T&UC

TUNNELING & UNDERGROUND CONSTRUCTION

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Large diameter tunneling in Seattle

Ground freezing challenges

Efficiency, safety in cross passage work

Special Editorial Section from the publisher of *Mining Engineering*

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COVER STORY

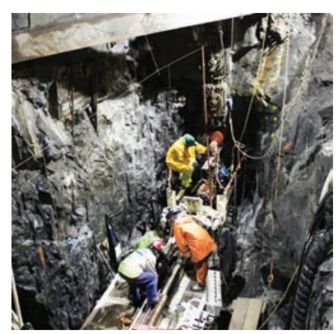
IN THIS ISSUE — The most challenging portion of the multi-billion dollar East Side Access project in New York City is the mining of the Northern Boulevard Crossing thanks to a host of issues including complex soil and a high water table. Ground freezing helped resolve these issues. See the story on page 36.

CONTENTS

FEATURE ARTICLES

31
Large diameter tunneling in Seattle is a sign of things to come
Christopher Bambridge

36
Ground freezing resolves complex challenges ahead of SEM tunneling
Gregory T. Ziegler, Patrick Rooney and Paul C. Schmall



42
Equipment adds efficiency, safety to cross passage work

46
Washington, D.C. hosts 2013 RETC
Steve Kral

DEPARTMENTS

2 Chairman's column

3 Underground construction news

50 Tunnel demand forecast

53 UCA of SME news

57 Coming events

59 Classifieds

60 Index of advertisers

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CHAIRMAN'S COLUMN

Summer brings changes in UCA leadership, and big news about WTC

On June 26, 2013, at the semi-annual meeting of the Executive Committee for the UCA Division of the SME, I assumed the position of UCA Chair. Outgoing Chair Jeff Petersen has done a great job guiding the UCA during the past two years, and I look forward to leading this organization during the next two years. This periodic orderly change of leadership is a hallmark of a strong organization. I would like to thank Jeff and the other outgoing members of the committee, Bob Palermo and Doug Harding, for their contributions, and welcome the newly elected committee members: Pam Moran, Kellie Rotunno and KN Murthy. The participation of contractors, engineers, owners and suppliers on our committee is one of the reasons the UCA is so effective in representing all facets of our industry.

UCA membership provides many benefits to members and the industry. Most of you are probably familiar with the conferences we sponsor: the biennial North American Tunneling (NAT) conference, next scheduled for Los Angeles, CA in 2014; the yearly George A. Fox Conference, held each January in New York City; and various regional conferences, such as the MegaProjects Conference to be held this November in Seattle, WA. These provide an excellent opportunity to learn the latest technology, network with industry experts and hear about lessons learned on past projects.

The UCA also awards scholarships to engineering students and has sponsored an online video to encourage young students to enter the underground industry (you can watch it a http://uca.smenet.org/jobs/index.cfm).

In addition, we provide a wealth of industry information in *T&UC* and through Onetunnel.org, offer discounts on industry publications

Well, we did, and we were successful. Special thanks go to our ITA Representative Randy Essex, and Jeff Petersen for the fine presentation at the ITA General Assembly. We look forward to holding 2016 WTC in San Francisco, CA, in conjunction with the 2016 NAT conference.

and produce special publications on topics of interest to the tunneling community. An upcoming special publication identifying the "Benefits of Going Underground" will help members educate the public and project owners about why an underground solution is frequently the best alternative for planned infrastructure projects.

Another major UCA responsibility is to serve as the United States representative to the International Tunnelling and Underground Space Association (ITA). In his last *T&UC* column, Petersen mentioned that, at the 2013 World Tunnel Congress (WTC) in Geneva, Switzerland, the UCA would make a bid to host the 2016 WTC. Well, we did, and we were successful. Special thanks go to our ITA Representative Randy Essex, and Jeff Petersen for the fine presentation at the ITA General Assembly. We look forward to holding 2016 WTC in San Francisco, CA, in conjunction with the 2016 NAT conference. We expect the number of attendees to more than double our typical NAT attendance. The 2016 NAT Chair Mike Smithson will work with Lok Home to incorporate the international aspects into the NAT program. These events are made possible through the hard work of

(Continued on page 27)

William W. Edgerton, UCA of SME Chairman

Crews finish excavating connector tunnel at Lake Mead project

Crews working on the Southern Nevada Water Authority's new water intake at Lake Mead have finished drilling and blasting a connector tunnel 122 m (400 ft) underground that will link the valley's two existing straws to the third one now under construction.

It took three years and more than $52 million to carve the 5-m (16-ft) high, 4-m (13-ft) wide half-mile long connector through fractured rock and seeping water from the nearby lake.

"This is a major milestone for us," Ericka Moonin, project manager for the water authority, told the *Las Vegas Review Journal* in June. "It's a critical part of the project, and it's a critical project for the community."

The tunnel does not form part of the main third intake design/build contract that is being constructed by the Vegas Tunnel Contractors joint venture (VTC), made up of SA Healy and Impregilo, but provides a critical connection between VTC's main tunnel and Southern Nevada Water Authority's existing Intake Pumping Station No 2.

The Las Vegas Valley draws 90 percent of its drinking water from Lake Mead. The $817-million third intake will keep that water flowing even if the lake shrinks low enough to shut down one of the community's existing intake pipes.

Conditions at the site deep beneath the shore of Lake Mead are dark and muggy. Water drips down from the ceiling and sprays from a few holes in the walls, creating an ankle-deep stream in places that is pumped out.

Joseph Savage is project manager for Renda Pacific, the Texas-based general contractor for the connector tunnel.

He told the *Las Vegas Review Journal* that crews expected to find water down there, but not this much. The "high ground water flow" and unstable rock delayed completion of the tunnel by 18 months and increased costs by at least $5 million.

(Continued on page 10)

New Zealand receives 10th largest TBM

The New Zealand Transport Agency (NZTA) announced that it will receive the world's 10th largest tunnel boring machine (TBM) for the construction of the twin 2.4-km- (1.5-mile-) long Waterview Connections tunnels in Auckland, which are part of the largest road construction project in New Zealand's history.

The state-of-the-art machine was designed and built over 14 months at Germany's Herrenknecht factory in Guangzhou, south China 's Guangdong province, specifically for this project. It will create tunnels wide enough for three lanes of traffic for Auckland's expanding motorway system.

The TBM's circular cutting head is more than 14 m (46 ft) wide.

The tunnel project to complete a Western Ring Route around New Zealand's largest city will cost the government agency NZ$1.4 billion, NZTA Auckland and Northland state highways manager Tommy Parker said in a statement.

The 87-m- (285-ft-) long machine was expected to arrive in Auckland in late July in 97 separate parts. It would be reassembled by a team of 30 in a 30-m- (98-ft-) deep trench at the tunneling site over three months, the *New Zealand Herald* reported.

"We are planning to have traffic using the tunnels by the end of 2016, which will give Auckland the connected and cohesive motorway system it needs to support growth in the region," Parker said.

It was the largest machine ever built for use in Australasia, and had been designed specifically for the local geology.

"Delivery and assembly of the TBM will be complex, the start of a construction process that will lift the development of New Zealand's transport infrastructure to a whole new level," Parker said.

Moving at a speed of 80 mm (3 in.) a minute, the TBM was expected to take a year to complete the first tunnel.

The NZTA said in March last year that the TBM would cost NZ$50 million ($38.95 million). ■

UCA of SME wins 2016 WTC

by Randy Essex,
Hatch Mott MacDonald

The International Tunnelling and Underground Space Association's 39th meeting was held from May 31 to June 7 in Geneva, Switzerland, in conjunction with the Swiss Tunnel Congress. The program drew more than 1,800 participants including more than 55 delegates from the United States, a total that was exceeded only in Vancouver in 2010. The World Tunnelling Congress (WTC) program included technical papers presented in concurrent sessions, as well as an innovative poster session presented in electronic format. Integrated with the technical sessions were the ITA General Assembly and programs presented by the ITA Committee on Technologies (ITAtech), ITA Committee on Education and Training (ITA-CET), ITA Committee on Underground Space (ITACUS) and ITA Committee on Operational Safety of Underground Facilities (ITA-COSUF).

One of the core activities of the ITA are the Working Groups. These are groups where international colleagues collaborate to transfer knowledge and develop best practice guidance documents. Two days of working sessions were held on the following topics, all of which were attended by at least one representative from the United States:

WG2 - Research
WG3 - Contracting practices
WG5 - Health and safety in works
WG6 - Maintenance & repair
WG9 - Seismic effects
WG11 - Immersed and floating tunnels
WG12 - Use of sprayed concrete
WG14 - Mechanized tunnelling
WG15 - Underground works and environment
WG17- Long tunnels at great depth
WG19 - Conventional tunnelling
WG20 - Urban problems, underground solutions

In addition, a new working group was approved – WG21, which will address Asset Management/Life Cycle Costing.

(Continued on page 22)

Jacobs wins second NYCDEP contract

The New York City Department of Environmental Protection (NYCDEP) selected the Jacobs Associates team to provide design and engineering services for the Catskill Aqueduct Repair and Rehabilitation project.

In addition to this project, Jacobs is also working on the Rondout-West Branch Bypass Tunnel, which is a critical part of NYCDEP's Water for the Future Program that aims to ensure the reliability of more than 193 km (120 miles) of water infrastructure and delivering 90 percent of New York City's 3.8 billion L/day (1,000 million gal/day) water supply.

This significant project will provide increased reliability and increase the Catskill Aqueduct's flow capacity during critical shutdown of the Delaware Aqueduct (required to complete connection of the new bypass tunnel). This will be accomplished through leak repairs, mechanical repairs and installation, and 103 km (64 miles) of detailed internal aqueduct inspection. Also required is the removal of an existing layer of biofilm deposits on the aqueduct's interior surfaces in order to perform detailed inspections. The detailed inspection will culminate in a comprehensive report providing structural rehabilitation and repair recommendations for the aqueduct's pipeline, siphon and gravity tunnel.

The winning project team includes subconsultants CDM Smith, HDR and Jenny Engineering. CDM brings an in-depth knowledge of the Catskill Aqueduct's mechanical components and operational requirements. HDR has a knowledge of the aqueduct's operational requirements and experience from previous leak investigation work. And Jenny Engineering brings expertise in tunnel inspection and condition assessment specific to the Catskill Aqueduct. This project was to begin in July 2013. ■

Save the date:

Cutting Edge Conference on Megaprojects

Nov. 3-5, The Westin Seattle, Seattle, WA

www.uca.smenet.org or www.tunnellingjournal.com

Lake Mead: Connector is a critical milestone

(Continued from page 3)

The connector tunnel was excavated roughly 3 m (10 ft) at a time, with hard-rock drills and explosives and heavy equipment mucking out debris.

Renda Pacific started the work in late 2009. Crews punched through to the water authority's existing intake system in March and wrapped up all major excavation work in May.

Workers are cleaning up and putting the finishing touches on the rough-hewn tunnel, which is flat on the bottom and rounded at the top, like a horseshoe 4.2-m (14-ft)-wide and 5-m (16-ft)-high.

The volume of the water rises and falls with the level in Lake Mead. The higher the lake is, the faster the tunnel floods.

Pumps at the bottom of the tunnel's 128-m (450-ft) vertical access shaft keep the flow at bay, sending the unwanted water to the surface to be cleaned up and released into the lake.

All of the moisture has wreaked havoc on the lighting system strung through the tunnel.

Water has caused far worse problems at the adjacent third intake site.

In July 2010, workers digging the 7-m (23-ft) tall, 4.8-km (3-mile) intake tunnel beneath Lake Mead's Saddle Island hit a fault zone, causing water and debris to flood the work area.

The company hired to design and build the intake, Vegas Tunnel Constructors, spent weeks trying to stabilize the fault, but the area flooded twice more, forcing a change order that added $39.5 million to the project and delayed its completion date by 593 days to the summer of 2014.

Then last June, Thomas Albert Turner, a 44-year-old worker with Vegas Tunnel Constructors, was killed in a construction accident in the third intake tunnel 182 m (600 ft) underground.

Within the next few months, a steel pipe 6-m (20-ft) long and 5-m (16-ft) in diameter must be lowered down the access shaft and cemented in place at the bottom.■


100
YEARS OF
DOING IT
BIG.

China planning to build $42 billion sea tunnel — the longest in the world

State media in China reported that the country will revive the long-stalled plan to build a $42-billion tunnel under the Bohai Strait, linking the county's eastern and northern regions, *Reuters* reported.

The 123-km (76.4-mile) tunnel will run from the port city of Dalian in northeastern Liaoning province to Yantai city in eastern Shandong, the *China Economic Net* website said.

The report did not say when the project will be completed.

China announced plans in 1994 to build the tunnel, at a cost of $10 billion. It was set to be completed before 2010. But for more than 20 years the project has remained stuck in the planning stage.

At the time, state media said the tunnel would shorten the traveling distance between the two regions by 1,000 km (620 miles).

At an estimated 123 km (76 miles) long, the tunnel would surpass the combined length of world's two longest underwater tunnels — Japan's Seikan Tunnel and the Channel Tunnel between the United Kingdom and France. To connect the bustling northern ports of Dalian and Yantai, the engineers will have to tunnel through two fault zones that have caused a slew of deadly earthquakes in the last century, including The 1976 Tangshan earthquake, which killed between 250,000 and 650,000 people.

The costs could be recouped in 12 years, said Wang Mengshu, a member of the Chinese Academy of Engineering, who estimated annual revenues from the tunnel at around 20 billion yuan or $3.7 billion, the website said.

The report comes nearly a month after Nicaraguan lawmakers gave a Chinese company a 50-year concession to design, build and manage a shipping channel across the Central American nation that would compete with the Panama Canal.

Japan has the world's longest undersea tunnel. The 54-km (33.5-mile) Seikan Tunnel links Honshu and Hokkaido islands and started operating in 1988. ■

Pair of TBMs break through on Line 5 Extension in Milan, Italy

Two TBMs manufactured and operated by the Italian company Seli have completed their current excavation work on the Line 5 metro extension project in Milan, Italy.

The two Seli earth pressure boring machines (EPBM) were operated by Astaldi/Ansaldo Breda/ATM/Alstrom joint venture and recorded their final breakthroughs at the Pozzo Orafi Station at TreTorri on June 15 and July 26, respectively.

The machines are each 6.79 m (22.3 ft) in diameter.

Excavation began in November 2012 at the Monumentale Station and progressed for a length of 1,930 m (6,330 ft), passing through the three intermediate stations of Cenisio, Gerusalemme and Domodossola.

The final breakthrough of TBM S-238 on July 26 concluded Seli's current excavation works for the Milan Metro project. The two TBMs broke through on the third of four drives at Domodossola Station on May 4 and May 20, respectively. TBM1 was relaunched for its final 370 m (1,215 ft) drive on May 29 and TBM2 restarted in mid-June.

In total, Selihas completed 2.2 km (1.3 miles) of twin running tunnels between Monumental Station and Tre Torri as part of an overall US$1.2-billion, 6.7-km (4.1-miles) LRT metro extension to Line 5 between Garibaldi and San Siro. The geology encountered along the alignment consisted of fluvio-glacial deposits and gravel in a sandy matrix.

The eastbound drives for the Line 5 extension between San Siro and Tre Torri are being completed using two additional TBMs. The total 10-station extension is expected to be completed and in service in time for EXPO 2015.

A feasibility study for a further 6.3 km (3.9 miles) Line 5 extension between Bignami and Monza has been completed, while 9.7-km (6-mile) and 14.8-km (9.2-mile) extensions are planned for Lines 2 and 3, respectively. ■

Crossrail unveils new station to the public

The public got its first glimpse of the improvements that major stations will experience across the Crossrail transport route in London as a result of a £90-million investment into improving the public spaces around the new stations.

The first station to experience the transformation was Paddington, with Crossrail taking down worksite walls around the new entrance to London Underground's Hammersmith and City line.

Crossrail began the upgrade to the Paddington station taxi rank and entrance to the Hammersmith and City line in 2010, ahead of starting work on its new station on Eastbourne Terrace.

A new canal-side plaza has been revealed next to the Grand Union Canal, along with new paths, green spaces, seating and bicycle parking, transforming the area into a vibrant location.

"Crossrail is not just delivering a new railway, but is working closely with local councils and Transport for London to transform the areas around stations," Crossrail chief executive Andrew Wolstenholme said. "This will deliver new squares, footpaths, lighting and green spaces, and provide improved passenger access to stations. Paddington has provided an advance look at how Crossrail will transform areas into vibrant, enjoyable and functional locations."

Kay Buxton, chief executive, Paddington Waterside Partnership, said, "The opening up of the canalside plaza by Crossrail provides much improved pedestrian access to the Grand Union Canal and a spectacular waterside public realm treatment. This high quality scheme complements the rich heritage of its setting and delivers the desired integration with neighboring development schemes at Paddington, including Merchant Square, North Wharf Road and Paddington Central."

Crossrail is the biggest construction project in Europe and is one of the largest single infrastructure investments undertaken in the United Kingdom.

The program includes multiple worksites with construction works running concurrently across the whole route.

More than 7,000 people are working directly on Crossrail at more than 40 construction sites - with thousands more jobs to be created during the coming years in the supply chain including more than 400 apprenticeships.

London's new east-west rail link, which will include the construction of 41 km (26 miles) of tunnels under the capital, is Europe's largest infrastructure project and on a scale nearly twice the size of the London 2012 Olympics.

Over the entire course of the project, it is estimated that Crossrail and its supply chain will create at least 75,000 business opportunities and support the equivalent of 55,000 full-time jobs across the United Kingdom ■

Four Robbins TBMs purchased by Brazil

As part of Brazil's massive metro program, Metro Fortaleza will be the first to use Robbins tunnel boring machines (TBM) in the country. Four 6.92 m (22.7 ft) Robbins earth pressure balance (EPB) machines have been purchased by the Brazilian government's Secretary of Infrastructure in the state of Ceara (SEINFRA) for Line 3 of Fortaleza's underground transit system. The new project is part of modernization efforts to transform the city's small two-line metro system into a high-speed, multi-track system for reduction of road traffic.

Although the machines have been purchased, a contractor has yet to be named. The contracting tender opened in May 2013, and five contractors were invited to submit proposals: Acciona/Centenco; Construcap/ Copasa; Mendes Junior/Isolux; Metrofor (consisting of Odebrecht and Andrade Gutierrez); and Mobilidade Urbana (consisting of Camargo Corrêa and Queiroz Galvão). The machines are anticipated to begin boring in 2014 once a contractor has been announced.

The machines are highly customized for the mixed ground project. Core drills underneath the city verified that challenging geology should be expected, including abrasive basalt and silty sand below the water table at water pressures up to 2.5 bar. Each machine is equipped with a durable mixed ground cutterhead powered by electric variable frequency drives (VFDs), and newly designed Robbins continuous foam and grouting systems for excavation in variable conditions. Behind each machine, Robbins continuous conveyors will maximize the safety and efficiency of the muck removal process.

In addition to the machines, Robbins also designed the segments for the tunnel. The segments will be installed in a 5+1 universal arrangement, and allow for 17 MPa (2,500 psi) push pressure — the maximum push force of the machine. The exceptionally high maximum thrust force of nearly 62,000 kN (14 million lb) at 410 bar will enable the machines to keep moving even in sticky ground conditions. A trapezoidal ring configuration will allow the keystone to be placed at any one of 16 positions. ■

Tunnel breakthrough at the Port of Miami

The Herrenknecht tunnel boring machine (TBM) named Harriet successfully completed the second tube of the Port of Miami Tunnel in May.

The 12.86-m (42.2-ft) diameter TBM mastered complex geological and hydrogeological challenges when crossing under the harbor twice thanks to a machine concept that Herrenknecht developed in collaboration with the client specifically for the project.

The road tunnel will significantly alleviate the traffic congestion in the world's largest cruise port and the city center of Miami, FL.

The earth pressure balance (EPB) shield excavated the two 1.2-km (0.75-mile) long tunnels directly under the fairway of the cruise ships in 17 months. Top performances were 18.7 m/d (61 ft/day) of excavated and lined tunnel and 100 m/w (330 ft/week).

"With this second breakout, we have successfully completed one of the most technically challenging tunneling projects undertaken in the world to date," said Louis Brais, project manager, construction company Bouygues.

From 2014 on, the twin-tubed tunnel with two lanes for each direction will connect the largest cruise ship port in the world, with four million passengers a year, with Interstate 395 and Interstate 95, thus relieving downtown traffic considerably. Currently, around 16,000 vehicles make their way through the narrow streets of the city center day after day. In addition to the cruise traffic, Miami is an important freight hub with around 7 Mt/a (7.7 million stpy) shipped.

The solution, developed specifically by Herrenknecht for the project, together with the client, was to extend the application range of the EPB shield machine type and adapt it to the unique geological conditions of the project. The aim was to safely control the soft but stable grounds at the tunnel entrance and exit and the porous limestone containing corals subject to expected high-water pressures beneath the middle of the fairway. The jointly developed system that ensured that the water-pressure could be dealt with, and at the same time ensured transport of the excavated construction ground, was referred to by the engineers as water control process (WCP).

(Continued on page 26)

WTC: 2016 meeting to be in San Francisco

(Continued from page 6)

The ITA elected a new executive council, with Soren Eskesen, from Denmark, being elected as the next ITA President for the period 2013-2016. Amanda Elioff and Rick Lovat (members UCA of SME) were two of four executive council members elected as vice presidents, and the United States was ratified as the host country for the 2016 World Tunnel Congress. It will be held in June, 2016 in conjunction with the North American Tunneling Conference in San Francisco, CA.

The next planned World Tunneling Congress events are as follows:

- Iguaçu Falls, Brazil, May 9-15, 2014, during the ITA-AITES WTC 2014 "Tunnels for Better Living."
- Dubrovnik, Croatia, May 22-28, 2015, during the ITA-AITES WTC 2015 "Promoting Tunnelling in South East European Region."
- San Francisco, USA, June 12-15, 2016, during the ITA-AITES WTC 2016 "Uniting our Industry."

Congratulations to the United States for winning the WTC 2016 bid and to the WTC 2016 committee members who contributed their time during the last two years to achieve this goal. ■

Randy Essex and Lok Home celebrate the awarding of the 2016 WTC meeting.

Marmaray tunnel in Turkey completes first test run

The tunnel linking Istanbul's European and Asian sides is complete, and Turkish Prime Minister Tayyip Erdogan was among the first people to take part in a trial run of the tunnel under Turkey's Bosphorus Strait, the busy shipping channel linking the Marmara Sea to the Black Sea.

The tunnel is part of a larger $5-billion "Marmaray" project that also includes an upgrade of existing suburban rail lines to create a 76-km (47-mile) line that, according to the government, will carry 1.5 million people a day across the city's two sides, *Reuters* reported.

The 13.6-km (8.5-mile) tunnel includes a 1.4-km (0.9-mile) immersed tube tunnel, the deepest of its kind in the world at 56 m (183 ft).

Erdogan said the project had been 150 years in the making and, by connecting "London to Beijing," served not only those in Istanbul and Turkey.

Construction on the tunnel began in 2004 by a Japanese-Turkish consortium, with funding coming from the Japan Bank for International Cooperation (JBIC) and the European Investment Bank (EIB).

The Marmaray, which has been beset by long delays, is now slated to open to the public on Oct. 29, the anniversary of modern Turkey's founding, making it the first of Istanbul's planned mega projects to be completed.

Erdogan has proposed several major construction projects for Istanbul, some of them facing stiff public opposition, including a canal parallel to the Bosphorus to ease shipping traffic, one of the world's largest airports, a third bridge spanning the Bosphorus and a large mosque overlooking the city.

The most controversial project put forward by the Turkish leader was the redevelopment of a central Istanbul park, which included the construction of an Ottoman-era military barracks and a mosque.

The plans sparked weeks of countrywide demonstrations when diggers moved in to uproot the park's trees. The protests mushroomed into a wider opposition to Erdogan and what protesters said was his increasingly authoritarian rule. ■


SPM 500
Dulles Corridor Metrorail

Port of Miami: Tunnel will connect Miami to the cruise ship port

(Continued from page 20)

The water-soil mixture is transported away by the screw conveyor with an attached slurryfier box and an integrated stone crusher by the closed slurry circuit, rather than by the open belt conveyor commonly used in EPB shields. "The TBM has done well," said Herrenknecht project manager Georg Schleer. "The customer used the EPB mode on two thirds of the route and the WCP mode on the middle section where pressures were higher than three bar."

After the start of the construction work in November 2011, the TBM needed nine months to build the first tunnel tube. Following breakthrough of the first tunnel in late July 2012, the 2.9-kt (3,400-st) machine was turned on Dodge Island and began its return journey for the excavation of the second, western tube in October. ■

The final breakthrough on the Port of Miami Tunnel came on May 6, 2013.

Chairman's column: UCA has doubled in size

(Continued from page 2)

the many volunteers of this organization and the SME staff.

On a final note, since 2004 when SME took over this organization from the AUA, membership has gone up by more than 100 percent to almost 1,000 members, and the UCA now has a sound financial foundation. The Executive Committee believes it is time to revisit our mission and determine how we can best serve the U.S. tunnel industry. To that end, we are developing a strategic plan, and hope to have it in place by early 2014. We will be soliciting input from all UCA members, so stay tuned. Or feel free to contact me or any of the committee members.

I sincerely appreciate the opportunity to serve as chair of the UCA Executive Committee and look forward to working with vice chair Art Silber, the Executive Committee, UCA members and the entire underground industry during the next two years. ■

Blasting on Colorado tunnel project completed

The last big blast of the Twin Tunnels widening project on Interstate 70 near Idaho Springs, CO broke through to daylight on July 19, signaling the start of a new phase of the $106-million project in the Colorado mountains.

Since April 19, crews from Kraemer/Obayashi joint venture have worked to widen the tunnels using state-of-the-art blasting techniques. In all, the crews set 70 charges, about six per week, to move about 15,000 m^3 (19,700 cu yd) of rock from the 194-m (635-ft) long tunnel, Colorado Department of Transportation spokeswoman Amy Ford told the *Denver Post*.

Rock blasting was one of the first key phases of the project, which includes expanding the eastbound bore of the tunnels and will add an eastbound lane between east Idaho Springs and U.S. 6.

Crews will reconstruct the eastbound I-70 bridge over Clear Creek to help flatten the curve at Hidden Valley, Ford said.

The entire Twin Tunnels project is scheduled to be complete in the summer of 2014, with three eastbound lanes of I-70 open by the end of 2013. ■

Veteran TBM sets landmark advance rate

A Robbins main beam tunnel boring machine (TBM) working at the Indianapolis Deep Rock Tunnel Connector (DRTC) project in Indianapolis, IN, recently achieved a new victory in its long career — a world record advance in 24 hours. The record rate occurred on June 12, 2013, when the machine achieved 124.7 m (409 ft) of excavation in 24 hours — a milestone for TBMs in the 6-7 m (20-23 ft) diameter range, the Robbins company reported.

The fast rate is just one of many triumphs for the 6.2-m (20.2-ft) veteran machine that was originally built in 1976 and used on multiple projects, most recently on the Second Avenue Subway Project in New York City. The robust TBM has been rebuilt multiple times.

Robbins main beam tunneling machine.

The machine, owned by the Shea/Kiewit JV contractor, was refurbished and redesigned in Cleveland, OH and Mt. Pleasant, PA. Its latest rebuild included a fitting with variable frequency drive motors and new components including a back-loading cutterhead with 48-cm (19-in.) disc cutters and rescue chamber.

The TBM was launched in early 2013 and began its excavation in limestone and dolomite rock. Muck removal is being achieved with a Robbins continuous conveyor system, including both horizontal and vertical belts hauling muck up a 76- m (250-ft) deep shaft.

Once complete, the Indianapolis Deep Rock Tunnel Connector 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 DRTC, which will include in its scope four shorter tunnels that will be added on afterward. The tunnels for project owner, Citizens Energy Group, will all be more than 60 m (200 ft) below ground.

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

Management software chosen for Thames Tideway Tunnel project

The Thames Tideway Tunnel team has chosen Bentley's ProjectWise to provide collaboration, work sharing and engineering content management for Thames Water's Thames Tideway Tunnel project. The project is designed to address the issue of combined sewage discharges from London's Victorian-era sewer system that enter the tidal River Thames, and thereby enhance water quality and help sustain the river for future generations. CH2M Hill is serving as program manager for the $6.1-billion project. Additional Bentley software being used on the project includes Structural Modeler, AECOsim Building Designer, STAAD, InRoads, gINT, Bentley Navigator and ProjectWise InterPlot.

Currently, there are more than 20 principal partners involved in the project and 50 other companies engaged in the preplanning phase. The project team needed a scalable solution to facilitate collaboration with multiple subcontractors and allow them to accurately predict costs for this fixed-price project. The use of ProjectWise enables the team to more efficiently and economically manage design processes, project data, governance, standards and subcontractors within a single federated and secure data environment. Moreover, the Bentley information modeling, structural and civil applications being used enable interoperability – further supporting collaborative and streamlined multi-disciplinary workflows.

Simon Williams-Gunn, engineering systems lead, Thames Tideway Tunnel project, said, "Thames Water will use ProjectWise to deliver models and drawings for planning processes based on BS 1192, enabling us to collaboratively work together within single and multiple offices and teams using the same information at once.

ProjectWise and BS 1192

The Thames Tideway Tunnel team is taking advantage of the new ProjectWise Business Process Tem-

(Continued on page 30)

(Continued from page 29)

plate that incorporates the BS 1192 processes and naming standards, with appropriate folder structures and workflow conventions. ProjectWise also provides the team with time-saving automated support of numerous key activities including searching, creating, registering, checking and issuing documents, as well as the tools for managing CAD standards to ensure that the growing team can create consistent work.

3D modeling enables management of an evolving project

The London sewer system uses a single pipe to carry sewage and stormwater runoff. It was designed to overflow into the tidal River Thames by combined sewer overflows (CSO) only during extreme rainfall, when the sewers reach capacity, to prevent homes and streets from flooding. However, modern-day pressures, including population growth and the increased intensity of precipitation in the United Kingdom, have resulted in increased discharges into the tidal River Thames – with discharges occurring, on average, once a week.

To capture this overflow before it reaches the river, there will be shafts 6 m (20 ft) across and 60 m (197 ft) deep at 22 CSO sites along the path of the tunnel that drop the flow down to the main tunnel. "There is a huge amount of engineering that goes into actually capturing the CSO. So we're building a building underground, using Structural Modeler to create 3D models," Williams-Gunn explained. In addition, Structural Modeler and AECOsim Building Designer are being used to create 3D models of other elements and structures at the CSO sites, including the shafts, head houses, stacks, and other buildings and landscaping.

These 3D models are shared with other software tools for fluid dynamic calculations as well as GIS software for studying the environmental impact of the stacks and the resulting odor. STAAD is used for structural analysis of reinforcement issues, such as where CSOs enter the river near bridges. The 3D models are also used to produce the 2D drawings necessary for engineering, planning and environmental needs.

InRoads for tunnel alignments

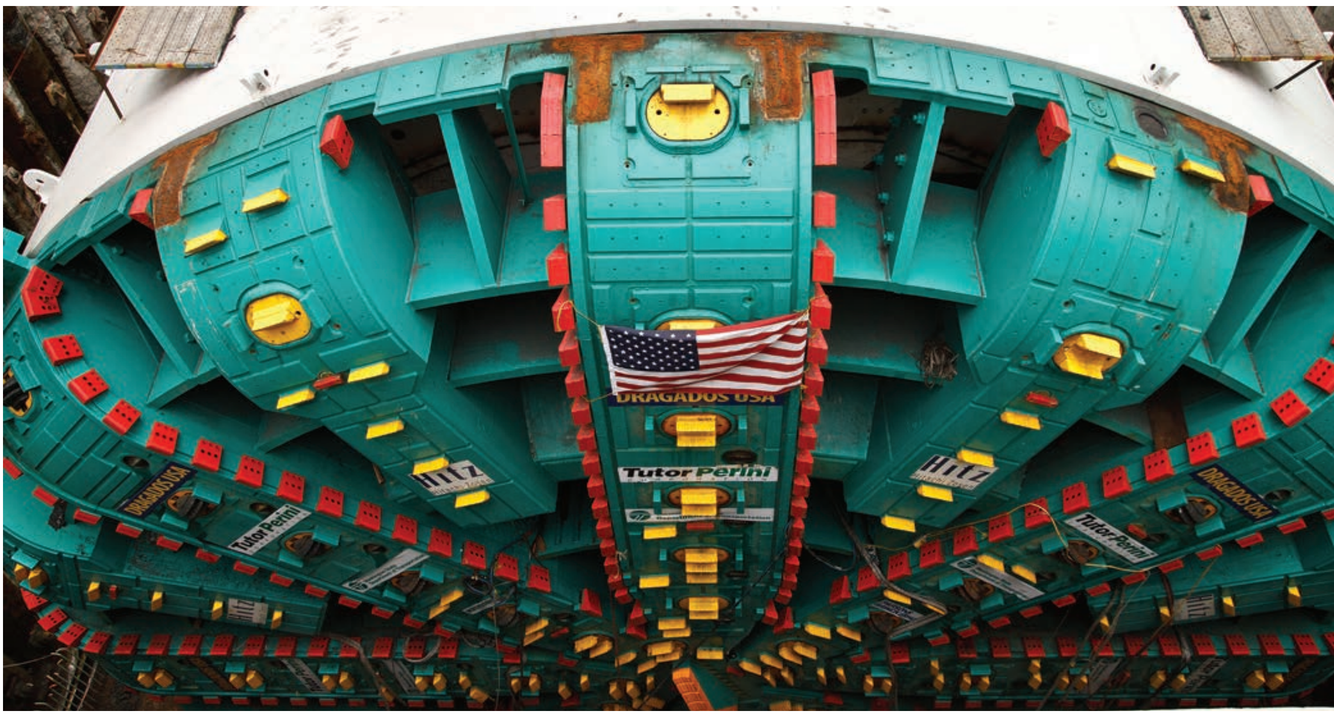
The tunnel will be London's deepest ever – being 75 m (246 ft) deep at its lowest point. With the myriad underground structures beneath the city, the project team must avoid the many other tunnels and conduits used for rail, road, electricity, gas and communications infrastructure. It must also prevent ground settlement from damaging the surrounding buildings. Settlement analysis will be conducted wherever the tunnel passes beneath or close to buildings and other structures, and mitigation efforts will be implemented as required.

The team is using InRoads to manage horizontal, vertical and 3D alignments of the main tunnel and various connection tunnels. In addition, it is implementing gINT to manage the huge amounts of geotechnical data needed for the tunnel, as its prior software was unable to handle the necessary quantity of data.

To meet the needs of various audiences and stakeholders, the Thames Tideway Tunnel project team will employ easy-to-use web tools to provide the required information to project decision makers. Moreover, Bentley Navigator will supply web-based access to 3D models for design review and clash detection. In addition, Bentley's ProjectWise InterPlot will be used for publishing web-based document sets and paper construction documents. The goal is to make all project information available to the entire team on the web. ■

FEATURE ARTICLE

Large diameter tunneling in Seattle is a sign of things to come



The tunnel boring machine for the SR 99 Tunnel project in Seattle, WA, the largest ever built, was manufactured by Hitachi Zozen in Japan and began boring on July 30, 2013.

The Washington State Department of Transportation (WSDOT) is constructing a new tunneled route under Seattle to replace the existing State Route 99, Alaskan Way Viaduct (AWV), which follows the historic waterfront for several miles. The viaduct separates the businesses that rely upon the tourist trade from the downtown area. The reconnection of the city to the waterfront areas will occur following the completion of the SR99 Replacement program that replaces the aging structure that was severely impacted by the 2001 Nisqually earthquake, with a state-of-the-art, twin-deck highway with a world record-breaking 17.4-m (57.3-ft) bored tunnel.

Constructed in the 1950s, the double-tiered viaduct is nearly 3.2 km (2 miles) long and runs parallel to city's waterfront. The viaduct, which is partially supported by the seawall, is a vital local and regional transportation link and carries about 110,000 vehicles each day. The seawall, built from concrete and timber in the 1930s, extends along Seattle's waterfront and supports the soil behind it.

Studies in the 1990s showed that the viaduct was nearing the end of its useful life, apparent by its exposed rebar and weakened columns. The 2001 Nisqually earthquake further damaged the viaduct, forcing WSDOT to temporarily close it for inspection and limited repairs. The viaduct and nearby seawall are vulnerable to another earthquake and continue to show signs of age and deterioration.

Following a collaborative process, WSDOT developed the following guiding principles to the viaduct replacement:

- Improve public safety.
- Provide efficient movement of people and goods now and in the future.
- Maintain or improve downtown Seattle, port and regional as well as state economies.
- Enhance Seattle's waterfront, downtown and adjacent neighborhoods.
- Create solutions that are fiscally responsible.

Christopher Bambridge

Christopher Bambridge is tunnel engineer manager, Alaskan Way Viadut Replacement Program, Hatch Mott MacDonald, Seattle, WA, email Christopher.bambridge@hatchmott.com.

- Improve the health of the environment.

WSDOT appointed Seattle Tunnel Partners STP, a joint venture of Dragados (USA) and Tutor Perini, in December 2011 to construct a bored tunnel replacement of the viaduct, under a design-build contract, with a value of $1.24 billion. The works are currently under construction, with the tunnel boring machine (TBM) launch having taken place in late July and an anticipated bore completion by the fall of 2014. Project completion is planned in early 2016.

TBM launch pit and TBM installation 2013.

Project planning

Planning for urban infrastructure within an environment of ever-increasing surface right-of-way (ROW) cost played a significant part in the design and ultimate configuration of the tunnel alignment. A single-bored tunnel has significantly less ROW cost over an equivalent scheme with twin bores. As a consequence, the single large diameter bored tunnel for a highway tunnel can have significant benefits to an owner. Elimination of the need for cross passages between twin bores, at approximately 183 m (600 ft) spacing for a highway tunnel, further reduces the financial burden. A double-deck highway tunnel optimizes the construction cost versus twin-bore tunnels of the same length. As an example, a double-deck highway tunnel within a single bore can reduce the surface ROW costs by more than 50 percent. The elimination of complex and sometimes risky cross passages further reduces the project risk. Construction costs on a like-for-like comparison of a twin bore versus a single-bore, four-lane highway of 3.2 km (2 miles) long has been shown to be in the region of $600 million.

Geology

The geology of project area has been affected by numerous glacial periods with repeated advance and retreat cycles. Each advance partially eroded older deposits and deposited new sediments, including glaciolacustrine clays and silt, glacial outwash sands and gravels, glacial till like soils with frequent cobbles and boulders being present. Each unit is of limited lateral extent and varies in thickness. It is not uncommon to find lenses of one material within a larger deposit of another.

Tunneling in the Seattle area is well understood. The King St. railroad tunnel built under the city more than 100 years ago is still in operation and is a major artery for the Burlington Northern Santa Fe Rail Road. More recently, tunnels constructed by earth pressure balance (EPB) and slurry TBM techniques have been constructed for light rail and for waste water infrastructure.

Factors of scale

Within an urban environment, large diameter TBM tunnels are still fairly uncommon. By contrast, metro tunnels are commonplace, and the impacts of these tunnels on the surface is well understood. The techniques employed to limit the impact from construction to acceptable levels are well developed. This is certainly the case in Seattle where Sound Transit has recently successfully completed the tunnel bores for the latest phase of the light rail system from central Seattle to the University of Washington. Owners and contractors understand the construction risks of tunnel construction in the 4.8-7.9 m (16-26 ft) internal diameter range.

The AWV bored tunnel at 17.4 m (57.3 ft) excavated diameter and 15.8 m (52 ft) internal diameter pushes the boundaries in terms of the scale of TBM tunneling. The operation of such a machine requires an increased level of awareness to the potential of impact on the surface and a skilled and experienced contractor.

The factors that impact ground movement have been studied at length, and contracts have been written to manage the projects' identified risks in the design phase, within the TBM procurement and throughout construction. The impacts of scale are clearly highlighted when a common urban tunnel 4.3 m (14.3 ft) in diameter is compared to the 17.4-m (57.3-ft) tunnel (Table 1).

TBM launch pit July 2013.

Of interest is the comparison of the volume of annular grout required for a mega TBM in comparison to that of the smaller reference tunnel. It can be seen that the volume of annular grout required to be taken into the tunnel is greater than the excavated volume of the smaller tunnel.

TBM control

If the effects of scale are not fully appreciated, large diameter TBM's have the potential to have a significant impact upon surface settlement. However, due to the increased size of the machines, the possibility of greater control and management of the factors that influence face loss is possible. The scale of the machines allows for features to be included that directly reduce the negative impacts to an acceptable and manageable level. These include:

- In spoke free air cutter replacement – reducing the need for manned intervention, potentially in compressed air, reducing TBM down time and improving worker safety. This process reduces the risk of ground loss caused during manned interventions.
- Multiple injection points along the TBM body – reduces the potential for ground to fall onto the TBM body.
- Multiple tail skin injection points – utilizing A+B grout with a rapid set to ensure complete filling around the segmental lining at all times. The provision of 100 percent redundancy of ports ensures that blockages are not a factor.
- Belt scales and volume control – allows accurate and reliable readings to be made of excavated material.

These features have been specified and incorporated on the AWV TBM. And, together with intentional reserve capacity, in all TBM thrust and mechanical systems, provided by the contractor will yield a performance that is best able to meet the anticipated challenges on the 2,740-m- (9,000-ft-) long tunnel drive.

Risk management

Risk management and the applicable apportionment of risk between the parties through contract provision is an important aspect of enabling larger diameter tunnels to be constructed successfully. It is the owner who has the ability to set the risk sharing model. And an educated owner will do so through discussion with the contractors who are capable of undertaking such large scale projects. Early contractor involvement (ECI), even if carried out through "discussion" rather than through any formal contractual process will allow the "appetite" of the industry to be gauged and due consideration given to the key issues and risks that impact upon a contractors perception of the contract and ultimately as to whether he will submit a qualified and competitive proposal. Target cost contracting, which is becoming the norm in Europe, allows the owner and contractor to set risk levels, the basis for change to costs and to better define the contractors' maximum financial exposure at an early stage. Target cost contracts may not be allowed through legislative regulation in all regions of the United States. But contractual measures can be established to equitably manage risk through measures such as:

- Owner to cover all or part of the additional cost due to inflation.
- Owner to cover premiums for bonds and insurances.
- Shared contingency funds for primary risks, e.g., intervention work and differing site conditions.
- Shared contingency fund for

the impacts of ground movement on property.

Details of the approach to establish an equitable risk management approach on the AWV project was presented at RETC in 2011.

TABLE 1

Comparative dimensions of a 4.3-m (14.3-ft) and a 17.4-m (57.4-ft) TBM.

Parameter	TBM diameter		Scale factor
	Reference TBM	Mega TBM	
Excavated diameter (ft)	14.3	57.35	4
Excavated volume/ advance cycle (cy)	23	596	26
Shield gap (in.)	19	15	0.8
Shield gap volume (cy/ft)	0.1	0.32	3.2
Tailskin gap (in.)	3.0	8.1	2.7
Annular grout volume per advance (cy)	1.6	28.0	17.5

Current works

The launch pit that has been formed by creating a deep wall of 1.5-m- (5-ft-) thick secant piles with drilled, tieback and cable anchors to create the required space to build the TBM. Hitachi Zozen delivered the TBM to the site in components up to 770 t (850 st) in weight in April 2013. The ability to transport large components significantly reduced the TBM installation time in the launch pit to a little more than three months. The works are currently under construction and the TBM launch took place in late July with an anticipated bore completion by the fall of 2014. At the north end of the project, TBM reception pit and excavation for the north operations building is currently ongoing and will be completed in time for the arrival of the TBM.

Conclusion

Large diameter tunnels are becoming increasingly viable as infrastructure needs of modern cities increase with the population. Technological advances in TBM manufacturing have allowed owners to investigate the potential for projects that, up to this point, have not been possible. In the road tunnel sector, tunnels in the range of 13 m - 14 m (42.6 ft - 46 ft) outside diameter are becoming commonplace in China and increasingly more so in the United States and Europe. The 15.5-m (51-ft) outside diameter Sparvo tunnel in Italy is leading the way in diameter for a major two-lane highway that was openly tendered. Single-bore, two-lane tunnels with limited height roadways, such as SMART in Kuala Lumpur, Malaysia and the ongoing Istanbul straight crossing tunnel, are offering traffic solutions that are matched to the local need. The 18.9-m (62-ft) outside diameter St. Petersburg project, if constructed, will take the world record away from the Alaskan Way Viaduct Replacement tunnel. Large diameter tunnels are here to stay, and projects such as the Alaskan Way Viaduct Replacement are setting the standards for others to follow and also to outperform as part of the industry's continuous improvement. ■

FEATURE ARTICLE

Ground freezing resolves complex challenges ahead of SEM tunneling

A complex soil profile and high water table, together with a below-grade active subway tunnel, an above-ground elevated railway line, and the heavily travelled Northern Boulevard all passing above the tunnel alignment, combined to make mining of New York's Northern Boulevard Crossing what is widely considered to be the most challenging portion of the multi-billion-dollar East Side Access project.

The Northern Boulevard Crossing is a vital link in this project which, when completed, will connect the Long Island Railroad to Grand Central Terminal in Manhattan. How the sequential excavation method (SEM) tunneling was successfully accomplished, despite the obstacles, was a textbook exercise in practical innovation coupled with close cooperation between the owner, the construction manager, Hatch Mott MacDonald, the designer, Parsons Brinckerhoff, the contractor, Schiavone-Kiewit, and specialty geotechnical contractor, Moretrench.

The 38-m- (125-ft-) long tunnel was to be mined 16.7 m (55 ft) below the ground water table between two 25-m- (85-ft-) deep access shafts and through soils consisting of glacial deposits including highly sensitive Bull's Liver-like silts, sands, boulders, till and bedrock. For short tunnel reaches through soft ground, SEM tunneling is the most economical option, but a relatively long soil stand-up time is required, together with adequate ground water control if the tunnel alignment is below the water table. However, several complicating factors limited available options for ground support and ground water control. Any disruption to subway or rail traffic was prohibited, eliminating vertical drilling for ground improvement, either from the surface or from within the subway tunnel. Horizontal drilling and jet and permeation grouting were considered. Jet grouting was rejected in light of the potential difficulties of working horizontally and below the water table. Permeation grouting was eliminated because of the high fines content in the soils. Conventional dewatering was also not an option since plumes in the vicinity of the tunnel alignment precluded lowering of the ground water.

Ultimately, the project team concluded that the most viable option of meeting all the constraints was the designer's scheme to use horizontal ground freezing to create a frozen arch above the tunnel alignment. This

Gregory T. Ziegler, Patrick Rooney and Paul C. Schmall

Gregory T. Ziegler and **Paul C. Schmall**, members UCA of SME, are vice president and project manager and vice president and chief engineer, Moretrench, and **Patrick J. Rooney**, member UCA of SME, is vice president-operations, Schiavone Construction Co. email gziegler@mtac.com, pschmall@mtac.com.

approach would provide excavation support and ground water control in one operation and, at the same time, obviate concerns regarding disruption to subway and rail traffic. Ground freezing was also ideal for the difficult soil conditions since obstructions are simply incorporated into the frozen soil matrix, and the freeze could be implemented through pre-existing pile clusters and the soil-rock interface, providing a tight water cutoff.

Project challenges

Freeze pipe alignment is critical to every ground freezing project. Design of the freeze is directly related to the spacing between the pipes. Any deviation greater than design tolerance can result in windows of unfrozen soil within the formation. A complicating factor for this project was that the freeze pipes had to penetrate four clusters of 304-mm (12-in.), concrete filled steel pipe piles supporting the elevated railway line, as well as cobbles, boulders and an undulating rock surface.

The pipes would also be installed from below the ground water table through a thick layer of Bull's Liver-like silty sands and silts. This material is historically very sensitive to construction-induced disturbance, likely leading to loss of ground, settlement and possible pipe movement. The Bulls Liver-like soils would also be susceptible to the formation of ice lenses and heave with the formation of the freeze. Ice lenses typically exert forces in the direction of the temperature gradient. For vertical freezes, the forces are lateral and are rarely an issue. For horizontal freezes, however, they are vertical. This would exacerbate heave of the structure, particularly at shallow depth.

Tunnel excavation prior to the removal of internal braces.

And last, but by no means least, the bottom of the existing subway tunnel beneath Northern Boulevard would be within just a few feet of the top of the frozen arch. Controlling heave in this zone during the freezing operation and settlement during thawing was important to avoid any adverse effect on these structures.

Design

The need for such extremely close control during the ground freezing operation drove an innovative ground freezing design that included provision for heave and settlement control. Ahead of freeze pipe installation, pre-grouting with horizontal compaction grouting methods was performed in the soils beneath the subway box to improve the ground and fill any open, water-filled zones. Compensation grout pipes were also installed to mitigate any settlement of the overlying structures during freeze pipe installation. A specially formulated noncementitious grout was formulated that essentially mimicked the strength and consistency of the in situ soils but would not leave cemented obstructions for any subsequent heave control that might be required.

If heave occurred during freezing, soil extraction would be performed through casings installed between the frozen arch and the base of the subway box. Soil extraction, or underexcavation, has been used previously to correct differential settlement, albeit on only a handful of projects. But it has never been attempted below the water table. However, given Moretrench's experience of drilling and working with difficult Bull's Liver-like soils below the water table, particularly on the adjacent East Side Access section, there was every indication that this approach would be viable, should it be required. A secondary arch of heat pipes was also incorporated to control the outward growth of the freeze.

Provision was also made for compensation grouting to be performed through the preinstalled pipes to mitigate structural settlement during thawing of the frozen ground following tunnel completion.

Ground freezing

The subsurface challenges on this project, with horizontal drilling to be accomplished below the water table through the sensitive soils, added to the complexity of the project, as well as restricting drilling methodologies. The specialty geotechnical contractor, therefore, instituted considerable measures to ensure that freeze pipe installation would be within tolerances, while also preventing ground loss.

Drilling for freeze pipe installation was a multiphase operation in line with the contractor's sequence of excavation that called for the installation of large concrete bracing slabs as the excavation proceeded. Once the slabs were poured, the next level could be excavated and the next set of freeze pipes drilled. High-speed coring platform drills, tracked geotechnical rigs, and a dual head skid mounted geotechnical drill were used to overcome the changing geology as the excavation progressed. Some of the most difficult drilling proved to be through the large boulders just above the undulating bedrock surface while maintaining alignment.

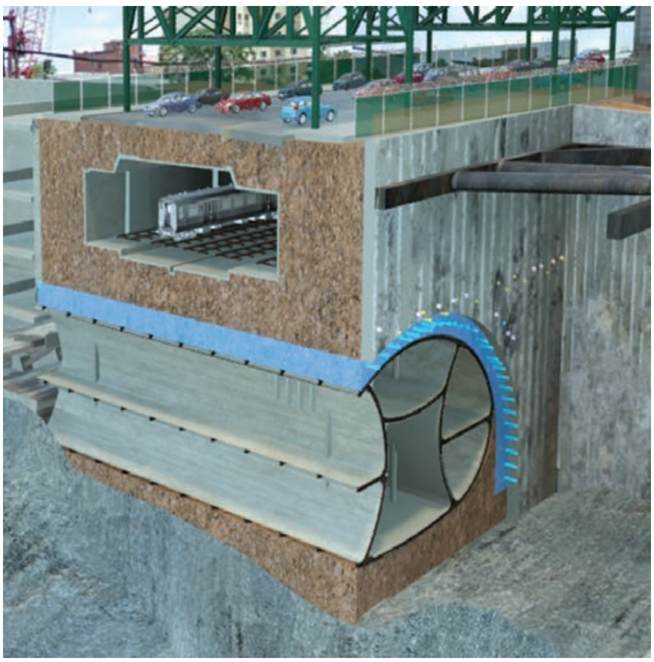
The bottom hole on each side of the frozen arch needed to be drilled full-length through competent rock to allow an impenetrable frozen seal to the bedrock. Accurate horizontal drilling, under almost 25 m (80 ft) of hydrostatic head, from drill pits blasted into the rock to accommodate the rigs, was a significant challenge. The specialty contractor, therefore, cored these holes and retrieved the cores to verify the rock quality.

Completed boreholes were surveyed for borehole deviation with a gyro survey tool that can be used in a horizontal orientation. The results of these deviation plots were used to select redrill locations, if necessary, and also incorporated into the thermal modeling that assisted Moretrench in verification of the as-built design.

The specialty geotechnical contractor used

Drilling of the bottom hole on each side of the frozen arch from drill pits blasted into the rock was necessary to allow a frozen seal into the bedrock.

The final design of the SEM was a modified three-over-three drift plan and took into consideration the in situ soil conditions observed during excavation of the early access chamber.



a large mobile freeze plant with two 400-hp rotary screw compressors. Anhydrous ammonia refrigerant was circulated in the closed loop freeze plant. Brine (29 percent calcium chloride solution) was cooled in a freeze plant's titanium plate heat exchanger and pumped through a piping system to all freeze pipes by a distribution manifold system. This included a distribution pipe underneath Northern Boulevard to service freeze pipes on the opposite side of the street from the main early access chamber.

A heating system was installed in 14 combination compensation grout/heat pipes drilled in the secondary arch above the crown of the freeze to limit the growth of frozen ground should excessive movement of the subway structure occur during formation of the frozen arch.

Once temperatures indicated formation of the frozen arch, a drain-down test of the internal water was conducted. Results of the test and subsequent temperature verification revealed two warm spots, indicating "windows" in the frozen arch due to moving ground water. A grouting program was initiated by the specialty geotechnical contractor to address this, and sodium silicate and cement-bentonite grouts were pumped to seal off the windows. A second drain-down test was conducted following the grouting program, with further temperature profiling confirming that closure of the frozen formation had been achieved, allowing mining of the tunnel to begin.

SEM tunnel excavation

The final design of the SEM was a modified three-over-three drift plan, where the two center drifts were revised to reflect a top heading, bench and invert excavation. The final design took into consideration in situ soil conditions observed during excavation of the access chamber. Drifts 1, 2 and 5 were excavated using a top heading and bench approach.

Round lengths were limited to 1.2 m (4 ft) in the upper drifts and 2.4 m (8 ft) in the lower drifts. Concurrency of excavation in the drifts was limited because of design limitations and short tunnel length. One of the unique difficulties anticipated to be encountered during this particular SEM was the fact that the alignment passed through underpinning piles supporting the elevated subway above, as well as the existing pile clusters that the underpinning piles had replaced. As an additional step during the cycle, the existing piles had to be cut at the excavation interface, while the excavation had to work around the temporary underpinning piles until the final liner was installed.

Initial ground support consisted of an insulating layer of shotcrete 76 mm (3 in.) to address the temperature impact of the ground freeze on the initial shotcrete lining. This was followed by installation of lattice girders at 1.2 m (4 ft) spacing, matching the geometry of the drift configuration, two layers of welded wire fabric and 305 mm (12 in.) of shotcrete.

Shotcrete pumps, loaders and excavators used during the excavation were fitted to accept various attachments including the bucket, hammer and grinder. Plant-batched shotcrete was primarily used, with dry mix stored on site for emergency conditions.

Given the proximity of the excavation to surrounding structures (subway, elevated subway, buildings and arterials), instrumentation and monitoring was critical to the operation. A combination of automated monitoring of existing structures as well as on site survey of line, grade and deflection yielded little or no movement.

After excavation was completed and the temporary interior sidewalls were removed, the final lining was installed. This consisted of 14 ring girders, necessary to support the pile clusters, #11 radial bars, #7 bars placed longitudinally, waterproofing, and a 762 mm (30-in.) pneumatically applied concrete final lining. The loads were transferred from the underpinning piles back to the original foundations after the final lining had achieved sufficient strength. Following additional monitoring to confirm stabilization and settlement, the underpinning piles were removed and the final lining was restored at the penetration points. Finish track work will be performed in future contracts.

Thawing and compensation grouting

Freezing of the protective arch was terminated in late February 2013, and a natural thaw method was selected by the owner. Settlement monitoring is in place for the roadway, underground subway and elevated train tracks. Previously installed compensation grout pipes have been profiled to determine areas of frozen soils. As of August, there is still frozen ground. This information is being used to develop a compensation grouting plan to address minor settlements that have occurred.

The rigorous controls instituted by specialty geotechnical contractor Moretrench throughout the Northern Boulevard crossing project paid dividends. Only 13 mm (0.5 in.) of heave occurred during the freeze and activation of the heat pipes, soil extraction, and pre-excavation compensation grouting were not required. ■

FEATURE ARTICLE

Equipment adds efficiency, safety to cross passage work

From a vast army of workers to gargantuan machines to immense volumes of material being moved, almost everything about the Port of Miami Tunnel (POMT) project points to tunneling on a massive scale. Almost.

The star of this underground and underwater show is a Herrenknecht tunnel boring machine (TBM,) nicknamed "Harriet" by a local Girl Scout troop. With her 12.9-m- (42.3-ft-) diameter cutting head and a total length of 139 m (457 ft), Harriet is boring through thousands of cubic meters of clay, dirt and sand, which is often mixed with coral and other materials, to create two 1,280-m (4,200-ft) traffic tunnels connecting Watson Island and the Port of Miami (Dodge Island) beneath Biscayne Bay, FL.

But in the midst of all of the oversized equipment and machines, a strong contender for the best supporting nod goes to a relatively tiny machine: the Brokk 400. Bouygues Civil Works Florida crews are using the compact, remote-controlled and electric-powered machine to excavate five cross passages between the twin traffic tunnels. The passages will be essential to the safety of people who drive their vehicles under the bay every day.

Under-bay excavation

The POMT project, launched in October 2009, consists of three primary components: excavation and construction of the traffic tunnels, connections to the Port of Miami's roadway system, and widening of the MacArthur Causeway Bridge. Bouygues Civil Works Florida is the design-build contractor and one of the lead companies on the project.

When the twin tunnels are complete, they will run under what's known as Government Cut, the main shipping channel in Biscayne Bay. At their deepest points, they will be 36 m (120 ft) below the floor of the bay. Each of the 12-m- (39-ft-) diameter tunnels will comprise two traffic lanes, curbs, walkways, ventilation fans and other safety features. Eastbound traffic will be moving into the port and westbound vehicles will be heading out.

The cross passages will provide emergency egress for drivers and passengers. They range in height and width from 3 – 4.2 m (10 - 14 ft), and from around 4.8 m (16 ft) to nearly 21 m (70 ft) in length. They are large enough to allow people to escape from one traffic tunnel to the other, and all five also will have additional room to store equipment for maintenance, pumping and other uses.

The Brokk 400 came to Miami courtesy of Bouygues plant and equipment manager Alain Mazzia, who first ran into one of the compact machines several years ago on a nuclear waste project in France. On that job, Mazzia was part of the team that dug two 500-m (1,640-ft) deep shafts, using a Brokk to excavate galleries at the bottom. When he looked at the complicating factors of excavating the POMT cross passages, the Brokk came to mind.

His reasons for bringing the Brokk 400 to Miami were straightforward. First, at only 4.2-m (14-ft) long, 1.5-m (5-ft) wide and less than 2-m (6-ft) tall, the Brokk 400 is small enough to stay out of the way when it's working in the main tunnels, where crews and larger machines are

The Brokk 400 rests in one of the main traffic tunnels. The bucket is one of four attachments – beam manipulator, bucket, breaker and drum cutter – that crews are using to excavate the five cross passages between the main tunnels.

The Brokk 400 waits in one of the main Port of Miami traffic tunnels. With the machine's small size, cross passage crew members can keep it out of the way of other crews and equipment moving in and out of the tunnels.

constantly coming and going. It also has exceptional maneuverability and can move freely inside the relatively cramped space of the passages. Next, since it is powered by an electric motor, there are no emissions. And while the Brokk 400 is small, it is powerful. With nearly 6,900 ft-lbs of breakout force, it can break through extremely hard and artificially reinforced ground. Finally, and most importantly, since it is remote-controlled, it removes operators and other crewmembers from potential danger.

"This is the perfect machine for this part of the project," Mazzia said. "With the cramped space, challenges in safe excavation and the need to stabilize the ground around the passages, the Brokk's power, precision, size and versatility make it ideal."

Dig, break, hold, repeat

The miners start and finish each cross passage by first cutting a rectangular hole through the concrete wall of the main tunnel, using the Brokk 400 to break up and remove the concrete. Once they move beyond the entry and before they come too close to the point where the passage will connect to the other traffic tunnel, they put the Brokk to work with four attachments – a breaker, a drum cutter, a bucket and a beam manipulator.

First comes the quantitative excavation in which the crews use the Brokk's breaker to remove the largest amount of material, break it down and size it. In areas where the ground is reinforced with grout or frozen for stability, they use the drum cutter, which excavates with less vibration. Then they use the bucket to load material into carts and remove it from the passage. The crews also use the Brokk, along with a specially designed beam manipulator, to place support ribs in the passages.

The qualitative excavation takes advantage of the precision and sensitivity of the Brokk's remote control to approach what Gregory Berger-Sabbatel, the cross passages field engineer, calls the "theoretical excavation limits" without overexcavating. These are areas outside of the passage's predetermined dimensions, or near the end of the passage where it will intersect with the traffic tunnel.

Steel support rib installation has provided a unique challenge, and Brokk retooled its standard beam manipulator specifically for the job. The ribs are horseshoe-shaped or circular, depending on the passage in which they are being placed. They come in several sections that need to be connected, and the full assembly needs to be attached to the inside diameter of the cross passages before excavation can move forward. In all of the tunnels, the ribs are placed at 1-m (3.5-ft) intervals.

The Brokk 400's three-arm design, which expands its reach horizontally and vertically, comes into play in placing the ribs. The beam manipulator grasps the top section of a steel rib, carries it to the installation point, lifts and positions it, then holds it in place while miners bolt the lower sections to it. With the ribs in place, the miners install wire mesh around the walls and ceiling and a contractor applies shotcrete. Then the process starts over again: mine, break and remove materials, reinforce with ribs, install wire mesh and apply shotcrete. Changing attachments before each task takes no more than 15 minutes.

"The multiple attachments, and how easy they are to put on and take off of the Brokk, really save time," said Eric Deltour, the Bouygues cross passages superintendent. "We keep them at the entrance to the cross passage so they're ready when we need them. When we change tasks from excavation to spoil removal to rib installation, changing tools is quick and efficient."

But before speed and efficiency, the primary concern for this type of project is safety. "The main danger in any mining is a ground collapse, and there is more of a chance for that during the quantitative excavation," said Berger-Sabbatel. "With the Brokk, the operator can stay out of the way with the remote control. The machine is the only thing out front, so everybody is safe."

Power and intensity

August Scalici, the field sales application expert at Brokk and an experienced miner himself, trained Deltour, Berger-Sabbatel and the crew members who are now excavating the cross passages. "It's an intense process," he said. "They have to keep water out while they're digging the passage and, when it's done, it has to be water tight and withstand the extreme pressure of the dirt on top of it. These guys are pros, and it's pretty interesting to see how it's all getting done."

Getting it done, Deltour said, requires leveraging all of the strengths of the Brokk that attracted Mazzia to the machine in the first place. For example, the small size comes into play not only inside the cross passages, where the Brokk can maneuver easily compared to other machines, but also in getting into the cross passage in the first place.

"The most challenging aspect is definitely the confined space," Deltour said. "This is different than traditional mining, where the miners have room to excavate. Also, the openings from the main tunnels into the cross passages are relatively small compared to the size and volume of the excavation we're doing. With the Brokk, our crews are able to get right in there and easily get the excavated material out."

The Brokk's power has been on full display as it has broken through materials being used to reinforce the soil and reduce the potential for cave ins. "We're treating the ground prior to the excavation, and in some cases during the excavation, to increase the ground strength," Berger-Sabbatel explained. "It keeps the cross passages stable and minimizes risk."

The soil is being stabilized around the cross passage excavation areas in two ways. The first method consists of creating a cohesive and watertight plug from the surface with Cutter Soil Mix panels completed by Malcolm Construction Co. out of San Francisco, CA. The second method is to freeze the ground by super cooling the water in the soil. This is accomplished by circulating chilled liquid brine through small pipes. Nicholson Construction Co. (Cuddy, PA) is drilling and installing the freeze pipes and Moretrench (Rockaway, NJ), is handling the freezing process.

Not to be overlooked is the Brokk's precision, which has been a must because the locations of cross-passage openings in both traffic tunnels are predetermined. "Before the excavation even begins, our surveyors align a laser along the cross passage," Berger-Sabbatel explained. "This gives us offsets from the laser point so we know how much left, right, up or down we need to excavate. The accuracy of the Brokk makes it much easier to follow the alignment given."

The little big guy

If everything remains in alignment and on schedule – in the tunnels where Harriet is eating her way from one side of Biscayne Bay to the other and in the small cross passages where the Brokk continues to make headway rib by rib – the POMT project will be completed and open to traffic in May 2014.

When it's all said, done and dug, there will be lessons learned for the companies who took on the project. For the men who relied on the Brokk 400 to excavate and fortify the five cross passages, it's this: even when you're talking about tunneling on a massive scale, never underestimate the little guy. ■

FEATURE ARTICLE

Washington, D.C. hosts 2013 RETC

Every two years, industry leaders and practitioners of tunneling and underground construction gather at the Rapid Excavation and Tunneling Conference (RETC) to learn from their peers about the most recent advances and breakthroughs in this unique field. Industry experts from around the world highlight their most recent projects and share real-world experiences. They also share with their colleagues new technologies and methodologies that attendees can take home to their respective projects.

The 2013 RETC was held June 23-26 in Washington, D.C., itself home to several major tunneling and underground construction projects. The conference is sponsored by SME. Attendance was 1,384 professionals. The accompanying exhibit hosted 159 companies in 188 booths.

A few of the topics covered in the technical sessions dealt with caverns and large spans, contracting practices, tunnel linings, design and planning, geotechnical considerations and instrumentation.

The conference was preceded by four short courses, all well attended. They were "Grouting in Underground Construction," "Tunnel Lining Design," "Microtunneling Application" and "Risk, Uncertainty and Hard Decisions." In addition, a sold-out field trip to D.C. Water's Blue Plains Tunnel took place following the conference. The Blue Plains Tunnel is part of the agency's Clean Rivers Project.

Also during the meeting, three students each received $5,000 scholarships from the UCA of SME, while another three students each received $2,500 scholarships from RETC (See page 53).

Technical programming

The technical programming during RETC included more than 100 papers presented in 22 sessions. Each paid attendee received a copy of the proceedings. The 1,364-page proceedings volume, edited by Michael A. DiPonio and Chris Dixon, is available from SME as a hardcopy, including a CD, or as an eBook. Contact SME Book Sales Coordinator, phone 303-948-4225, 303-948-4200 or 800-763-3132, email books@smenet.org or kiser@smenet.org, online www.smenet.org/store; $139 member; $119, student member; $179, nonmember.

Steve Kral, Editor

The following is a sampling of some of the presentations.

Highly successful ground support for high cover: A case study of the West Qinling rail tunnels. China's West Qinling rail tunnels are being excavated under high cover of at least 1,000 m (3,280 ft), for the entire length of the bored tunnels. B. Khalighi, of the Robbins Co., described a unique system of ground support that was designed to combat difficult ground conditions. Two 10.2-m- (33-ft) diameter main beam tunnel boring machines (TBM) were engineered around the concept of those versatile support systems, which allow a variety of types of support to be installed in varying conditions.

Tunneling in Belgium. Three major infrastructure projects in Belgium are currently being built by Germany's Wayss & Freitag Ingenieurbau. K. Rieker discussed a few of the construction challenges of the projects and some of the unique construction methods that were developed and successfully implemented. Some of the challenges included tunneling beneath live runways at Brussels International Airport, construction of a rail tunnel under an existing road tunnel in Brussels using hand-dug diaphragm walls and pipe-jacking and slurry TBM tunneling beneath the harbor of Antwerp with minimal cover.

Challenges of EPB tunneling in Prague. In November 2012, two earth pressure balance (EPB) machines completed two 4.8-km- (3-mile-) long tunnels as part of the Prague Metro V.A.'s subway extension in Prague, Czech Republic. This was the first time EPB technology was used in the country and, as a result, according to K. Rossler and D. Cyron, of Metrostav a.s. Praba, the project became a testing ground for various solutions to overcome challenges of the mechanized excavation.

To comply with the subway extension construction schedule, the excavations of three stations and EPB tunnels had to run in parallel. So mining of the three underground stations had to be done before the EPBs arrived. To allow for an early start of the station's finishing works, an intermediate openpit was built for relocating the EPBs. This cleared the first two stations for final lining formworks.

Summary and lessons learned from New York City tunneling instrumentation. New York City has a number of major tunneling and underground construction projects. Three large tunnel projects for subways and regional rail systems are currently under way, along with several smaller projects. D. Roy, of GZA GeoEnvironmental, summarized the geotechnical instrumentation programs required for each of the three large projects — the East Side Access, the No. 7 Line Extension and the Second Avenue Subway projects.

The speaker's intention was to provide insight into the unique specification and contractual practices for the geotechnical instrumentation requirements of each project. Based on each project's experience, the speaker provided recommendations for geotechnical instrumentation procurement, specifications, instruments and data management systems.

Construction challenges for the city of Austin's Deep Interceptor sewer tunnels. Construction of the Austin Downtown project took place between 2010 and 2012. It included 6,280 m (20,600 ft) of 2.4-3-m- (8-10-ft-) diameter bored tunnel, lined with 915-2,300-mm (36-90-in.) polymer pipe. Six new 21-27-m (70-90-ft) deep, 3.6-7.6-m- (12-25-ft-) diameter shafts were excavated using a variety of construction techniques. Also included were tie-ins to the Toomey Lift Station, the Govalle Tunnel and diversions to the South and North Austin Interceptor sewers. E. Dawson et al. described the challenges involved with the project including low cover, grouting of ground water inflows and three crossings of Lady Bird Lake.

Customized concrete form design for South Cobb Tunnel project. The South Cobb Tunnel project in Austell, GA includes an 8.8-km (5.5-mile), 8.23-m- (27-ft-) excavated diameter tunnel, with a 7.32-m (24-ft) finished diameter, cast-in-place concrete lining. Three tunnels are connected to the bottom of the 12.2-m- (40-ft-) diameter South Cobb shaft. They are the 7.32-m- (24-ft-) diameter TBM tunnel, the 7.32-m- (24-ft-) diameter tail tunnel and the 7.32-m- (24-ft-) diameter pump station tunnel.

R. Chen, of J.F. Shea Construction, described how customized concrete forms were designed and fabricated onsite to satisfy concrete lining requirements. Due to their large dimensions, the tunnel-shaft junctions were difficult to design and fabricate. Chen said that AutoCad 3D is an effective tool to characterize the geometry of the complicated shapes required by the tunnel-shaft junction.

Lake Mead underwater intake structure and tunnel connection. Mead J. Nickerson, J. McDonald and W. Kunz, all with S.A. Healy, provided an overview of Nevada's Lake Mead Intake No. 3 Tunnel and Shafts Project. This project includes a 183-m- (600-ft-) long vertical intake shaft; a 4.8-km- (3-mile-) long TBM-mined, 6.1-m- (20-ft-) inside diameter segmentally lined tunnel; and a composite concrete and stainless steel intake structure that is placed within 100 m (330 ft) depth of water at the bottom of Lake Mead.

The authors discussed the operations related to the setting of the intake structure into the excavated shaft located in the bottom of the lake. The work consisted of placing a guiding frame into the excavated hole to seat the intake structure in the proper position, surveying of the intake location and placement of tremie concrete around the submerged intake structure.

A review of portal design concepts for mountain tunnels. Tunnels located in mountainous terrains must enter and exit through portals, or transition zones, between surface and underground construction. So planners must consider the technical aspects of slop stability and tunnel stability. D. Richards, et al., said that because the portal is near the surface, the ground is usually more weathered, requiring more intense ground support than in deeper, less weathered zones.

The authors reviewed the influence of topography, climate, rock type and rock structure upon tunnel portal stability and design. They also considered tunnel variables such as tunnel size, tunnel opening geometry, pillar width for parallel tunnels and the risk of landslides, rockfalls or avalanches at the portals. They also presented some case studies to illustrate practical portal design solutions for initial and final ground support for the surface and underground aspects of the portal zone.

Planning and development of the Waterview connection tunnels. The government of New Zealand has targeted seven major infrastructure projects to upgrade the country's transportation system. The largest of these projects was the completion of the Western Ring Route. It is the largest and most complex highway project ever undertaken by New Zealand.

The water connection tunnels is the key part of the project, as they will provide the missing connection between SH20 and SH16, according to T. Parker, et al. The 2.5-km-long (1.5-mile-) twin, three-lane tunnels will be excavated by the largest EPB tunnel boring machine used in Australasia, the authors said. The project has been in the planning stages for more than 10 years but was stalled for various reasons. When the global financial crisis hit in early 2009, the Waterview connection tunnels project was fast-tracked as an economic stimulus project. The authors described the history and planning of the project, along with the challenges that were presented by the concurrent procurement and planning approval process required to meet an ambitious procurement timetable.

Upcoming UCA of SME events

The UCA of SME's annual George A. Fox conference is scheduled for Jan. 28, 2014, at the Graduate Center, City University of New York. Also, the 2014 North American Tunneling conference will be held June 22-25, 2014 at JW Marriott Hotel in Los Angeles, CA. For more information, contact SME Meetings Department, phone 800-763-3132, 303-948-4200, email sme@smenet.org, online www.smenet.org. ■

FEATURE ARTICLE

Istanbul Strait Road Tube Crossing to link Asia and Europe

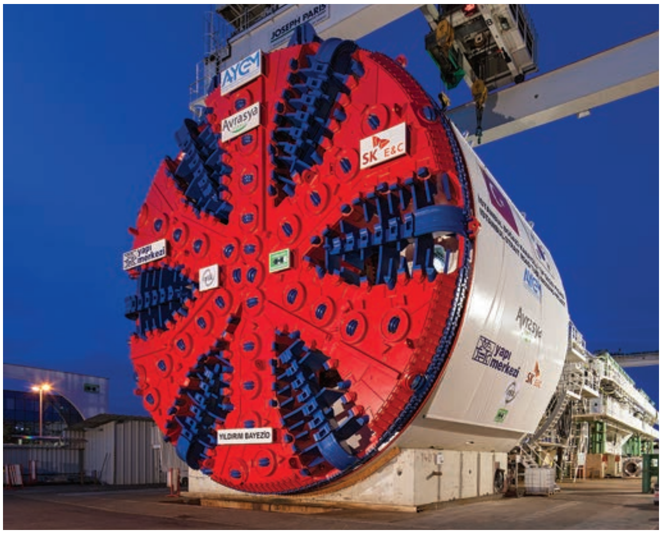
A large-diameter road tunnel will cross beneath the strait in Istanbul and expand the infrastructure bottleneck between Europe and Asia. The technical planning of the tunneling operations poses complex challenges. Therefore, the construction consortium ordered a specially adapted tunnel boring machine (TBM) from Herrenknecht. The 13.6-m (44.6-ft) machine, a Mixshield, was completed in early July 2013 in Schwanau, Germany.

To get from the European to the Asian side of Istanbul, people and goods have to cross the Bosporus Straits. So far, two road bridges as well as ferries provide the only transport link between the two parts of the city and the two continents. The tense traffic situation for the nearly 14 million residents of the city and for international transit traffic should be improved considerably thanks to the construction of a new road tunnel under the Bosporus.

"The project is certainly one of the most challenging tunneling operations currently being addressed in the world," said Herrenknecht project manager Georg Schleer. The route of the "Istanbul Strait Road Tube Crossing Project" runs around 100 m (330 ft) below sea level at its deepest point. The interior diameter of the tunnel will be 12 m (40 ft) so that two lanes in each direction can be accommodated. They will extend one above the other on two levels. 3.34 km (2.1 miles) of the tunnel with a total length of 5.4 km (3.3 miles) are being created by a 13.6-m- (44.6-ft-) diameter Herrenknecht TBM that will begin its underground mission from a launch shaft on the Asian side.

Extensive geological and hydrogeological preliminary investigations showed that the tunnel builders must reckon with water pressures of up to 12 bar. The executing Turkish-South Korean construction consortium YMSK, consisting of Yapı Merkezi Insaat ve Sanayi A.S. and SK Engineering & Construction Co. Ltd., ordered a specially developed Herrenknecht TBM type Mixshield for this project. "The machine's engineering presented us with a real challenge," said Schleer. The main task, he explained: "Even if the pressure is extremely high up front at the tunnel face, the client must be able to change the cutting tools quickly and safely if necessary." The result was a new type of cutting wheel, where time- and cost-consuming access for maintenance work under pressurized air can be reduced. The complete cutting wheel is accessible from the rear of the machine under atmospheric pressure. From there, all disc cutters and a large part of the cutting knives can be changed safely. In addition, the mixshield is equipped with a special, newly developed lock system. It allows pressurized air access at well more than 5 bar where necessary.

This Herrenknecht 13.6-m- (44.6-ft-) diameter TBM was designed specifically for the project.



To detect strong material wear early and to tackle necessary maintenance accesses in a targeted manner, wear detectors are integrated into the excavation tools as well as in the steel construction of the cutting wheel. Moreover, the disc cutters are equipped with the disc cutter rotation monitoring (DCRM) monitoring system, which was developed by Herrenknecht. It provides data about the rotational movement and temperature of the disc cutters in real time to the machine operator in the control container. Thus, conclusions can be drawn regarding the condition of the tools and change intervals can be better planned.

In the Herrenknecht factory in Schwanau, the Mixshield was named Yildirim Bayezid. This is the name of a sultan who drove the expansion of the Ottoman Empire successfully forward at the end of the 14th century. After its dismantling, transport and assembly at the jobsite, the Herrenknecht Mixshield will start its tunneling work in Istanbul at the end of 2013. Following the opening of the tunnel, the new quick link between Europe and Asia will initially be operated for 26 years by the joint venture Avrasya Tüneli Isletme Insaat ve Yatırım A.S. (ATAS) and subsequently handed over to the government of Istanbul.

The Bosporus was crossed with a tunnel boring machine for the first time in the years 2008-2009. An earth pressure balance shield from Herrenknecht was used for the construction of a water tunnel. In addition, a total of about 56 km (33 miles) of Istanbul's metro are being built using machines produced in Schwanau. ■

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	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
Purple Line - Plymouth Tunnel	MD Transit Administration	Baltimore	MD	Subway	1,000	30x40	2015	Under design
Anacostia River Tunnel Northeast Branch Tunnel Northeast Boundary 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	Awarded to I-H-P JV Under design Under design Pre Qual under way
Biscayne Bay Tunnel	Miami Dade Water and Sewer Dept.	Miami	FL	Sewer	5,200	12	2013	Nicholson low bidder
Olentangy Relief Sewer Tunnel	City of Columbus	Columbus	OH	Sewer	58,000	14	2014	Under design
Blacklick Creek San. Interceptor Tunnel	City of Columbus	Columbus	OH	Sewer	24,000	10	2014	Under design
Alum Creek Relief Tunnel Phase 1 Phase 2	City of Columbus	Columbus	OH	Sewer	30,000 21,000	18 14	2015 2017	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
Shoreline Storage Tunnel	NEORSD	Cleveland	OH	CSO	16,100	21	2021	Under design
Southerly Storage Tunnel	NEORSD	Cleveland	OH	CSO	17,600	23	2024	Under design
Big Creek Storage Tunnel	NEORSD	Cleveland	OH	CSO	19,500	20	2026	Under design

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Ohio Canal Interceptor Tunnel	City of Akron	Akron	OH	CSO	6,170	27	2014	Under design
Northside Interceptor Tunnel	City of Akron	Akron	OH	CSO	6,850	24	2021	Under design
ALCOSAN CSO Program	Allegheny Co. Sanitary Authority	Pittsburgh	PA	CSO	35,000	20	2016	Under design
Fall Creek	Indianapolis DPW	Indianapolis	IN	CSO	19,600	18	2016	Under design
White River Tunnel	Indianapolis DPW	Indianapolis	IN	CSO	27,800	18	2016	Under design
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	Bid date 5/30/13
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	Tutor-Perini low bidder
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	Bid date 6/25/2013
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	Pre Qual underway Under design Under design
JWPCP Effluent Outfall Tunnel Project	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	McNally low bidder Ad 3rd Q 2013
Second Narrows Tunnel	City of Vancouver	Vancouver	BC	CSO	3,600	14	2013	Under design

UCA Executive Committee issues call for nominations

The UCA Division seeks recommendations and nominations from all UCA members for interested individuals to serve on the UCA Executive Committee for the term 2014 to 2018. Current bylaws allow a 19-person executive committee. Membership on the committee consists of three officers, chair, vice chair and past chair, and four directors from each of the following areas: engineers, contractors, owners and suppliers. The UCA Executive Committee seeks a balanced representation from the four areas, but it has the option to have more members in one or more areas and fewer members in others.

If you would like to nominate someone for consideration, forward your recommendation to Mary O'Shea (oshea@smenet.org) at SME headquarters by Nov. 25, 2013. Please remember that the individual must be a member of the UCA of SME. Staff will compile all nominations for the UCA Nominating Committee's consideration. A few items are requested to help with the committee's decision.

- Identify in which of the four areas the individual should be considered for service: engineer, contractor, owner or supplier.
- Provide a brief biography or résumé outlining the person's industry experience and service to UCA and other professional organizations. ■

UCA SCHOLARSHIPS

UCA of SME scholarships awarded every year

Every year, the Executive Committee of the UCA of SME awards several $5,000 scholarships to the most qualified candidates who apply for the stipends. In 2013, three $5,000 awards were made. In addition to the cash awards, travel expenses and free registration to the annual conference are also given to the recipients.

Applicants are required to be enrolled in an undergraduate or graduate academic program related to tunneling or underground infrastructure. Hands-on experience in the underground environment is also a plus. The Scholarship Committee of the UCA evaluates all applicants based on categories that include, but are not limited to, the candidates' passion for underground work, their potential for success and academic achievements to date, the strength of the candidates' recommendations from educators or employers, any prior UCA involvement and their financial need as presented in the application.

The UCA Executive Committee and the Scholarship Committee are asking all UCA members to promote and disseminate the availability of the scholarship and the application process within their organizations — especially to relatives and friends.

Any prior experience, such as internships or summer jobs in the tunneling or underground industry in the planning, design, construction or operation of tunnels and shafts, is a benefit to the applicant being considered. The applications are available at www.smenet.org/scholarships. ■

UCA presents scholarships at RETC

The Executive Committee of the UCA of SME presented three, $5,000 scholarships at the UCA luncheon during the Rapid Excavation and Tunneling Conference (RETC) in Washington, D.C. this June. Each scholarship recipient also received full conference registration, airfare, hotel accommodations, the proceedings volume, tickets to conference events and $200 for other expenses.

HAMED LASHKARI holds a bachelor of science degree in mechanical engineering from the University of Tehran. He is currently studying for his master of science degree in mechanical engineering at The Pennsylvania State University. He has worked for The Robbins Co. maintaining and improving the disc cutter monitoring system mounted on the TBM in Kuala Lumpur, Malaysia. He is a member of SME and the American Society of Mechanical Engineers.

SEAN WARREN holds a bachelor of science degree in geology and a master of science in engineering from the University of Nevada-Reno (UNR). He is currently a Ph.D. candidate in geological engineering at UNR. He is a member of the Mackay School of Mines' SME student chapter and attends the SME Northern Nevada section meetings.

As a staff geological engineer for Golder Associates, Warren worked at the Red Dog Mine in Alaska, at a remote mine site in Armenia, at a jungle camp in Surinam and at a gold mine in Bolivia.

UCA SCHOLARSHIPS

HAMED ZAMENIAN holds a B.S. degree in civil engineering from Shomal University in Iran. He is currently pursuing a master of science degree in construction engineering management technology at the Purdue School of Engineering and Technology at Indiana University. He is a graduate assistant in the Center for Underground Tunneling Education and Research (CUTER), a cooperative tunneling venture between the city of Indianapolis and the university. He is also assisting the director of CUTER in preparing a tunneling construction course for undergraduates, graduate students and industry professionals. Zamenian is a student member of SME, and the North American Society of Trenchless Technology. ■

Artie Silber, UCA Scholarship chair, presents a UCA scholarship award to (l-r) Hamed Zamenian, Hamed Lashkari and Sean Warren.

RETC SCHOLARSHIPS

The Rapid Excavation and Tunneling Conference (RETC) Executive Committee annually awards one or more scholarships to students who wish to develop their skills in the rapid excavation and tunneling field. The committee awarded two scholarships at the June 2013 RETC conference in Washington, D.C. Erin Keogh, an engineering senior at the Colorado School of Mines (CSM), and Marion King, a junior in the Mining and Minerals Engineering Depatment at Virginia Tech, each received $2,500 scholarship plus expenses to attend the 2013 RETC.

Recipients

ERIN KEOGH worked as an engineering intern in the fabrication shop at the Kiewit Infrastructure Underground District in Pacific Junction, IA. She assisted in cost analysis and project scheduling and worked in the machine shop, where she was able to observe the rebuilding of large pieces of tunneling equipment. She also worked with a software company in the development of a mine rescue simulator and emergency response training, which was presented at the SME Annual Meeting in Denver, CO. She assisted in the training of the U.S. Army 911th Engineer Company (technical rescue) when they attended underground search and rescue training. Keogh is a member of the Society of Women Engineers, the American Society of Civil Engineers, the UCA of SME student chapter at CSM and a member of the CSM student mine rescue team.

MARION KING has worked as an intern for Alpha Natural Resources in underground and surface coal operations. She also worked as a co-op student at the Mosaic Co.'s potash mine in Florida and for Morton Salt in Louisiana. King is a member of the Burkhart Society, the SME Student chapter at Virginia Tech, Women in Mining, the Wesley Foundation and Alpha Omega Epsilon, the engineering professional and social sorority. During the school year, she serves as a Virginia Tech resident advisor.

RETC attendance awards

The goal of the RETC student conference scholarship program is to provide students with skills and information for a career in the underground industry and to provide career and networking opportunities. Applicants must be full-time sophomore, junior, senior or graduate students with a designated major in an applicable field of engineering (civil, mechanical, mining, electrical, geological) or construction management.

The 2013 awards paid the travel expenses for seven students who wished to attend the 2013 RETC in Washington, D.C. From the Colorado School of Mines: **APRIL CLEMMENSEN, IAN DONOVAN, BENJAMIN J. GOERTZ, EMILY HILDRETH, CONOR LENON** and **LISA MORI**; from Drexel University: **TYSON THOMAS.**

Application forms for RETC scholarships and attendance awards can be found on the SME website at www.smenet.org/scholarships. ■

WOMEN IN TUNNELING

A closer look at Women in Tunneling

by Liz Stone and Brenda Bohlke

About five years ago, Brenda Bohlke glanced around the room at a tunneling conference and was astonished at the number of women who were present. As an industry veteran, she has firsthand experience of a time when women were seldom found working in the tunneling and underground construction sector.

The noticeable increase of women in tunneling led Bohlke to a second realization. There is little opportunity for women to interact, talk together and network, because the number of women in the industry is still very low. At conferences, dispersion among other attendees further restricts these opportunities. Therefore, the concept of Women in Tunneling (WIT) was born, and the group was formed in June 2012.

Originally, WIT was sponsored by five major companies: Kiewit, The Robbins Company, Jacobs Associates, Arup and Bradshaw Construction. Sponsorship changed in 2013 when WIT received support and funding from the UCA of SME for its annual reception and future events.

WIT's objectives are simple: to provide opportunities for women to get to know one another, to learn from each other and to attract more women to the field of tunneling. Several vehicles for networking have already been established, including a Linkedin group with a growing number of members, and the annual WIT reception as part of the North American Tunneling (NAT) conference and RETC.

Future plans include a community blog to which all group members can post, a standing article in the *Tunneling and Underground Construction* magazine and features in other tunneling publications that support WIT, such as *Tunneling Journal* and *TunnelTalk*.

Today, there are more than 200 professional women working in tunneling in North America alone and more overseas. WIT's numbers will undoubtedly grow by word of mouth, increased networking efforts, and by inviting women who seldom attend conferences and are not members of tunneling industry groups to join WIT. WIT has already succeeded in finding members by contacting company leaders and finding out how many women their companies employ.

The group's growth has been reflected in the two WIT networking events. The first one occurred at NAT in Indianapolis in 2012 and the second at RETC in Washington, D.C. this past June. At the 2012 event, 27 women attended. This year, more than 40 women attended. Another example of the group's growth is apparent on the WIT LinkedIn page, which has grown to 120 members since it was established in June 2012.

The key to WIT's success is the continued interest, energy and participation from women across the industry, within the United States and internationally. WIT hopes to maintain a list of women in leadership roles, such as those in federal, state or other public agencies, public works or private entities. In addition, the group hopes to recognize women on the move by providing the latest news about career changes, promotions, project assignments and general profiles.

Women in Tunneling gather at a reception in the Omni Shoreham Hotel at the 2013 RETC.

In order for the group to flourish, WIT asks that you help spread the word. You can do this by joining the LinkedIn group, by providing the names of the women in your companies and by sharing your ideas on how the group can further grow and develop.

More information will be coming soon about the blog, upcoming articles and the group's 2013 survey. All of this information will be released on the LinkedIn website.

Contact WIT

Brenda Bohlke**,** Women in Tunneling chair, bmbohlke@hotmail.com.

Mary O'Shea, sponsor administrator, UCA of SME, oshea@smenet.org.

Liz Stone, communications lead, stonel@robbinstbm.com.

LinkedIn Group, www.linkedin.com/groups/Women-in-Tunneling-4470112/about?trk=anet_ug_grppro. ■

UCA AWARDS

UCA issues call for award nominations

The Underground Construction Association will present the UCA awards at the 2014 North American Tunneling conference in Los Angeles, CA. The awards are:

- Outstanding individual.
- Project of the year.
- Outstanding educator.
- Lifetime achievement award.

The nominations for the awards will be reviewed by the UCA Executive Committee during its January meeting, and the committee will vote on and approve the award nominees. The recipients' photos and biographies will appear in the March issue of *T&UC*.

Guidelines and nomination forms are available on the UCA of SME website, uca.smenet.org. Please submit your nominations by Jan. 6, 2014 to Mary O'Shea at oshea@smenet.org. ■

PERSONAL NEWS

Brierley Associates announces the opening of a new office in Burnsville, MN headed by **TODD CHRISTOPHERSON**, a senior consultant with the firm. Christopherson is a registered professional engineer in Minnesota with more than 30 years of experience in structural and geotechnical engineering and construction management. Previously, Christopherson was president of Amcon Construction Management LLC. He is a member and past chapter president of the Minnesota Society of Professional Engineers and a past state president of the Minnesota Chapter of the Construction Management Association of America. Brierley plans to expand the Minnesota office to five professionals within the next 36 months.


CHRISTOPHERSON

HEINER SANDER (SME) has joined HNTB Corp. as vice president and tunnel practice leader, east. He is based in the firm's Arlington, VA office. Previously, Sander led the business development, management and operations of ILF Consultants. He has more than 30 years of experience in project management, design and construction management of tunneling and underground engineering projects under design-bid-build and design-build delivery methods. His extensive background in tunnel boring machine projects and the New Austrian Tunneling Method will support the firm's tunneling team and add additional experience to these valuable practices.


SANDER

Jacobs Associates has promoted **RICK VINCENT** (SME), P.E., to lead associate in its Cleveland, OH office. For almost 20 years, he has applied his comprehensive tunnel and structural design experience in managing and designing large underground projects of all types. Currently, Vincent is project manager for the city of Akron's Ohio Canal Interceptor Tunnel project and the Northeast Ohio Regional Sewer District's Advance Facilities Plan and Program Support Services project in Cleveland.


VINCENT

ROSA CASTRO-KRAWIEC recently joined Jacobs Associates' Boston office as a senior associate. She is a structural engineer with 29 years of experience in structural design production, engineering services during construction and project management. ■

OBITUARIES

BHASKAR THAPA
In memoriam

Jacobs Associates, the California Department of Transportation, the Contra Costa Transportation Authority and the Alameda County Transportation Commission are saddened to announce the death of Bhaskar Thapa, Ph.D., P.E. on June 19, 2013. Thapa would have celebrated his 50th birthday in September. His life's most significant engineering achievement — the Caldecott Fourth Bore — is on schedule to open later this year.

Thapa, a lead associate with Jacobs Associates, was one of the lead designers and design representatives for the Caldecott Fourth Bore. A native of Nepal, Thapa received a Ph.D. in geotechnical engineering from the University of California, Berkeley, and M.S. and B.S. degrees in civil engineering from Carnegie Mellon University in Pittsburgh, PA.

Thapa, who had been on staff with Jacobs Associates for more than a decade, was an expert in the New Austrian Tunneling Method, which was the selected method of excavation for the Caldecott Fourth Bore.

Thapa played a critical role on the project during his eight-year involvement — from design through excavation, assessing and mapping the complex and abruptly changing ground conditions along the tunnel's alignment. His efforts contributed to the project's excellent safety record, the flawless precision of the breakthrough in late 2011, and the successful completion of tunnel excavation and final lining construction in 2012.

"Bhaskar recently enjoyed seeing the fruits of his labors when the tunneling and final lining were completed for this challenging project," said Michael T. McRae, principal with Jacobs Associates. "He was incredibly proud of this achievement and we often spoke about the pride he would feel when driving his two boys and wife through the tunnel."


THAPA

A resident of Contra Costa County, CA, Thapa is survived by his wife and their two sons. He also leaves behind many friends and colleagues.

Jacobs Associates has established the Bhaskar Thapa Family Memorial Trust, for the benefit of Bhaskar's wife and his two young sons. Contributions in his memory can be sent by a check made out to The Bhaskar Thapa Family Memorial Trust to any Wells Fargo branch, or to Jacobs Associates, 49 Stevenson St. 3rd Flr., San Francisco, CA 94105. ■

Photo by Karl Nielsen, MTC.

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BUSINESS OFFICE

SME - 12999 E. Adam Aircraft Cir., Englewood, CO 80112 USA

+1-800-763-3132 • Advertising: x243

Direct: +1-303-948-4243

Fax: +1-303-973-3845

www.smenet.org

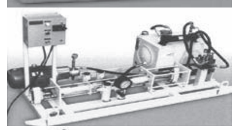
EDITOR
Steve Kral
kral@smenet.org

SENIOR EDITOR
Bill Gleason
gleason@smenet.org

PRESS RELEASES
Steve Kral
kral@smenet.org

ADVERTISING AND PRODUCTION/ MEDIA MANAGER
Ken Goering
goering@smenet.org

PRODUCTION DESIGNER
Nate Hurianek
hurianek@smenet.org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+1-215-794-3442
Fax: +1-215-794-2247
marshatabb@comcast.net

DARREN DUNAY
CANADA
+1-201-781-6133 • Cell: +1-201-873-0891
sme@dunayassociates.com

EBERHARD G. HEUSER
EUROPE
+49 202 2838128
Fax: +49 202 2838126
egh@heusermedia.com

PATRICK CONNOLLY
UNITED KINGDOM
+44 1702-477341
Fax: +44 1702-177559
patco44uk@aol.com

KEN GOERING
INTERNATIONAL SALES
+1-303-948-4243
Fax: +1-303-973-3845
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ADVERTISER INDEX • SEPTEMBER 2013

ABC Industries 30
Advanced Concrete Technologies 38
Alpine Equipment 22
Antraquip Corp 14
Atkinson Construction 26
Atlas Copco Construction & Mining USA LLC 7
Becker Mining America 45
Bradshaw Construction Corp 36
Brierley Associates LLC 42
Brokk Inc 16
Brookville Equipment Corp 37
CDM Smith 10
CTS Cement Mfg Corp / Rapid Set Products 18
Daigh Co Inc 43
David R Klug & Associates Inc 33
Dr Mole Inc 38
DSI Underground Systems 15
Euclid Chemical Co 39
FKC-Lakeshore 23
Geokon 12
Hatch Mott MacDonald 34
Hayward Baker Inc .... Back cover
HIC Fibers 44
HNTB Corp 27
Itasca Consulting Group 19
Jacobs Assoc 40
Jennmar Corp 17
Kelley Engineered Equipment 40
Kiewit Infrastructure Co 5
McDowell Brothers Industries Inc 35
Messinger Bearings, A Kingsbury Brand 11
Mining Equipment Ltd 6
Moretrench 21
Naylor Pipe Co 29
New York Blower Co 13
Normet Americas 24
Pacific Boring 43
Parsons 8
Putzmeister Shotcrete Technology 25
Resourceful Events Co Ltd 28
Sandvik Construction .... Inside front cover
Spendrup Fan Co 32
Sterling Lumber Co 20
Stirling Lloyd Products 42
Surecrete Inc 41
Tensar International Corp 3
The Robbins Co 9
Xylem 4

Micropiles – South Ferry Loop Station New York, NY

Fracture & Permeation Grouting – Lower North Outfall Sewer Rehabilitation Project, Los Angeles, CA

Jet Grout Secant Pile Wall – South River Tunnel Project, Atlanta, GA

Jet Grouting – Brightwater Conveyance System, Seattle, WA

Compaction Grouting – Highway 85 Sinkhole above Utility Tunnel, Brighton, CO