock (whichever is higher) were used to perform the required dewatering/pressure relief. The ejector system consists of 50 ejector wells installed on the interior of the excavation support on approximately 7- to 9-m (25- to 30- ft) centers along the secant piles wall and slurry wall (Fig. 8).

Buildings and SOE wall movements

As the excavation advanced to the subgrade level and concrete mud mat has been cast, the deflections of the walls were monitored by inclinometers installed in the slurry walls. Figure 9 compares the measured wall deflection from a wall inclinometer located south of East 94th Street at the completion of excavation with the predicted wall deflection from the soil-structure interaction finite element staged analysis. The two deflection curves have similar shape, but the maximum deflection predicted from the analyses is 6 cm (2.4 in.) and the measured maximum wall deflection is 3.8 cm (1.5 in.). In the analyses, moderately conservative soil parameters are used, and conservative building surcharge and sidewalk live loads are used, which may contribute to the higher predicted wall deflection. The SOE performed as it was designed. However, SOE wall movements is not the only construction activity that impacts building movements.

FIG. 10

Steel star and tie rod supports on building facade.

Utility relocation

The installation of a continuous rigid SOE, whether it is temporary secant wall or a permanent slurry wall, involves the relocation of utilities. In a major urban area such as New York City, the subsurface utility network is extensive and the actual path of many utility runs are unknown. It is only when trenches are excavated that the full extent of the utility work is understood. In addition, permanent relocations such as the 1,067-mm (42-in.) in diameter sewer required pile supports. The very nature of this work does not allow these trenches to be constructed using a "rigid" SOE or for that matter even within a watertight "flexible" SOE such as sheet piling. Therefore, these excavations, often immediately adjacent to sensitive or fragile buildings, can result in building foundation movements.

Slurry wall construction

Data obtained Clough and O'Rourke (1990) and others document that both vertical and horizontal ground movements occur behind slurry wall panels during their construction. The amount of movement is a function of panel width, panel depth, ground conditions and construction technique.

Pre-construction of buildings

Another factor that must be considered is the condition of the building prior to construction. Along the alignment of the launch box, building quality varies from high quality, pile supported structures to 100-year-old unreinforced masonry structures that were classified as fragile prior to the start of construction. Figures 10 and 11 illustrate a series of remediation measures that became necessary to support the facade of a number of these buildings that were classified as fragile prior to construction. The remediation measures include the installation of steel star/tie rods drilled to the masonry wall of these buildings. These tie rods were attached to timber floor beams that had been ungraded to truss structures. These systems proved highly effective in safeguarding these facades from further movements.

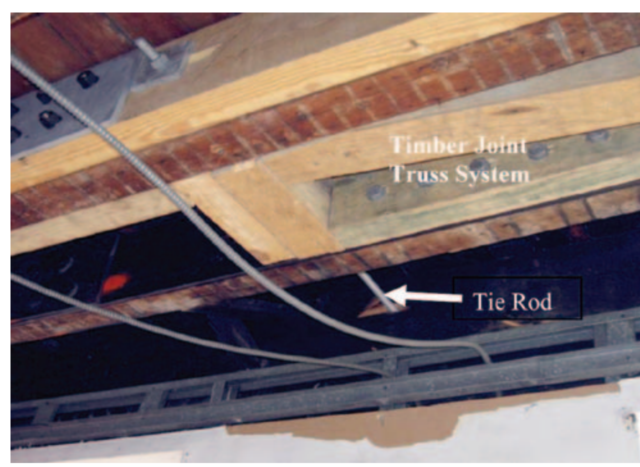
Conclusions

The Second Avenue Subway project is the first major expansion of New York subway system in more than 50 years. The design and construction of the TBM launch box involved many challenges, including maintaining the vehicle and pedestrian traffic, relocating complex network of utilities, excavating a 18-m (60-ft) deep cut-and-cover supported excavation next to buildings in an urban environment. The engineers, contractors and the owner have collectively planned and considered all possible means to apply the least impact on the neighborhood.

Performing all the work previously mentioned while maintaining the way of life for area residents, keeping businesses in full operation and not interrupting any of the utility services supporting this densely urban site has proven to be a challenging task. This took great efforts and planning of all three teams from the owner (New York City MTA), to the design team (DMJM Harris/Arup) and the contractor (Skanska-Schiavone-Shea) to bring this project to its current success. ■

FIG. 11

Existing timber joints reinforced as a truss and tie rod.



FEATURE ARTICLE

Tunneling and trenchless technology key to Charleston's infrastructure

Charleston, SC is anything but boring. The city was founded in 1670 and has played a significant role throughout the history of the United States. Located along the coast of the Atlantic Ocean in the southeastern United States, Charleston was a vital city in America's early existence. Charleston's coastal location has helped the city become the fourth largest cargo port in the United States and earn the 2011 designation as the number one travel destination in the United States by the *Conde Nast Traveler Magazine*. Part of Charleston's charm and beauty can be attributed to its historic structures and churches that line nearly every sidewalk, roadways that were laid out based on the width of horse carriages, great weather, southern hospitality and coastal living.

Now imagine the challenges of installing new, or replacing aging infrastructure, in this setting. Every shovel full of dirt, every stick of pipe and every roadway subsurface has its own historic story to tell. For engineering minded individuals, Charleston's infrastructure has almost as fascinating a history as its more visible surface structures. Charleston was among one of the first American cities to construct separate sanitary and storm water drainage infrastructure. This concept has roots dating back to the city's founding and is a credit to the foresight of its founding fathers who understood the basic health differences between sanitary and storm water.

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The dense, highly urbanized tourist district presents numerous challenges when it comes to major infrastructure projects. Challenges include property acquisitions, high property values, limited construction site availability, neighborhood impacts, environmental assessments, permitting requirements, cultural and historical approvals and geological factors, including seismic considerations. Charleston Water System and the city of Charleston understand these challenges firsthand. As a result, they have both turned to innovative construction methods to overcome many of these challenges as they manage the area's water supply, waste water and storm water management services. Charleston Water System oversees the water and waste water service, while the city of Charleston oversees the storm water service. Tunnels and trenchless technology have roots in Charleston dating back to 1928, when a system of water supply tunnels were constructed to bring water from the Edisto River and Foster Creek to the Hanahan Water Treatment Plant to supplement ground water sources. This trend of constructing tunnels for "water" conveyance has continued throughout the years until present day, where tunnels are still being designed and constructed. To date, nearly 80 km (50 miles) of tunnels have been constructed or designed in and around Charleston by these two entities.

Why have so many projects over the years in Charleston relied on underground construction? The answer lies, in part, on Charleston's geologic setting and on the inherent benefits of underground construction.

FIG. 1

Charleston's Lowcountry.

Basic geology

The geology in Charleston can be categorized into two basic classifications: surficial soils (shallow sedimentary deposits) and Cooper marl. The Charleston peninsula is part of an estuary, and, as such, the surficial and shallow geology is influenced by a combination of marine and continental processes. The surficial soils were deposited in a range of sedimentary facies including fluvial, overbank, tidal marsh, tidal channel, tidal flat, lagoon, beach, barrier island and shallow marine. They consist primarily of highly plastic organic silt and clay with interbedded sand lenses. The typical engineering characteristics of the material are very high moisture content and very low strength with a consistency of soft to very soft.

Below the surficial soils is the Cooper group, a thick sequence of marine sediments known locally as the Cooper marl. The Cooper marl is a relatively massive, homogenous, olive green, highly calcareous, phosphatic, fossiliferous, clayey sand and silt that lies 9 to 18 m (30 to 60 ft) below the ground surface. An irregular errosional contact surface often separates the Cooper marl from the surficial soils, and the farther inland one travels the closer the Cooper marl is to the surface. The Cooper marl is a remarkably homogenous formation and exhibits consistent engineering properties with very little variation. The Cooper marl is an excellent tunneling medium, as it exhibits sufficient standup time for erection of initial support, yet it is soft enough to excavate by shovel and air spade if desired.

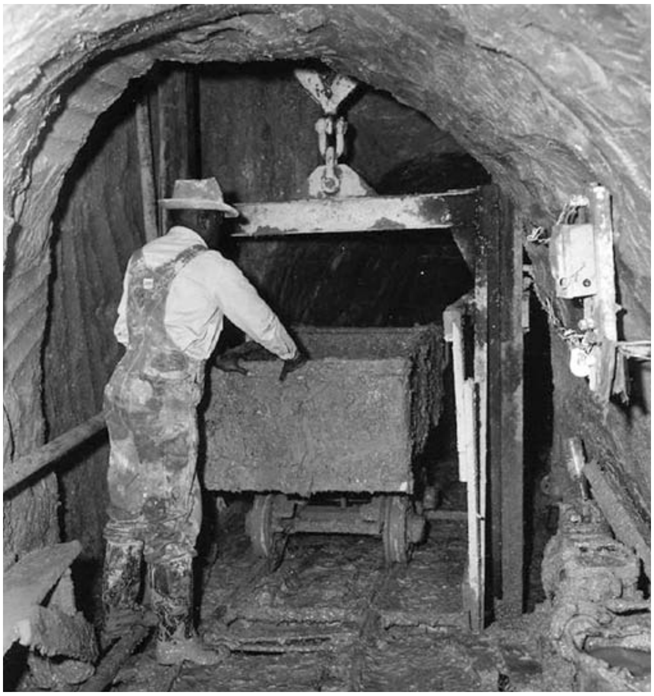
Cooper marl, while composed of clayey sand and silt, cannot easily be defined by the Tunnelman's Ground Classification system (Heuer, 1974). The Cooper marl's strength and standup time can primarily be attributed to the calcareous bonds that give the soil formation "rock-like" properties in its natural state. Once the calcareous bonds are broken, they do not remold and the material loses its strength. For this reason, the more the Cooper marl is handled and broken down, the more difficult it becomes to handle. It turns into a sticky, sloppy mess. This is also the same reason it is difficult to use the Cooper marl as any type of structural fill.

Topography

The coastal environment has helped Charleston prosper over the years, as it is ideal for commerce and travel. However, its location has also played a part in some of its most difficult challenges. The coastal region of South Carolina is commonly referred to as the "low-country," and with good reason (Fig. 1). The average elevation of the city is only a few feet above sea level, with little to no change in topography. Engineers have struggled with these elevation constraints since the city's origin. Gravity systems have especially been difficult to construct as even moderate slopes will push the infrastructure at or below the tidal zones. The limited amount of available differential head greatly restricts the system's ability to effectively flow by gravity at moderate to high tides. This has facilitated the need for Charleston to divide the peninsula into a series of smaller basins that help limit the length of the gravity line runs. This characteristic has played an important role in shaping the use of tunneling in Charleston.

FIG. 2

Edisto River tunnel construction.



History of tunnels within each service

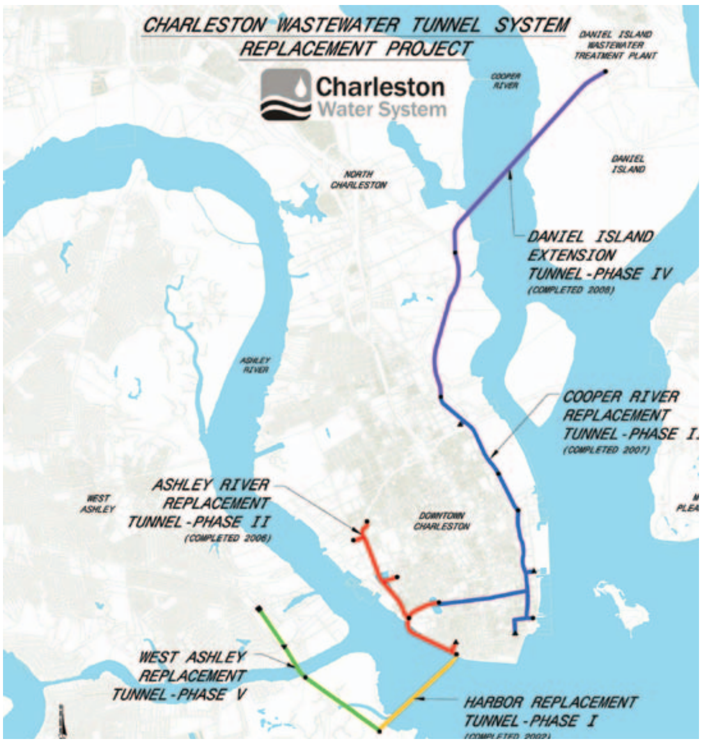
Water conveyance. Providing an adequate water supply facilitated the need to find a reliable water source for the growing Charleston population. Early Charlestonians obtained their drinking supply from shallow wells and rain water collected in large cisterns. This arrangement continued from the time the first settlers arrived in Charleston until the early 1800s. As the population grew, poor sanitation practices eventually contaminated many of the wells and forced city leaders to begin looking for a clean, reliable source of water.

Around this same time, Charleston began hearing of London's success with deep artesian wells. As a result, in 1823 the city council commissioned the construction of several artesian wells. But it would take nearly 50 years of trial and error and advances in the field of geology before artesian wells would become Charleston's primary source of water.

Continued growth soon outgrew the 7.5 million L (2 million gal) yield the city's artesian wells provided. The city council appointed a committee to find a new water source. In 1902, engineers recommended damming the Goose Creek, a tidal tributary of the Cooper River,

FIG. 3

Sewer tunnel replacement program.



to develop a fresh water reservoir. The reservoir was constructed and eventually the city council formed the Commissioners of Public Works of the City of Charleston (CPW) to operate the city's water system. CPW, now known as Charleston Water System (CWS), became an integral part of the community.

As fortune would have it, heavy rains in July 1916 washed away part of the Goose Creek dam and the area was immediately followed by the drought of 1917-1918. The resulting water shortage forced CWS to look for an immediate and long-term water source to supplement the Goose Creek reservoir. CWS found temporary relief in the Ashley River by constructing a pump station and a 5-km (3-mile) wood-stave pipeline. However, community leaders began to recognize that an even larger water supply was necessary to attract future development and maintain current industries. One of the industries Charleston was trying to attract was the West Virginia Pulp and Paper Co. It was looking to build a plant near Charleston but needed a large supply of fresh water. A partnership was formed and CWS agreed to provide additional water supplies from the Edisto River. In turn, the paper company agreed to fund the construction of the Edisto River Tunnel (Fig. 2).

It took CWS nine years (1928-1937) to build the 37-km (23-mile) unlined tunnel (completed in two phases), all hand excavated, to deliver water from the Edisto River to the Hanahan pumping station. The tunnel cost $1.36 million and provided a gravity supply of 264 ML/d (70 million gpd) to the plant. The Edisto River became CWS's primary source of water, and continues to provide raw water to the Hanahan plant (Williams, 2010). The success of this tunnel laid the ground work for all the tunnels that followed, including several later additions to the water supply tunnels.

Waste water

Prior to the 1920s, Charleston had the peninsula divided into a series of 13 waste water subbasins. Near-surface gravity lines conveyed the waste water to a centralized low point within each basin upon which a drain was connected to the harbor. The harbor outfalls did not perform well during high tidal events, so Charleston Water System incorporated pump stations during the 1920s within each basin to convey the waste water directly to the harbor. In the 1960s an effort to battle increased concerns over the environmental impacts of discharging raw waste water directly into the Charleston Harbor and, coupled with new state and federal regulations, Charleston Water System began looking for alternatives to improve the water quality in the Charleston Harbor.

Decades of dumping raw sewage into the Charleston Harbor had culminated in fish kills, swimming restrictions and public outcry. Water quality issues in other parts of the country were also gaining attention, and public pressure forced state and national lawmakers to act. In 1963, state lawmakers passed what was dubbed the "Charleston Harbor Pollution Law," requiring municipalities to implement waste water treatment by 1970. Soon after, Congress followed suit by passing the Federal Water Pollution Control Act Amendments of 1972, collectively known as the Clean Water Act.

Charleston Water System began developing plans to construct a centralized waste water treatment facility. Selecting an appropriate site was not easy. Ultimately, a small parcel of land locally referred to as Plum Island, was purchased across the Ashley River, just west of the Charleston peninsula. The site was not immediately adjacent to any other structures or property owners and provided a convenient location to discharge the treated flows directly back into the harbor. However, getting the flows to the new site across the river would require innovative thinking.

The success of the early water conveyance tunnels coupled trying to find available land for a waste water treatment facility, led CWS to turn to tunneling alternatives. The inherit benefits of tunneling allowed such a treatment facility location to be feasible and reduced the public impacts to an already built-out peninsula. Charleston Water System first tested this approach by constructing a shaft and 31 m (100 ft) of tunnel in an area that is currently in the middle of one of the South Carolina State Ports Authority container shipping ports.

The test tunnel was constructed by Charleston Water System's own work force. The initial concept was to construct an unlined tunnel similar to the original water tunnels further inland. However, spalling of the Cooper marl became prevalent as it began to dry out after exposure to the outside air. Initial support of steel ribs and timber lagging was eventually installed for the worker's protection. The test tunnel was deemed a success and later contracts were awarded for construction of a sewer tunnel collection system to the new treatment facility being constructed on Plum Island. This system was constructed in the late 1960s through the early 1970s and improved the water quality in the Charleston Harbor.

In the 1990s, CWS began discovering extensive corrosion in the tunnels after commercial divers were hired to inspect the tunnel system. What they found was unsettling: collapsed ribs (which supported the tunnel structure), gaping holes in the carrier pipe and accumulation of sludge. Engineers feared the severity of the deterioration could cause a blockage in the tunnel, which would result in sewer overflows in downtown Charleston. The divers made temporary repairs, but their findings made it clear that Charleston needed a new sewer tunnel system.

CWS immediately began an aggressive replacement program to build a new tunnel system. The fast-tracked project was divided into several phases (Fig. 3); the first phase, the Harbor tunnel, was completed in 2001; the second phase, the Ashley sewer tunnel, was completed in 2006; and the third phase, the Cooper sewer tunnel, was completed in 2008. In addition to the replacements tunnels, an extension tunnel was also added to collect sewer flows from an area known as Daniel Island in order to consolidate operations and adhere to permitting regulations (Benjamin, 2007). Design of the final replacement phase, the West Ashley sewer tunnel, was recently completed and NTP is anticipated in early spring of 2013. The sewer tunnel replacement program is the largest infrastructure program in the utility's history.

Storm water. Proper drainage infrastructure has proven difficult over the years, with flooding being a major obstacle for all Charlestonians and its many visitors. The city of Charleston has always struggled with implementing a feasible storm water solution. There is no place for the storm water flows to go after a rain event due to the limited topography relief, minimal elevations above sea level and the adverse tidal influences. In fact, several areas in Charleston will flood during high tidal events without any rain. The most severe flooding occurs when rain events coincide with the high tides as the drainage has nowhere to go. This can result in hours of standing water on the streets and in the neighborhoods (Fig. 4).

In 1837, the mayor of Charleston offered a $100 gold coin to anyone who could come up with a feasible storm water solution. Many ideas were submitted in pursuit of this gold coin but no one design stood above the rest. A solution was ultimately born by the mayor by combining several of the best ideas. The early solution was to construct a network of interconnected brick arches that discharged storm water to either the Cooper River or Ashley River on either side of the peninsula. Gates were installed on the outfalls to control the tidal waters. The system was also slightly undersized to help facilitate scouring velocities to reduce sedimentation during flood events or high tidal exchanges.

FIG. 4

Typical Charleston flooding.

Unfortunately, the system was never very efficient in conveying the storm water flows to the harbor, particularly during high tide events. Although the system provided some minor flood relief, the frequent flooding could not be overcome. Years of siltation and build up of other debris has further clogged the already undersized system. Today, many of the gates have since been removed.

The city of Charleston first implemented tunnel techniques on its Meeting Street/Calhoun tunnel. The project was actually designed as a major open cut endeavor to fix the frequent flooding issues. However, after input from various contractors, the project was converted into a deep underground conveyance tunnel in an effort to minimize impacts to existing utilities and avoid public disruption. The tunnel project incorporated a new pump station to discharge the tunnel flows out into the Cooper River.

This concept has proven highly successful for the city. As a result, two other projects have been designed with the Market Street drainage improvements project currently under construction and slated for completion in 2014 and the US 17 Spring Fishburne drainage improvement project anticipated to bid in early 2014. Additional basins also have conceptual tunnel systems that may be implemented in the future.

A brief listing of some of the prominent tunneling and trenchless construction projects is included in Table 1.

Throughout the years

Numerous tunneling methods have been employed in Charleston throughout the years. Charleston has seen tunnel boring machines (TBM), roadheaders, digger shields, microtunnel machines, drill-and-blast, and hand mine operations. Although advances in underground construction have made tunneling possible in nearly every type of ground condition, Charleston's unique geology has allowed for such a varied and sometimes simplistic application of technologies.

With the success of all these tunnels in one geologic formation, it can be easy to think all the "surprises" have been found. Even the most basic, explored geologies can have secrets locked deep underground and should not be taken for granted. An example of this can be found during the Daniel Island extension tunnel completed in 2008. During that project, a previously unidentified sand lens was discovered within the Cooper marl. The sand lens was approximately 10-m- (30-ft-) thick, well defined and extended over 2.4 km (1.5 miles). This was believed to be the first time a significant variation in the Cooper marl had ever been documented. Miles and miles of tunnels had already been excavated at or below the depth where the sand lens had been identified. In addition, numerous geotechnical investigations had been completed for other projects, as most buildings on the Charleston Peninsula are supported on piles founded in the Cooper marl. Discovery of this sand lens is an excellent example highlighting the importance of adequate geotechnical programs during the early phases of the project. Each geotechnical program must be tailored to the specific project, regardless of the amount of previous historical data. If an unexpected "surprise" can be found in

TABLE 1

Summary of Charleston tunneling.

Tunnel	Function	Service date	Length (ft)	Excavated diameter (ft)	Finished diameter (ft)
Water service					
Edisto Tunnel–Phase I	Raw water	1928	23,760	7	7
Edisto Tunnel–Phase II	Raw water	1937	98,200	7	7
Filtered Water Tunnel	Raw water	1946	310	8	8
McDowell Tunnel	Raw water	1957	12,672	7	7
Back River Tunnel	Raw water	1976	Unknown	8.5	8.5
McDowell Tunnel Extension	Raw water	1981	10,700	8.5	8.5
Bushy Park Tunnel	Raw water	1998	12,700	8.2	8.2
Waste water service					
Charleston Sewer Test Tunnel	Waste water	1966	101 ft	6.5	N/A
Original Cooper River Tunnel	Waste water	1969	18,480	7	2–1
Original Ashley River Tunnel	Waste water	1969	7,920	7	2.5–1.7
Original Harbor Tunnel	Waste water	1969	5,280	7	2.5
Original West Ashley Tunnel	Waste water	1969	8,300	8	2.5
Harbor Wastewater Replacement Tunnel	Waste water	2000	5,100	8	4.5
Ashley River Replacement Tunnel	Waste water	2004	11,845	7	4.5–1.7
Cooper River Replacement Tunnel	Waste water	2005	18,085	7–8	4.5–2.5
Daniel Island Extension Tunnel	Waste water	2006	18,494	8	4.5
West Ashley Sewer Tunnel	Waste water	TBD	9,400	TBD	54
Storm water service					
Meeting/Calhoun Stormwater Tunnel	Storm water	1999	4,500	10	8
Market Street drainage improvements	Storm water	TBD	4,000	TBD	10
Spring Fishurne drainage improvements	Storm water	TBD	9,000	TBD	12

a geological formation as extensively investigated as the Cooper marl, there is no telling what secrets other geologies not as homogeneous may hold. Funds spent on adequate geotechnical programs are always worth the investment and the cost equates to pennies when compared to the costs of unexpected "surprises" during construction.

Conclusion

Communities across the country are faced with the reality of implementing large-scale infrastructure projects in urban environments, many of which require large conveyance systems. The underlying drivers to these projects can be as diverse as the solutions and include mandated consent decrees to control CSO's and SSO's, drought mitigation efforts or simply the replacement of aging infrastructure. Many utility owners are now realizing they have an expanding arsenal of underground construction options at their disposal. Tunneling and trenchless methods have taken a strong foothold in many of these communities. The avoidance to surface disturbance that tunneling can provide is a major advantage in urban construction. As communities continue to expand, there will be a growing need for tunneling and trenchless applications, as owners begin to take into account the emotional and political costs that in the past have largely been ignored on more traditional projects. Charleston is a showcase for the increasing viability of underground construction techniques and other communities can benefit from the city's foresight and ingenuity. (References are available from the author.) ■

Lining	Depth (ft bgs)	Construction method	Comments
		Water service	
None	50–80	Hand	
None	50–80	Blasting and pneumatic spades and shovels	
Concrete	50–80	Unknown	
None	50–80	Hand	
None	50–80	TBM	Average advance rate: 91.6 ft/ 8 hr shift
None	50–80	TBM	Average advance rate: 120 ft/10 hr shift
None	50–80	TBM	Average advance rate: 104.4 ft/ 8 hr shift
		Waste water service	
N/A	105	Hand/ Air Spades	
PCCP	115	Roadheader and TBM	
PCCP	115	Roadheader	
PCCP	120	Roadheader	
PCCP	115	TBM	
Hobas	120	TBM	
Hobas	120	TBM/Handmine/Roadheader	
Hobas	85–110	TBM/Handmine/Roadheader	
Hobas	115	TBM	
Ribs & Lagging	120	TBM	Design complete
		Storm water service	
Concrete	135	TBM	
Concrete	80–135	TBD	Design complete
Concrete	135	TBD	Design Complete

FEATURE ARTICLE

Construction starts on the New Semmering Base Tunnel

In April 2012, work started on one of the most ambitious construction projects of Austria's ÖBB-Infrastruktur AG — the New Semmering Base Tunnel. Scheduled for completion in 2024, the 27.3 km (17 mile) tunnel through the Semmering range will cut the journey time on the south railway connecting Lower Austria and Styria. Before construction can begin at the entrance portal and tunnel bores, the work concentrates on the above ground sections with the clearance and excavation of the entrance ramp site. The slope is currently being excavated by the Baubeteiligungsgesellschaft m.b.H. BBG-GRAZ. The cut face is shored up with shotcrete and permanent self-drilling anchors produced by Minova MAI, an economical bolting solution for softer rock formations. After completing the surface construction work, the twin-bore, single-track tunnel will be cut through the Semmering by conventional and continuous excavation beginning in 2015.

Once completed, the New Semmering Base Tunnel will be one of the longest rail tunnels in Austria. It will act as a vital link on the route crossing Europe's heartland from Northern Germany to Italy, which currently has to climb the steep Semmering pass between Gloggnitz and Mürzzuschlag on a historic mountain railway recognized as one of the UNESCO World Heritage sites. The old route imposes considerable limitations on heavy freight transport, and passenger trains have to slow down to a speed of around 50 kph (31 mph). The New Semmering Base Tunnel will bypass this bottleneck and cut 30 minutes off the journey time between Vienna and Graz. It represents a particular advantage for freight traffic, since the new route's minimal incline of 8.4 percent removes all obstacles for even heavy freight trains.

Preparing the tunnel entrance precut

Construction on the new route started in early 2012 with preliminary work on securing the entrance slopes in the Gloggnitz section by the Baubeteiligungsgesellschaft (BBG-GRAZ). For shoring up the cut face, BBG-GRAZ relies on permanent self-drilling anchors supplied by Minova MAI GmbH. "We have worked with Minova a number of times already, and we are very satisfied with the excellent advice and the flexibility that Minova has given us," Franz Schweighofer, managing director of BBG-Graz explained.

The excavation of the precut proceeds in the so-called pilgrim steps process, in which cuts of a horizontal length of 6-10 m (20-33 ft) and height of 2 m (6 ft) are made with blocks of soil of similar dimensions remaining in place between each cut. The cuts are then secured with shotcrete and self-drilling anchors before moving to the next sequence. The CE-certified permanent self-drilling anchors provided by Minova MAI are a particularly effective means for such bolting in soft or sandy rock formations.

Anchoring for stability

For more efficient anchoring, BBG-GRAZ relies on a semi-mechanized setting process that uses an integrated rotary injection adaptor (IRIA). In this method, the hollow-rod anchors with lost (sacrificial) drill bit act as their own drill. Depending on the ground conditions, a cementitious grout or resin is pneumatically injected into the rod during drilling. Once the planned depth has been reached, a specialized anchoring grout is fed through the rod, which hardens to a concrete strength sufficient to bear the intended loads. A selection of drill bits is available to match the geological properties at the destination: the varied geology of the Gloggnitz site meant that the entire drill bit range provided by Minova MAI is being used. With a precut of around half a kilometer in length and a cut height of approximately 10 m (33 ft), the site uses around 1,600 permanent self-drilling anchors at lengths of 8-12 m (26-39 ft), arrayed in a 1.5 x 1.5 m (4 ft x 4 ft) grid. 5,000 m^2 (53,800 sqft) of shotcrete cover the new slope's surface.

Tunneling to begin in 2015

The New Semmering Base Tunnel will hold two parallel shafts, each measuring 10 m (33 ft) in diameter. The twin bores will be spaced at a distance of 40 to 70 m (131 to 230 ft) from each other and connected by cross-passages every 500 m (1,600 ft) to act as escape routes in the event of emergency. The geological challenges of the chosen tunnel route mean that the tunneling work commencing in 2015 will rely on two methods: conventional tunneling by excavation and blasting according to the New Austrian Tunneling Method (NATM), and continuous excavation with tunnel boring machines (TBM). Almost 28 km (17 miles) of tunnel will be cut for the New Semmering Base Tunnel, proceeding in multiple sections from both ends of the route until the two shafts meet far beneath the Semmering.

Powering on through the Alps

The current plans envision the tunneling work to be finished and the shafts ready by 2020. Once fully furnished and equipped, passenger and freight trains can begin to pass the New Semmering Base Tunnel at speeds of up to 230 kph (142 mph) at the end of 2024. ■

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Gateway Tunnel project	Amtrak	Newark	NJ	Subway	14,600	24.5	2015	Under study
2nd Ave. Phase 2-4	NYC-MTA	New York	NY	Subway	105,600	20	2015-20	Under study
Water Tunnel #3 bypass tunnel	NYC-DEP	New York	NY	Water	20,000	22	2015	Under design
Water Tunnel #3 Stage 3 Kensico	NYC-DEP	New York	NY	Water	84,000	20	2017	Under design
Cross Harbor Freight Tunnel	NYC Reg. Develop. Authority	New York	NY	Highway	25,000	30	2016	Under study
Silver Line Extension	Boston Transit Authority	Boston	MA	Subway	8,400	22	2018	Under design
Hartford CSO program	MDC	Hartford	CT	CSO	32,000	20	2014	Under design
South Conveyance Tunnel	City of Hartford	Hartford	CT	CSO	16,000	26	2015	Under design
Red Line Tunnel - Cooks Lane Tunnel	MD Transit Administration	Baltimore	MD	Subway	14,000	22	2015	Under design
Red Line Tunnel - Downtown Tunnel	MD Transit Administration	Baltimore	MD	Subway	36,000	22	2015	Under design
Anacostia River Tunnel Northeast Branch Tunnel Northeast Boundry Tunnel First Street Tunnel	DC Water and Sewer Authority	Washington	DC	CSO CSO CSO CSO	12,500 11,300 17,500 17,500	23 15 23 23	2013 2018 2021 2021	Under design Under design Under design Under design
Biscayne Bay Tunnel	Miami Dade Water and Sewer Dept.	Miami	FL	Sewer	5,200	12	2013	Under design
Olentangy Relief Sewer Tunnel	City of Columbus	Columbus	OH	Sewer	58,000	14	2014	Under design
Alum Creek Relief Tunnel Phase 1 Phase 2 Phase 3	City of Columbus	Columbus	OH	Sewer	30,000 21,000 25,800	18 14 10	2015 2017 2019	Under design Under design Under design
Dugway Storage Tunnel	NEORSD	Cleveland	OH	CSO	16,000	24	2013	Under design
Doan Valley Storage Tunnel	NEORSD	Cleveland	OH	CSO	9,700	17	2015	Under design
Westerly Main Storage Tunnel	NEORSD	Cleveland	OH	CSO	12,300	24	2020	Under design
Lower Mill Creek CSO Tunnel - Phase 1 Phase 2	M.S.D. of Greater Cincinnati	Cincinnati	OH	CSO	9,600 15,000	30 30	2014 2015	Under design Under design
Ohio Canal Tunnel	City of Akron	Akron	OH	CSO	6,170	27	2014	Under design
Northside Tunnel	City of Akron	Akron	OH	CSO	6,850	24	2021	Under design
ALSCOSAN CSO Program	Allegheny Co. Sanitary Authority	Pittsburgh	PA	CSO	35,000	20	2016	Under design
Pogues Run Tunnel	Indianapolis DPW	Indianapolis	IN	CSO	9,700	18	2016	Under design
White River Tunnel	Indianapolis DPW	Indianapolis	IN	CSO	27,800	18	2016	Under design

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
*Drumanard Tunnel	Kentucky DOT	Louisville	KY	Highway	2,200 x 2	35	2012	Bids 10/26/12
St. Louis CSO Expansion	St. Louis MSD	St. Louis	MO	CSO	47,500	30	2014	Under design
KCMO Overflow Control Program	City of Kansas City, MO	Kansas City	MO	CSO	62,000	14	2014	Under design
Mill Creek Peaks Branch Tunnel	City of Dallas	Dallas	TX	CSO	5,500	26	2014	Under design
North Link Light Rail Extension	Sound Transit	Seattle	WA	Transit	35,000	22	2014	Under design
East Link Light Rail Extension	Sound Transit	Seattle	WA	Transit	30,000	22	2016	Under design
Chinatown NATM Station	San Fran. Muni Transit Authority	San Francisco	CA	Subway	340	60	2013	Bid date 03/19/2013
Third Ave. Subway Tunnel	San Fran. Muni Transit Authority	San Francisco	CA	Subway	10,000	22	2015	Under design
L.A. Metro Regional Connector	Los Angeles MTA	Los Angeles	CA	Subway	20,000	20	2014	Prequalifications under way
LA Metro Wilshire Extension Phase 1 Phase 2 Phase 3	Los Angeles MTA	Los Angeles	CA	Subway	42,000 26,500 26,500	20 20 20	2014 2015 2017	Under design Under design Under design
LAX to Crenshaw	Los Angeles MTA	Los Angeles	CA	Subway	12,200	20	2012	Award 1Q, 2013
LA CSO Program	L.A. Dept. of Public Works	Los Angeles	CA	CSO	37,000	18	2015	Under design
Freeway 710 Tunnel	CALTRANS	Long Beach	CA	Highway	26,400	38	2016	Under design
SVRT BART	Santa Clara Valley Trans. Authority	San Jose	CA	Subway	22,700	20	2014	Under design/ delayed
BDCP Tunnel #1 BDCP Tunnel # 2	Bay Delta Conservation Plan	Sacramento	CA	Water	26,000 369,600	29 35	2015 2017	Under design Under design
Kaneohe W.W. Tunnel	Honolulu Dept. of Env. Services	Honolulu	HI	Sewer	15,000	10	2013	Bid mid 2013
Eglinton-Scarborough Tunnel	Toronto Transit Commission	Toronto	ON	Subway	40,500	18	2014	Under study
Yonge St. Extension	Toronto Transit Commission	Toronto	ON	Subway	15,000	18	2016	Under study
Hanlan Water Tunnel	Region of Peel	Toronto	ON	CSO	19,500	12	2013	Pre Qual JV's announced
West Trunk Sewer Phase 1 West Trunk Sewer Phase 2	Region of Peel	Toronto	ON	Sewer	30,000 16,000	11 11	2013 2013	Bid 03/20/2013 Ad 2nd Q 2013
Second Narrows Tunnel	City of Vancouver	Vancouver	BC	CSO	3,600	14	2013	Under design
Evergreen Line Project	Trans Link	Vancouver	BC	Subway	10,000	18	2012	Prequalified JV's announced
UBC Line Project	Trans Link	Vancouver	BC	Subway	12,000	18	2015	Under design
Kicking Horse Canyon	BC Department of Transportation	Golden	BC	Highway	4,800 x 2	45 x 32	2015	Under design

DIVISION EXECUTIVE BOARD NOMINEES

UCA Executive Committee welcomes new members

Three new members will join the Executive Committee of the Underground Construction Association (UCA) Division of SME at the Rapid Excavation and Tunneling Conference, June 23-26, 2013 in Washington, D.C. They are Kellie Rotunno, Krishniah N. Murthy and Pamela S. Moran. The committee also welcomes returning members Lester M. Bradshaw Jr. and Robert Goodfellow.

Krishniah N. Murthy

Krishniah N. Murthy is the executive director of Transit Project Delivery for the Los Angeles County Metropolitan Transportation Authority (LACMTA). He directs the construction division, which is responsible for engineering development and construction of transit projects. The division also has responsibility for all the environmental compliance in design and construction and for the agency's robust sustainability program.


MURTHY

LACMTA has recently finished the construction of a major rail extension, bus rapid transit and express lanes projects. It is currently constructing a 16.1-km (10-mile) I-405 carpool lane. Metro is now in different stages of procurement for Measure 'R' rail extensions, such as a subway to the Westwood, Regional Connector and the Crenshaw Line. He has also managed large transit projects for LACMTA and the Metropolitan Atlanta Rapid Transit Authority in Georgia.

Prior to joining LACMTA, Murthy was with Parsons Brinckerhoff as senior vice president in its Los Angeles office. He has also served as principal-in-charge for many transit projects, such as Valley Metro rail in Phoenix, AZ; the Mission Valley East Extension in San Diego, CA; Trinity commuter rail in Fort Worth, TX; the New Orleans Canal Street Trolley Extension, LA; the New Delhi Metro, India and several design/build transit and highway projects.

Kellie Rotunno

Kellie Rotunno joined the Northeast Ohio Regional Sewer District as the director of engineering and construction in March 2008. Prior to joining the district, Rotunno worked for 21 years as a consulting engineer for several national firms. She has a B.S. in geological engineering from the Michigan Technological University. She is a registered-professional engineer in Michigan and Ohio and is recognized as a board-certified environmental engineer by the American Academy of Environmental Engineers.


ROTUNNO

As director of engineering and construction, Rotunno is responsible for the delivery of the district's capital improvement program. She has overseen the planning, design and construction awards of nearly $1 billion in new capital projects. Her leadership in the district's negotiations with the U.S. Environmental Protection Agency and the U.S. Department of Justice on the long-term combined sewer overflow (CSO) control plan led to the recent settlement and signing of a consent decree. Rotunno will oversee the challenging implementation of the long-term CSO plan, known as Project Clean Lake, including the design and construction of more than 33.7 km (21 miles) of deep storage tunnels. The tunnels will capture more than 15.1 GL (4 billion gal) of annual CSO volume and will vary in size from 5.1 to 7.3 m (17 to 24 ft) in diameter. Both rock and soft-ground tunnel techniques are anticipated to be deployed on the program.

Pamela S. Moran

Pamela S. Moran, a senior tunnel and waterproofing engineer, received a B.S. in civil engineering from The Pennsylvania State University in 1987. She is a registered professional engineer in nine states and a member of the American Society of Civil Engineers and the UCA of SME.

Since 2009, Moran has been director of engineering for Wisko America. As director, she is responsible for marketing, estimating and bidding all work in the United States and Canada. She not only prepares waterproofing construction work plans and shop drawings on numerous projects, but also assists design engineers writing flexible membrane specifications, developing details for challenging conditions and updating contractors and engineers about new developments in flexible waterproofing technology.

From 1991 to 2009, Moran was vice president of engineering for the Dr. G. Sauer Corp. She worked her way up from project engineer to project manager to vice president of engineering. She focused on tunnel design and rehabilitation using the New Austrian Tunneling Method (NATM), also commonly known as the sequential excavation method. She developed finite element models and frame models to simulate three-dimensional tunnel excavation and structural support. Then she developed the excavation sequence, pre-support, initial lining waterproofing and final lining in the form of specifications and engineering drawings. In addition, Moran has designed flexible membrane waterproofing systems for a number of cut-and-cover and open cut stations and structures.

Some of Moran's key underground waterproofing construction projects include the Caldecott Fourth Bore, Oakland, CA and the Sound Transit U220 and U230 projects, Seattle, WA.

Lester M. Bradshaw

Lester M. Bradshaw Jr. is president and treasurer of Bradshaw Construction Corp. in Ellicott City, MD. He has B.S and M.S. degrees in civil engineering from the Georgia Institute of Technology and an M.B.A. from Harvard University.

In the late 1960s, Bradshaw began his professional career as a tunnel laborer for Eastern Tunneling Corp. He continued working for Eastern Tunneling through college as a co-op student, becoming a tunnel engineer, surveyor, estimator and project manager.

After earning his M.B.A. at Harvard Business School and completing a year as a senior financial analyst at the corporate headquarters of Standard Oil of Indiana (Amoco), Bradshaw returned full time to the tunneling industry as the tunnel engineer, estimator and financial controller for Eastern Tunneling Corp. Shortly thereafter, he helped found Bradshaw Construction Corp. (formerly L.M. Bradshaw Contracting) as its vice president and treasurer. His duties included chief engineer/estimator, safety officer and financial manager throughout the 1980s. In 1991, he became president and treasurer.

During his 26 years as a corporate officer for Bradshaw Construction, Bradshaw has overseen the construction of more than $200 million of tunnel construction throughout the eastern United States and Puerto Rico. The projects have ranged from 106.7-cm (42-in.) wood box tunnels for Baltimore City steam lines to 4,573 m of 244 cm (15,000 ft of 96 in.) TBM tunnel for a raw water intake. They also include many industry firsts in the United States, such as the 365.8 m of 488 cm (1,200 ft of 192 in.) NATM tunnel built under compressed air, the first microtunneling project in the mid-Atlantic (1991) and the first hard rock microtunnel (2004). In addition, he has been the managing partner of several joint ventures building major tunnels and shafts in the southeastern United States.


BRADSHAW

Bradshaw is a member of the American Society of Civil Engineers, UCA of SME, the North American Society for Trenchless Technology and is a former local and national board member of the National Utility Contractors Association.

Robert Goodfellow

Robert Goodfellow is senior vice president at Aldea Services LLC. He has more than 20 years of experience in tunnel design working on major water and transportation projects across North America and around the world. These include the Jubilee Line Extension, the Copenhagen Metro, Washington Metropolitan Area Transit Authority, Central Artery, East Side Access and various major combined sewer overflow tunnels.

Goodfellow has contributed to several industry committees. He has chaired committees on tunnel rehabilitation, risk management, tunnel concrete and local tunnel conferences.

He participated on the organizing committees of the North American Tunneling Conference (NAT) and George A. Fox conference and was a session chair at the NAT, the Rapid Excavation and Tunneling conference, George Fox and Cutting Edge tunneling conferences.

Goodfellow is widely published and was the primary author and editor of industry standards for specification of concrete for tunnel projects. He has also participated significantly in several industry efforts to publish guidelines on contracting practices and megaprojects. He is currently co-chair of a committee updating the Code of Practice for risk management of tunnel work for the U.S. market. ■


GOODFELLOW

Ray Henn honored as a Distinguished Member of SME

by David Klug, past chair of the UCA of SME Division

Raymond Henn, senior consultant with Brierley Associates, LLC in Denver, CO and longtime Underground Construction Association (UCA) of SME member, was inducted into the Class of 2013 as a Distinguished Member of SME. Henn, a SME member for 39 years, received the honor at the banquet held during the SME Annual Meeting in Denver on Feb. 27, 2013.

Henn has been, and continues to be, very involved throughout the industry in various UCA of SME activities and events. He was the president of the American Underground Construction Association (2002-2004), the predecessor of the current UCA of SME. He also received the American Society of Civil Engineers 2002 Roebling Award in Construction Engineering and the UCA of SME's 2008 Outstanding Individual Award.

Henn is dedicated to educating the next generation of tunnelers and spends a considerable amount of time teaching courses and mentoring students in tunneling and underground construction as an adjunct professor at the Colorado School of Mines. He is also the Mining Engineering Department's faculty advisor to the UCA of SME's Student Chapter at the Colorado School of Mines. I have known and worked with the "Good Doctor Henn" for more than 15 years. Currently, we are working together on the *UCA Handbook for Underground Construction and Tunneling* that is being developed as a reference book for the industry.

Henn's other industry passion is collecting mining and tunneling memorabilia. The "Henn Museum" is in the basement of his home, so if you are ever in the Denver area, ask him for a tour. He is known for being cheap — excuse me, he prefers frugal — so there is an entrance fee. But, with a proper contribution to the cause, it can be waived. There are some very interesting items in his collection. He has dedicated his time, and that of his wife Pat, to collecting historical items that need to be preserved and observed by others in the industry.

Henn has a passion for and has made many contributions to our industry. Please join me in congratulating him on receipt of this prestigious and well-deserved industry award. ■

CSM establishes Grewcock chair in UC&T

The Colorado School of Mines (CSM) has announced the Bruce E. Grewcock endowed chair in Underground Construction and Tunneling (UC&T).

Academic programs and research within the UC&T center provide student training and education with exposure to site characterization, design and construction of underground infrastructures (water, highway or subway tunnels) and subsurface underground facilities underneath major metropolitan cities.

The center currently offers an interdisciplinary minor program and an area of specialization for undergraduate students, and it is developing interdisciplinary degree programs for graduate students. Students in the program participate in focused coursework, industry-driven research, field trips and technical conferences. They also have the opportunity to work with industry professionals on special projects and internships.

As the program grows, students, faculty and industry partners plan to collaborate on new, specialized training and emerging research initiatives related to underground construction and tunneling.

The endowed chair is named for 1976 CSM alumnus Bruce E. Grewcock, president and chief executive officer of Peter Kiewit Sons. Grewcock joined Kiewit's mining operations in 1992 and was elected to the board of directors in 1994. He was named president and chief operating officer in 2000 and assumed the duties of chief executive officer in 2005. ■

PERSONAL NEWS

SAM SWARTZ P.E., an associate in the Seattle, WA office of Jacobs Associates, has received the 2012 James Wilton Award. The employee award honors the memory of James Wilton, former principal and president of Jacobs Associates, and recognizes the innovative accomplishments and contributions made by its employees. Swartz received the award at the 2012 management meeting in California last November.


SWARTZ

Swartz has 15 years of engineering experience on major tunnel design projects. He currently provides design support services for the construction of Sound Transit's University Link Light Rail project and is acting as senior reviewer on Sound Transit's final design of the Northgate Link Extension, both located in Seattle, WA. ■

March 2013

3-7, NASTT's 2013 No-Dig Show, Sacramento, CA. Contact: Benjamin Media Inc., 10050 Brecksville Road, Brecksville, OH 44141, phone 330-467-7588, fax 330-468-2289, e-mail vlosh@benjaminmedia.com, website www.benjaminmedia.com.

June 2013

15-21, bauma, New Munich Trade Fair Center, Munich, Germany Phone: 49-89-949-11348, Fax: 49-89-949-11349m email: info@bauma.de www.bauma.de.

May 2013

22-24, Ground Improvement and Support in Underground Construction and Mining, Golden, CO. Contact: Levent Ozdemir, 780 Kachina Circle, Golden, CO 80401, Phone: 303-526-1905, email: lozdemir1977@aol.com, website http://csmspace.com/events/grndimprovsupt.

More meetings information can be accessed at the SME website — http://www.smenet.org.

18-20, International Sympsosium on Tunneling and Underground Space Construction for Sustainable Development, Seoul, South Korea, website http://www.tunnel.or.kr.

31- June 7, WTC 2013, Geneva, Switzerland, Contact: Swiss Tunnelling Society, c/o World Tunnel Congress 2013, Rheinstrasse 4, CH-7320 Sargans, Switzerland, phone 41-0-844-31-05-13, fax 41-0-817-25-31-02, e-mail info@wtc2013ch, website www.wtc2013.ch.

June 2013

23-26, RETC 2013, Washington, D.C. Contact: Meetings Dept., SME, 12999 East Adam Aircraft Circle, Englewood, CO 80112, phone 800-763-3132 or 303-948-4280, fax 303-979-3461, e-mail sme@smenet.org, website www.smenet.org.

November 2013

3-5, Cutting Edge: 2013 Conference On Pressurized TBM Tunneling, Seattle, WA. Contact: Contact: Meetings Dept., SME, 12999 East Adam Aircraft Circle, Englewood, CO 80112, phone 800-763-3132 or 303-948-4280, fax 303-979-3461, e-mail sme@smenet.org, website www.smenet.org. ■

ADVERTISER INDEX • MARCH 2013

Colorado School of Mines
College of Engineering and Computational Sciences
Bruce E. Grewcock Chair (Professor)

Colorado School of Mines (Mines) seeks applications and nominations for an anticipated endowed chair in Underground Construction and Tunneling. The search is open to highly qualified candidates for the academic rank of Full Professor.

A Ph.D. in a field closely related to UC&T is required. The successful candidate is expected to have a distinguished record of scholarship, including funded research, and experience in teaching and advising, with national and international professional recognition that would merit appointment as a tenured Full Professor. In addition, the successful candidate should must have a demonstrated history of successful program leadership, and superb organizational, interpersonal and communication skills. The successful candidate will also have an intimate knowledge of the UC&T industry. Industrial experience and credibility with the UC&T industry is an essential qualification.

For the complete job announcement and directions on how to apply, visit: http://inside.mines.edu/HR-Academic-Faculty

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cutting edge

November 3-5, 2013
The Westin Seattle,
Seattle, Washington

2013 CONFERENCE ON **MEGAPROJECTS**

Following the highly successful 2012 Conference on Pressurized TBM Tunneling, in Miami, **North American Tunneling Journal** and the **UCA of SME** are again pleased to present a timely conference focused on modern megaprojects.

The conference will again feature critical presentations from international experts, panel discussions, and open mic sessions along with a tailored exhibit and the unique opportunity to visit the SR-99 Alaskan Way Bored Tunnel Project.

Mark your calendar today!

10% of the profits from this event will be donated to the UCA of SME's Student Scholarship Fund

For more information about the conference, exhibit or sponsorship opportunities, please contact:

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