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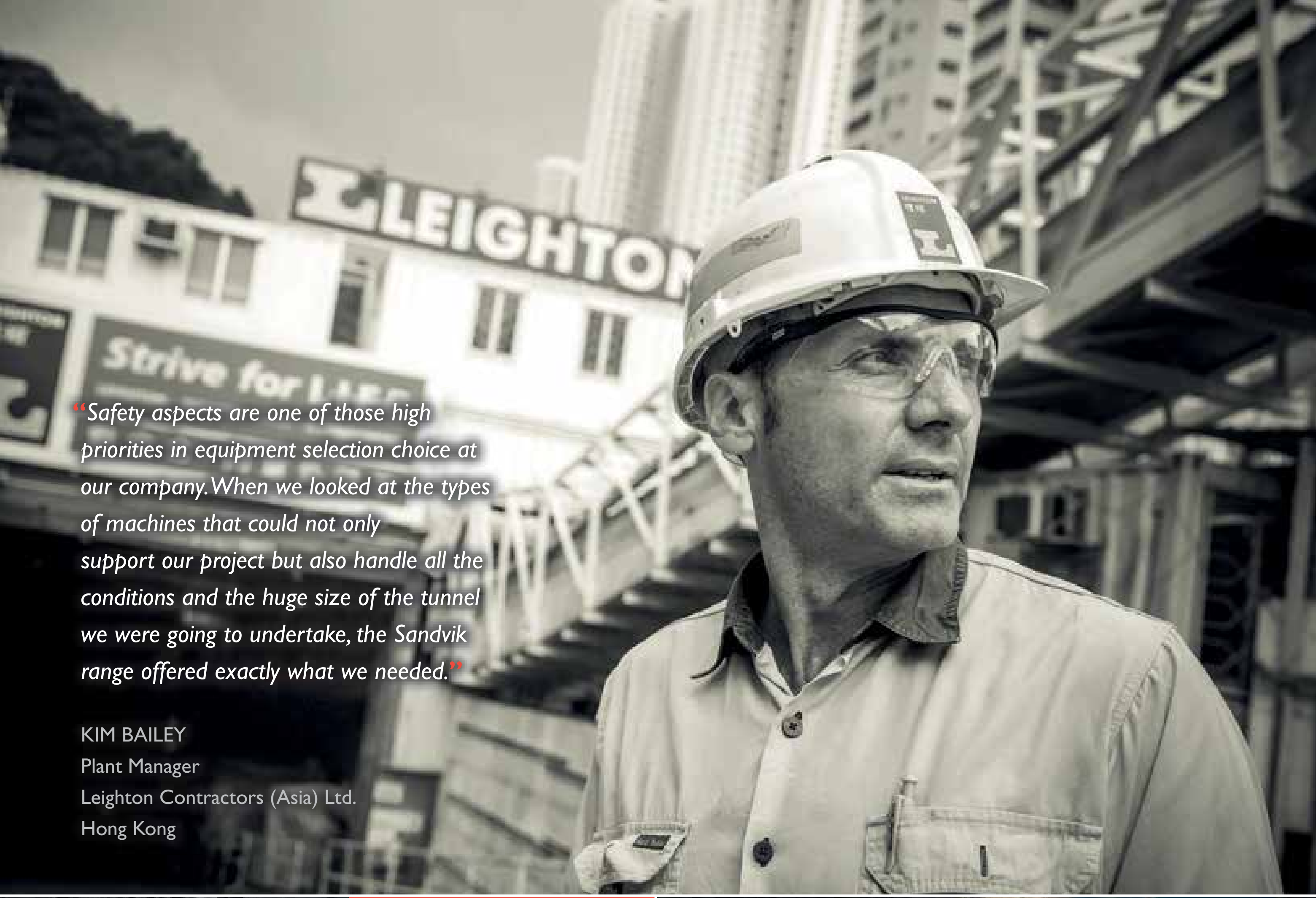
THE OFFICIAL PUBLICATION OF UCA OF SME   WWW.TUCMAGAZINE.COM   VOLUME 8 NO 3 SEPTEMBER 2014

TBM's greatest challenges

NAT in Los Angeles

Special Editorial Section from the publisher of *Mining Engineering*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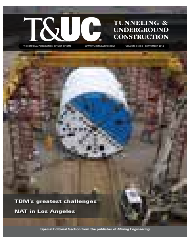
COVER STORY



In this issue — Tunnel boring machine tunneling is an ever-increasing prospect for underground construction. But each new tunnel has its own unique challenges, page 27. The North American Tunneling Conference, held in Los Angles, CA, attracted 1091 attendees, page 38. Cover photo shows the Kargi project in Turkey. Photo courtesy of The Robbins Co.

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DEPARTMENTS

CHAIRMAN'S COLUMN

Developing future leaders in our industry

I've received a lot of feedback on my Chairman's column in the March 2014 issue of T&UC, with respect to the need for bringing more young engineers into the tunnel industry. The underground industry is unique in that success is derived as much, or more, from project experience as from knowledge gained in school/university. Because of this, graduate engineers must have field experience on construction projects as well as mentoring from more experienced tunnel hands in order to advance their careers. Each of our own firms has programs to introduce young engineers into the world of underground construction. These programs typically include a mix of in-house training, mentoring, out-of-house seminars and conference attendance. The UCA has tried to provide a wide variety of programs to help firms meet the demand for this practical training, from annual tunnel conferences to regional topic-specific sessions, many of which include field trips. Other associations, including the Moles, also provide such opportunities for young engineers.

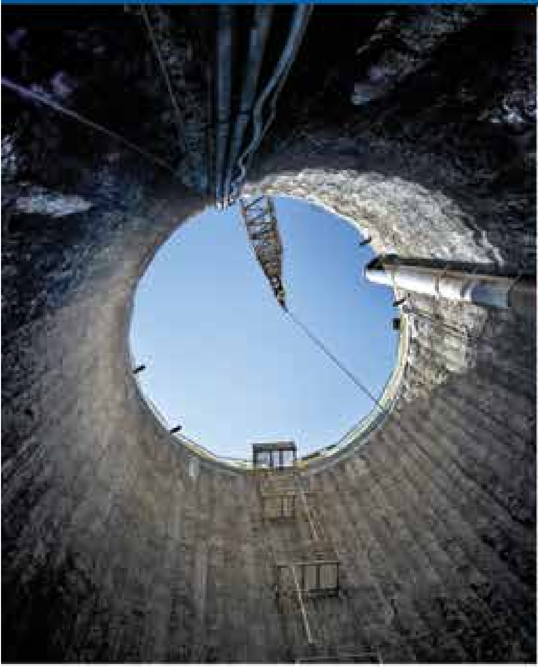
In an attempt to facilitate the integration of young engineers into our industry, as reported elsewhere in this issue, (*see story on page 38*) at its June 25, 2014 meeting in Los Angeles the UCA Executive Board approved the establishment of a Young Tunnelers' Committee. The idea behind this committee is to encourage discussion between industry and government professionals and university students under the age of 35, and thus provide a vehicle for young people to advance their careers by networking with people of similar age.

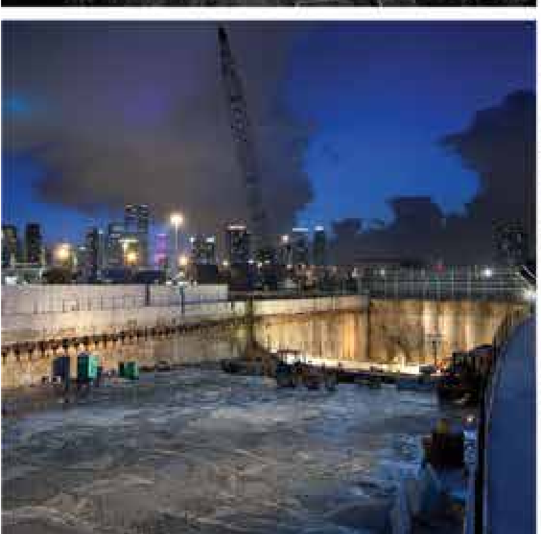
Other initiatives that have been undertaken within the past two years include published videos by the UCA and the ITA, which encourage young people to consider a career underground. Even the ASCE, in its video "What do Civil Engineers Do?," used a young tunnel engineer as an example of the interesting work that is going on underground.

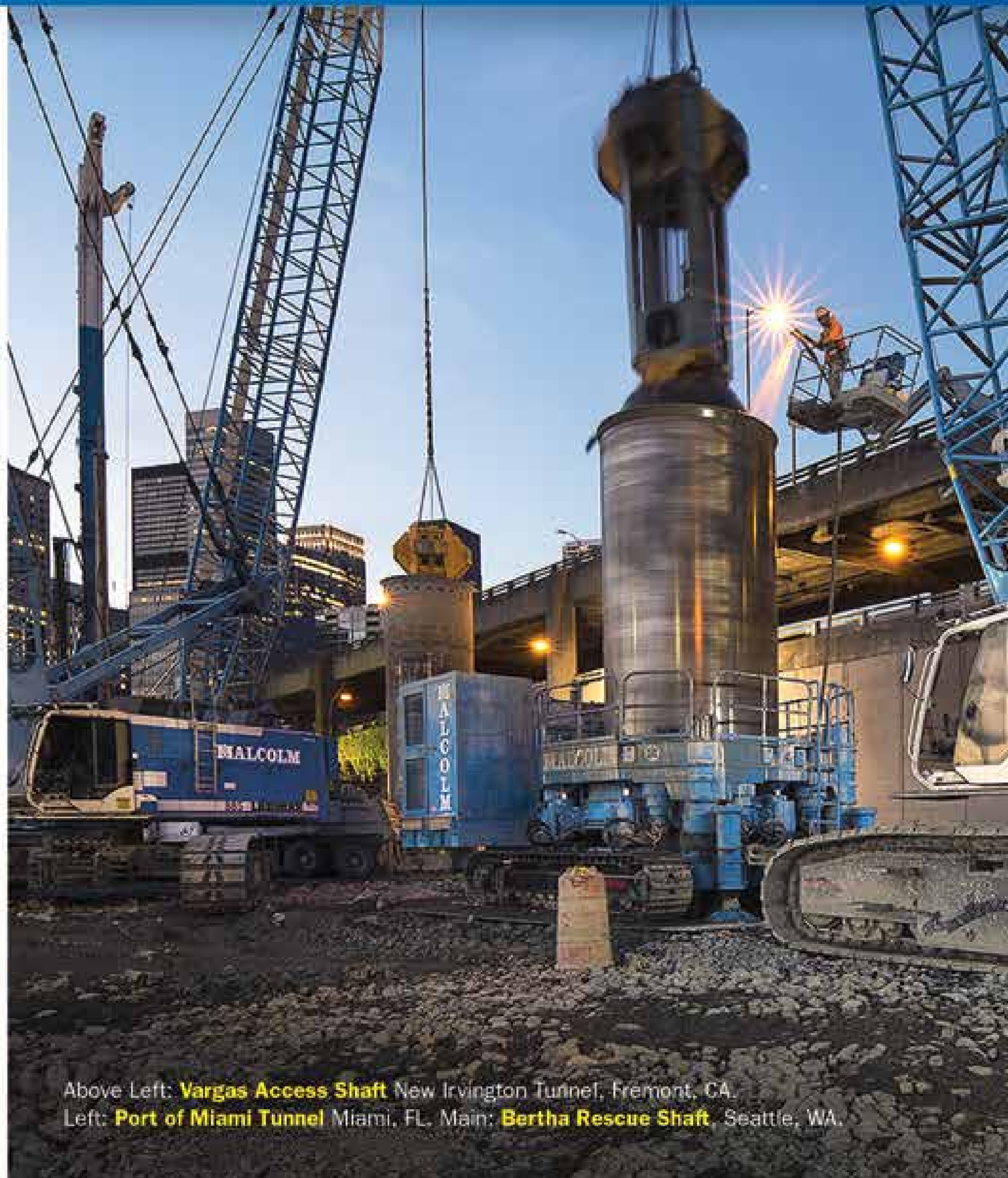
The UCA Executive Committee has broadened its representation by adding a representative from academia, Mike Mooney from the Colorado School of Mines, as an executive board member in an attempt to bring an educator's focus to the UCA's governing board.

The UCA is hopeful that such initiatives, along with the training done by our individual firms, will result in sufficient young leaders being developed to keep our industry moving forward. ■

William W. Edgerton,
UCA of SME Chairman







Above Left: **Vargas Access Shaft** New Irvington Tunnel, Fremont, CA.
Left: **Port of Miami Tunnel** Miami, FL. Main: **Bertha Rescue Shaft**, Seattle, WA.

Bertha expected to be running again by March

The Seattle Tunnel Partners (STP) unveiled a plan on its website of how it will access and repair the tunnel boring machine (TBM) that stalled in January while digging the Highway 99 Tunnel under downtown Seattle, WA. The plan calls for repairs to be completed by March 2015.

Access to the stalled machine, named Bertha, was delayed this summer when crews digging the deep access pit hit concrete that must be worked through.

The 36-m- (120-ft-) deep vault in front of the machine should be done in August instead of July, project director Chris Dixon of STP told *The Seattle Times*. After that, it will take a few weeks to excavate the dirt inside, and prepare a crane to lift the tunnel drill's front-end parts, before the drive bearing and other parts can be fixed.

He said the stalled Highway 99 tunnel drill still will be ready to resume its dig to South Lake Union by March, as previously announced. The repair plan included a two-month cushion, known as "float," that is now down to one month, Dixon said.

An official tunnel update vouches for March, but program administrator Todd Trepanier said that this latest delay "has increased our concern in the ability for STP to resume mining in March," given the fact repairs have not begun yet.

The ring-shaped pit will allow a giant crane to hoist Bertha's entire 1.8-kt (2,000-st) front end, so the 17.5-m (57.4-ft) diameter cutterhead and its drive system can be laid on the surface and repaired. The main bearing and its leaky seals will be replaced, and gaps within the cutting disc will be widened to reduce clogs when muck passes through.

Bertha sits in wet soil near the waterfront, after digging 312 m (1,025 ft) of the 2,825-m (9,270-ft) route since its launch one year ago.

The latest challenge is caused by the geometry of the vault.

Malcolm Drilling, the pit subcontractor, is installing the pit walls as a barrier against ground water that presses inward at triple atmospheric pressure.

This requires crews to install an initial series of 3-m- (10-ft-) diameter columns 1 m (6 ft) apart, then to install another set of columns between those. The secondary columns require carving a 0.6-m- (2-ft-) wide arc from each of the adjoining columns.

Drilling is done with spinning steel tubes with teeth on the ends — but the excess concrete wasn't flaking away as expected.

"We thought they would chew through the concrete better than they've been able to," Dixon said.

Malcolm brought in a pair of gravity-driven chisels and dropped them inside the tubes to break the recalcitrant concrete — which adds an extra step, several times per column.

Only then can the fragments be scooped out, using clamshell shovels.

Dixon told *The Seattle Times* that the concrete was expected to crumble more easily. The pilings in Seattle turned out more difficult to cut than piling half this size elsewhere, Dixon said.

(Continued on page 24)

Seattle Tunnel Partners release Bertha repair plan

The Seattle Tunnel Partners (STP) unveiled its plan to repair the tunnel boring machine (TBM) that stalled in January while boring the Highway 99 Project in Seattle, WA.

STP's work plan contains four major repair and enhancement elements:

- Replacing the damaged seal system with a more robust system.
- Replacing the main bearing.
- Installing enhanced monitoring systems.
- Adding steel to strengthen the machine and accommodate the new seal system.

Other major enhancements of the work plan include:

- Widening the openings at the center of the cutterhead.
- Improving the soil conditioning injection system.
- Installing bit- and wear-resistant steel on the cutterhead.
- Extending the length of the agitator arms in the mixing chamber.

"We are committed to the success of this project," said Seattle Tunnel Partners project manager Chris Dixon. "We're confident these repairs and enhancements will enable this machine to successfully tunnel beneath downtown Seattle. We won't resume tunneling until we're certain Bertha is up to the task."

STP will provide the Washingto State Department of Transportation with additional supporting information about rebuilding the machine in the coming months, in accordance with the design-build contract, to demonstrate how the repairs will meet the contract's performance and technical requirements, including:

(Continued on page 24)

Tutor Perini wins dispute over Big Dig project

In June, Massachusetts Superior Court Justice Thomas Billings awarded $80 million to Tutor Perini and its joint-venture partners for some of the cost overruns from the Big Dig project in Boston, MA.

The Big Dig project was the most expensive highway project in the United States and was plagued with cost overruns, eventually costing $24 billion to complete.

The case involving Tutor Perini was a complicated one, as the parties submitted more than 12,000 pages of documents to the court, *KUOW* reported.

In the end, the judge said Massachusetts and its taxpayers were responsible for those cost overruns, not the Tutor Perini joint venture.

The judge agreed with an expert panel set up specifically to resolve disputes on the Big Dig.

MassDOT officials had treated that dispute review board's findings as recommendations only and had rejected findings that called for MassDOT to foot the bill on 29 disputed cost overruns.

"This decision certainly vindicates our position and the vigor with which we pursued this litigation over all these years," a company press release quoting chief executive officer Ronald Tutor stated.

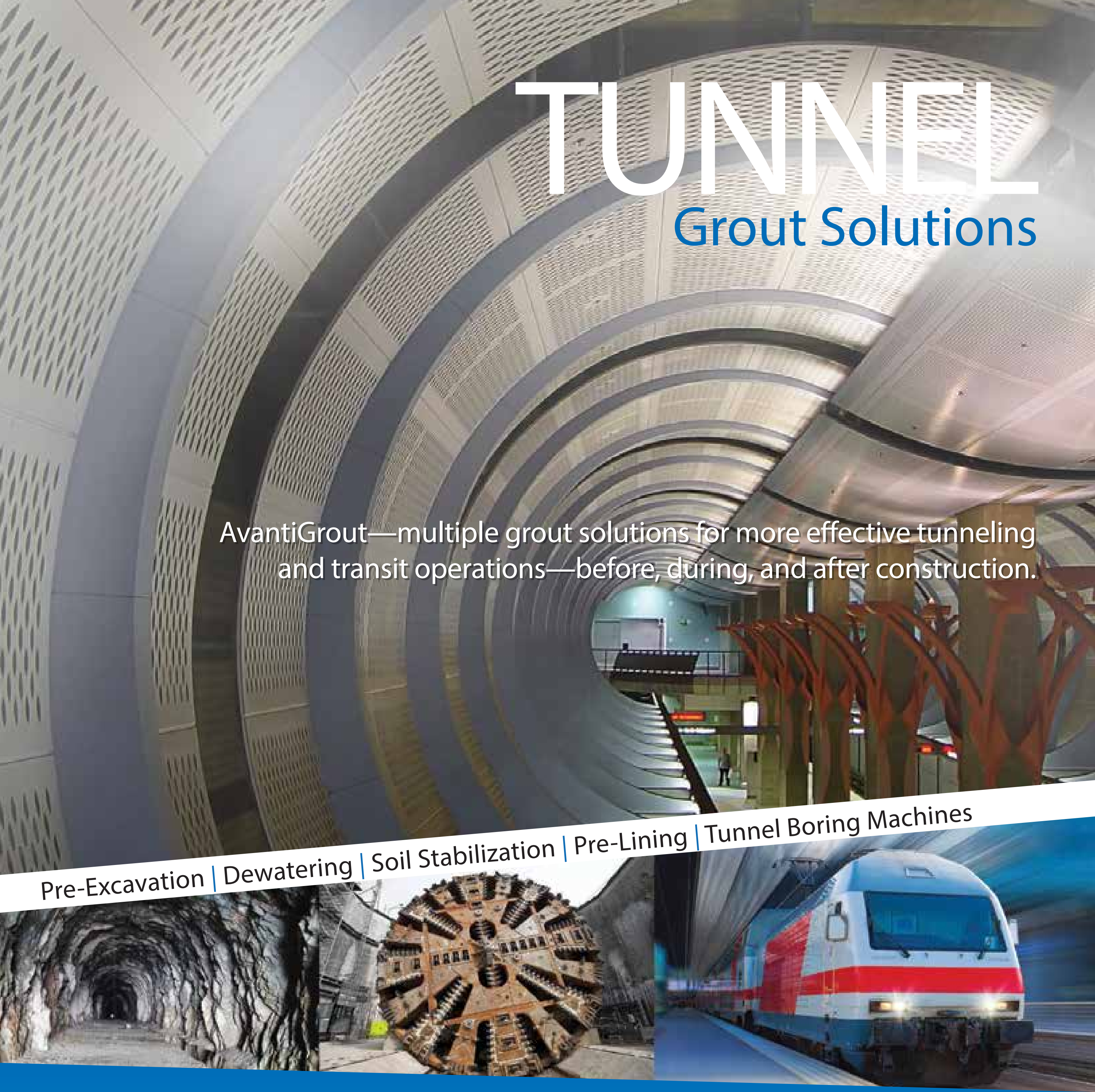
Tutor Perini is currently one of two companies involved with Highway 99 tunnel project in Seattle, WA. Tutor Perini and Spain's Dragados S.A. are the two halves of the Seattle Tunnel Partners joint venture.

In the end, the judge said Massachusetts and its taxpayers were responsible for those cost overruns, not the Tutor Perini joint venture.

Tutor Perini spokesman Jorge Casado declined to answer questions about the Big Dig case. So did MassDOT spokesman Michael Verseckes, citing pending litigation.

"There's always the potential

(Continued on page 22)



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Additional Crossrail extension considered

An extra £14.8 billion Crossrail branch could be added to the project that would link more of the home counties into the east-west London high-frequency train line service, the British government announced.

Transport secretary Patrick McLoughlin said the proposed scheme could be extended into Hertfordshire, giving stations direct commuter services across the capital, *The Guardian* reported.

Eastern branches of Crossrail, the mega transportation project in London that includes 21 km (13 miles) of new tunnels, will begin service next year. By 2020, the project will have 200 m (650 ft) trains operating.

Now the Hertfordshire stations of Tring, Hemel Hempstead, Berkhamsted and Watford Junction could be added to the network by a new rail link between Old Oak Common and the west coast mainline, allowing commuters direct access to the city and Canary Wharf.

The branch could help alleviate pressure on Euston station in London ahead of the arrival of HS2, a problem that has been pinpointed by the capital's transport chiefs, who are pressing for Crossrail 2 – a complementary north-south line across the capital by Euston – to be started as soon as possible.

Addressing Crossrail workers at Farringdon station in London, McLoughlin said the Hertfordshire plan would "provide flexibility and reliability while we build HS2 into Euston."

"It would be a huge boost to Crossrail and London commuters. We're going to examine, right away, how we can run extra services direct into the city and through to Canary Wharf from key stations like Tring, Hemel Hempstead, Harrow and Watford – without the frustrating need to change at Euston."

He said the proposals must not affect the timetable or service pattern for the existing Crossrail scheme, scheduled to become fully operational by 2019.

In other news regarding Crossrail, the project has manufactured the last of its 250,000 concrete

(Continued on page 25)

Major project in Phoenix nearing completion

The McOrmond Drive sanitary and storm sewer trunk project, the largest tunnel project ever in Phoenix, AZ, is nearly complete.

The $32-million project is scheduled to be completed in December, a few months behind schedule, the *StarPhoenix* reported.

The sanitary sewer and storm sewer trunks are being tunneled by Michels Canada Co.

"We've done smaller tunnels before, but this is the largest one we have ever undertaken," said Dan Willems, special projects manager with the city's major projects division.

Willems said as the city expands, the need for alternative technologies that limit disruptions also grows.

"Tunneling does take a little longer, but the social and economic impacts are much less because you are not disturbing as much of the surface as you would with an open-cut project," he said. "As the city grows, much like many other cities, you will start to see these (trenchless) types of technologies used more and more frequently."

The project consists of two tunnels, each 1.5-km (0.93-miles) long. The storm drain tunnel has been completed and the sewer tunnel is about 130 m (426 ft) complete.

"The ground has been a little harder than we expected, but we have dealt with that and (we're) moving through that without any real issues," said Craig Vandaelle, project manager for Michels Canada.

He said the second tunnel is scheduled to be finished in early September, and all the work will be completed by the end of the year. It was originally scheduled to be complete this summer.

The laser-guided boring machine, electrically powered and hydraulically driven, can tunnel about 16 m/day (52 ft/day).

As the machine digs the tunnel, which is at a depth of about 16 m (52 ft), the displaced material is transported on a conveyor onto rail cars and then sent to the surface. After every 1.2 m (4 ft) of tunnel is dug, workers install a primary liner. Once finished, a fiber-reinforced polymer pipe will be put into the tunnel.

Willems said the pipe should last 100 years or more. ■


JENNMAR

TBM overcomes difficult ground in Turkey

Multiple fault zones, variable face conditions and squeezing ground requiring extensive bypass tunneling: these were just a few of the challenges overcome in order to successfully complete Turkey's Kargi Kizilirmak hydroelectric project. A Robbins 10 m (32.8 ft) diameter double shield tunnel boring machine (TBM) achieved breakthrough on the project July 5, 2014 after a run through some of the most difficult conditions ever encountered by Robbins field teams. The machine type, selected jointly by the owner, consultants, Robbins and the contractor Gülermak of Turkey, excavated through 7.8 km (4.8 miles) of complex geologi-

(Continued on page 26)

The Kargi Kizilirmak hydroelectric project, for Norwegian-owned Statkraft AS, will generate 470 GWh annually, which is enough to power about 150,000 homes.

AECOM acquires URS Corp. for $6 billion

AECOM announced that it will acquire all outstanding shares of URS for a combination of cash and stock valued at approximately US$4 billion or $56.31 per URS share, based on the AECOM closing share price as of July 11, 2014. Including the assumption of URS debt, the total enterprise value of the transaction is approximately $6 billion, AECOM said in a statement.

The combined company will be a leading, fully integrated infrastructure and federal services provider with more than 95,000 employees in 150 countries. It would have calendar year 2013 pro forma revenues of more than $19 billion and EBITDA of approximately $1.3 billion.

"This combination creates an industry leader with the ability to deliver more capabilities from a broad global platform to reach more clients in more industry end markets," said Michael S. Burke, AECOM president and chief executive officer. "Clients, employees and stockholders of both companies will benefit from the opportunities created by these expanded capabilities, broad global reach in key growth markets and economies of scale. In one step, we will dramatically accelerate our strategy of creating an integrated delivery platform with superior capabilities to design, build, finance and operate infrastructure assets around the world."

Martin M. Koffel, chairman and chief executive officer of URS, said, "This is a compelling strategic combination that we believe will benefit our clients, stockholders and employees. URS stockholders will receive significant, immediate value from the transaction and will be able to participate in the future prospects of the combined company, which we expect will be better positioned to compete for major, complex projects across a diverse range of end markets and geographic regions. Our two businesses are complementary. We anticipate that employees from the combined company will benefit as the organization integrates its leadership talent and capitalizes on its greater scale to invest in its people, improve their career opportunities and advance their capacity to compete globally." ■

Two TBMs deployed for drainage system in Qatar

Two Herrenknecht tunnel boring machines (TBM) were deployed for a major drainage system in the Qatari capital of Doha. Construction of the almost 10-km (6-mile) tunnel is part of some major infrastructure projects for which Qatar has ordered more than 20 Herrenknecht machines.

With annual rainfall of less than 100 mm, Qatar is one of the driest landscapes on earth. But individual driving rain showers lead to extensive flooding in the densely populated capital of Doha. A comprehensive drainage system covering an area of 170 km (105 miles) aims to ensure improvement in the southern section of the city.

Two Herrenknecht TBMs are driving a tunnel 20 to 30 m (65 to 98 ft) underground for the Abu Hamour Southern Outfall Project. The earth pressure balance (EPB) shields, with a diameter of 4.5 m (14 ft), are designed for Doha's soft limestone soil. Muck comprising excavated material serves as the support medium for the EPB shield, providing the requisite pressure balance at the tunnel face. Protected by the shield skin, the tunnel is excavated using ring-shaped reinforced concrete segments. The individual segments are transported through the tunnel as it is completed and connected to form closed rings (segmental lining process) directly behind the TBM with an erector.

By way of the main tunnel extending 9.5 km (6 miles), up to 16.5 m^3 (4,360 gal) of water per second will later be conveyed to a central pump station near the New Doha International Airport.

Herrenknecht tunneling technology was also used in designing some of the inlets during an initial construction phase. Using a slurry AVN machine from Herrenknecht, a total of 4 km (2.5 miles) of tunnel with an outer diameter of 3.6 m (11.8 ft) were excavated with the pipe jacking method in 2008. This is a remarkably large diameter for pipe jacking.

With its Vision 2030, Qatar aims to offer its citizens the highest possible standard of living. Some projects are already being implemented and range from surface water discharge to traffic infrastructure. Herrenknecht is also involved in the new Doha Metro System, with a total of 21 EPB shields, many of which have already been delivered. ■

Skanska wins contract for extension line in Los Angeles

The Los Angeles's Metropolitan Transportation Authority (Metro) awarded the $1.6-billion Purple Line subway extension contract to Skanska.

The Metro cited Skanska's experience on local transit projects in its 9-3 decision to go with the Swedish firm, despite a competing bid from Dragados that came in about $200 million less than Skanska's.

The Los Angeles Times reported that Skanska USA, which has been involved in the construction of three other Metro rail projects, reportedly said it could finish the job 10 months earlier than the timetable called for.

The American division of Spanish firm Dragados proposed to do the job five months ahead of schedule and for $192 million cheaper. However, *The Los Angeles Times* reported that the Metro felt Dragados' lack of familiarity with the project requirements would likely lead to delays and additional costs.

Heavy construction on the project is slated to begin by the end of the year. When the Westside subway opens, in 2023, the 6.2-km (3.9-mile), $2.7-billion tunnel will link downtown Los Angeles to the Miracle Mile. The project's budget is now $288 million more than Metro's original estimate.

Metro board member Ara Najarian voted to approve the contract with Skanska and pointed to a Dragados' work on the highway-99 project in Seattle, WA where the world's largest tunnel-digging machine has been stuck under downtown for almost a year, delaying a major highway project.

Dragados filed a formal complaint with Metro, arguing that the board gave "unfair and misleading" advice during the bidding process. Dragados said the transit agency is overlooking the 241 km (150 miles) of subway tunnels it has built all over the world, adding that it plans to finish the Seattle job.

Despite the issues associated with Dragados, three members of the Metro board voted for it.

"I'm having a hard time leaving $192 million on the table," L.A. County Supervisor Don Knabe said during the meeting. "This process is extremely flawed." By choosing Skanska, Metro is "putting all its eggs in one basket." ■

TBMs breakthrough at Delhi Metro twin tunnels

Delhi Metro announced the completion of two tunnels on the Janakpuri (West)-Botanical Garden corridor. Two parallel tunnels at Dabri Mor were completed with the help of two tunnel boring machines (TBM).

The two TBMs — named 'Riddhi' and 'Siddhi' — emerged at the Dabri Mor station after boring the two 1.2-km- (0.7-mile-) long twin tunnels. While one of the TBMs was inserted in December last year, the other TBM had started work in January. These are the first tunnels to be completed on this corridor, the *Times of India* reported.

Delhi Metro Rail Corp. spokesperson Anuj Dayal said, "This is the first occasion that twin tunnels have been completed together in any metro project in India. The decision to go for a twin TBM breakthrough was taken since both TBMs were progressing almost simultaneously. The first such instance of a twin breakthough had happened during work on the 8.6-km (5.3-mile) long Toronto-York Spadina subway extension in year 2002."

The tunnels have been constructed at a depth of 16.5 m (54 ft) and the internal diameter of the tunnels is 5.8 m (19 ft). The casting of the segments has been done at the Dwarka casting yard. According to Delhi Metro, the construction was a major engineering challenge as the tunnels passed underneath thickly populated residential and commercial areas and needed extensive geotechnical instrumentation and monitoring.

"Extensive geotechnical instrumentation and monitoring was done to ensure the safety of the structures above. Various monitoring instruments like inclinometers, magnetic extensometers, piezometers, rod extensometers, precise level markers, bi-reflex targets, crack meters, etc., were used," Dayal said.

At present, about 28 TBMs are engaged in tunneling works in different parts of Delhi, compared to 14 TBMs used in phase two. ■

New fire supression system for Eisenhower tunnel

The Colorado Department of Transportation (CDOT) has received $25 million from state and federal governments to install a new fire suppression system in the Eisenhower Tunnel.

"It's going to be the greatest improvement to tunnel since initial construction," CDOT Project Manager Raelene Shelly told *CBS4 Denver*.

For the past 40 years there has been one main source for putting out fires at the tunnel.

"We have 52 employees here at the tunnel that are all trained in basic firefighting skills," Shelly said.

"They currently run hurricane force winds through there if there's ever a fire, but what we're looking at getting the funding to install is a sprinkler system," U.S. Rep. Jared Polis said.

The system design has been picked and a contractor is ready to start next year.

"There's a linear heat detector on the ceiling of the roadway and it will detect heat which will send a signal to the control room. An operator will decide whether or not there's a fire," Shelly said.

Sprinklers will go through ventilation already in place.

"The system is designed to be installed inside the plenum space, which actually sits above the roadway. There will be minimal lane closures," Shelly said.

The sprinkler water will be warmed throughout the year so it doesn't freeze.

"We can detect a fire within 15 m (50 ft)," Shelly said.

"This investment can save lives and it really will. By having the sprinkler system in place we, can really avoid the type of incidents that have happened in Europe and other places that have cost dozens and dozens of lives," Polis said.

Work begins this fall. CDOT expects to have the project completed by December 2015. ■

Save the date:

George A. Fox Conference

Jan. 27, 2015, New York, NY

www.uca.smenet.org

Big Dig: Contractor awarded $80 million

(Continued from page 6)

for a dispute or a disagreement on any contract," said Matt Preedy with the Washington State Department of Transportation (WSDOT). "It could be a small contract, a large contract — usually, the larger the contract, the larger the dollar value of the issues."

The tunnel boring machine (TBM) being used on the Highway 99 project, owned by the WDOT, is currently stalled with a restart of work expected in March of 2015.

WSDOT officials say their downtown Seattle tunnel project is very different from Boston's Big Dig, with its multiple tunnels and bridges.

One thing they have in common: both set up many-layered processes to resolve any disagreements between the people building the project and the people paying for it.

"The way we like to set up contracts is to provide multiple opportunities to resolve the nature of the dispute before going to court," Preedy said. "If we're able to do that, it usually saves time and money for all parties involved."

Among other disputes, Seattle Tunnel Partners and WSDOT are currently at odds over who's responsible for an estimated $125 million needed to repair the stalled TBM, called Bertha. That dispute hasn't gone to the project's three-member dispute-review board yet.

Unlike the Big Dig's dispute review board, the SR-99 project's board can only make recommendations; its decisions are not binding.

The $80-million Big Dig dispute lasted 15 years, and the tug of war on Big Dig overruns continues. The actual construction in central Boston finished nearly a decade ago. ■

Save the date:

Cutting Edge 2014: Groundwater Control for Tunneling

Nov. 3-5, The Westin Times Square, New York, NY
www.ucaofsmecuttingedge.com

Cutting Edge 2014:
Groundwater control for tunneling

Groundwater, the nemesis of every tunneler, is the subject of the third annual Cutting Edge conference, in New York, NY, Nov. 3-5, 2014.

From dewatering to pre-excavation grouting, cut-off walls to pressurized tunnel boring machines, SEM construction to water-proofing and lining — the conference will feature subject-specific presentations focusing on innovations and practical experience from projects around the world.

This unique two-day event — organized in partnership by *North American Tunneling Journal* and the UCA of SME — will also feature forum discussion sessions, a tailored exhibit and the opportunity to visit projects in the New York City area, including the East Side Access project. For more information visit http://www.ucaofsmecuttingedge.com.

Attendees of the 2013 Cutting Edge Conference toured the Highway 99 Tunnel Project in Seattle, WA. This year's conference will include site visits in the New York City area.

Bertha: Access to TBM is slower than expected

(Continued from page 4)

Also, 11 columns have been added to the original design, for a total 84. So far, 53 of the 84 buried columns are completed, he said.

The extra columns will form a second layer along the south side of the ring. Engineers are expecting Bertha to be healthy enough to bore through the concrete wall to reach the open-air access shaft. When the machine drilled through a concrete wall earlier in Sodo, it made slow, steady progress, but the cutting teeth eroded quickly. Dixon predicted the machine will grind through the double wall just fine.

He said STP refuses to take shortcuts in building the circular ring, which is designed to reinforce itself against compression from all sides.

Barring further major problems, STP expects to finish the four-lane highway link from Sodo to South Lake Union in fall 2016, under a $1.44-billion contract. The partnership, led by Dragados USA and Tutor Perini, has filed a $125-million claim related to repair delays, which the state Department of Transportation denied, setting the stage for prolonged negotiations or a legal battle. ■

Repair: STO outlines repair plan of Bertha

(Continued from page 4)

- An analysis demonstrating that the machine's structure can withstand all loads from the surrounding ground and its own operation.
- Seal design details and background calculations.
- Design of revised conditioner injection systems and cutterhead openings.
- Updated operations plan including enhanced instrumentation and monitoring for key machine components.
- Complete testing program for all modified machine components prior to restart of mining. ■

Staten Island-Brooklyn water siphon project more than 50-percent complete

A $250-million siphon project that will deliver drinking water from Brooklyn to Staten Island is more than 50-percent complete.

The project, which includes the installation of a new 31-m- (100-ft-) deep water tunnel, was delayed because of damage suffered from Hurricane Sandy, *silive.com* reported.

The project involves excavating a new, deeper siphon 31 m (100 ft) under New York Harbor to convey drinking water from Brooklyn to Staten Island. Once the new tunnel is ready, the two existing, shallower, nearly 100-year-old water connections will be removed.

The siphon project, managed by the city Economic Development Corp., is jointly funded by the city Department of Environmental Protection and the Port Authority of New York and New Jersey.

When the project is finished, it will allow dredging work to be completed in the Anchorage Channel to accommodate the larger, next generation post-Panamax container ships in local marine terminals.

The New York and New Jersey Harbor Deeping project New York and New Jersey Harbor Deepening Project is managed by the U.S. Army Corps of Engineers. ■

Crossrail: Final concrete segments manufactured

(Continued from page 8)

segments, used to line the tunnels of Europe's largest infrastructure project.

The final piece was cast at a specially built Crossrail factory in Chatham, Kent. The factory has produced 110,000 tunnel segments to line Crossrail's 12-km (7.4-mile) long eastern twin tunnels, from east London to Farringdon. Segments for the western tunnels from Royal Oak to Paddington were manufactured at a separate facility at Old Oak Common. Segments for the Thames Tunnel between Plumstead and North Woolwich were manufactured in Ireland.

At peak, the Chatham factory operated 24 hours a day, five days a week and, on average, manufactured 330 segments per day. Each segment weighs 3.4 t (3.7 st). Seven segments and a keystone form a complete tunnel ring in the new Crossrail eastern tunnels, which are being built by joint venture Dragados Sisk.

The Chatham factory sustained 120 jobs for local people, including two apprentices. Maidstone-based Brett Concrete supplied 140,000 m^3 (4.9 million cu ft) of concrete for the segments and Medway Ports facilitated 260 river barge movements from Chatham to Limmo Peninsula, near Canning Town, where segments feed Crossrail's 1 kt (1,100 st) boring machines. Using river transport removed approximately 10,000 truck journeys from the roads of Kent and east London. ■

Robbins: Final concrete segments manufactured

(Continued from page 12)

cal conditions that proved to be a challenge nearly from the outset.

The machine was launched into poor geology that resulted in delays to the project and forced team members to find innovative solutions that included major in-tunnel modifications to the machine. In the first 2 km (1.2 miles) of boring, a total of seven bypass tunnels were needed to free the TBM from collapsed ground. The cutterhead stalled on numerous occasions, as the conditions varied widely from solid rock to running ground. Small and wide faults along the alignment added another level of complexity, as the excavation was located very close to the North Anatolian fault line in Turkey's relatively recent rock formations.

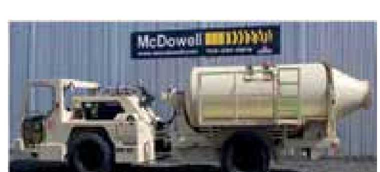
The contractor, owner, consultants and Robbins engineers worked together to generate solutions to improve progress in the difficult conditions. The contractor, with the assistance of the Robbins field team, installed a custom-built canopy drill and positioner to allow pipe tube support installation through the forward shield. Drilled to a distance of up to 10 m (33 ft) ahead of the cutterhead, 90 mm (3.5 in.) diameter pipe tubes provided extra support across the top 120° to 140° at the tunnel crown. Injection of resins and grout protected against collapse at the crown while excavating through soft ground. As a result of successful use of the probe drilling techniques, Gülermak was able to measure and backfill cavity heights above the cutterhead in some fault zones to more than 30 m (100 ft) and, in addition, it was able to help detect loose soil seams and fractured rock ahead of the face.

"The cooperation and trust between the contractor, project owner, and Robbins management, engineering and field service resulted in the correct modifications being successfully installed on the Kargi TBM," said Glen Maynard, Robbins site manager.

Despite the slow progress initially, the Robbins double shield TBM made some remarkable advances once modifications were in place. An advance rate of 600 m (1,968 ft) in one month was achieved in March 2013. In a project best of approximately 723 m (2,372 ft) was achieved in spring 2014, including a daily best of 39.6 m (130 ft) in April 2014. In so doing, the TBM significantly outperformed a drill-and-blast heading progressing from the opposite end of the tunnel. Crews at that heading progressed in relatively good ground conditions for 4 km (2.5 miles), where they achieved very impressive advance rates of nearly 300 m (985 ft) per month. The entire tunnel, with both TBM and drill-and-blast portions, is 11.8 km (7.3 miles) in length.

"This has been the toughest job in my tunneling career," said Yunus Alpagut, Robbins' representative in Turkey who was involved in the project from the start. "It is a testament to the skill and dedication of the Robbins team and the Gülermak contractor team that it has ended successfully."

Once online the Kargi Kizilirmak hydroelectric project, for Norwegian-owned Statkraft AS, will generate 470 GWh annually, which is enough to power about 150,000 homes. The tunnel will source water from the Kizilirmak River, sending it to a new generating station operated by Statkraft. ■



FEATURE ARTICLE

The greatest challenges in TBM tunneling: Experiences from the field

FIG. 1

Double shield TBM for Kargi.

Tunnel boring machine (TBM) tunneling is an ever-increasing prospect for underground construction, and, with each new tunnel bored, there are unknown elements. When boring through the earth, even extensive geotechnical baseline reports can miss fault lines, water inflows, squeezing ground, rock bursting and other types of extreme conditions. This article draws on the considerable field service experience within Robbins to analyze successful methods of dealing with the most challenging conditions encountered.

Many tunnel projects are located in areas with relatively poor access along the tunnel alignment and bored under extremely high overburden. These two factors often result in limited geological information. It would be reasonable to state that the deeper the tunnel, the greater the level of uncertainties. When faced with these uncertainties everyone involved with the project including the owner, the contractor and the machine supplier must be prepared to tackle geological surprises. This article describes the problematic geological conditions and associated difficulties faced on three separate projects and the measures that were taken to overcome these difficulties.

Jim Clark and Steve Chorley

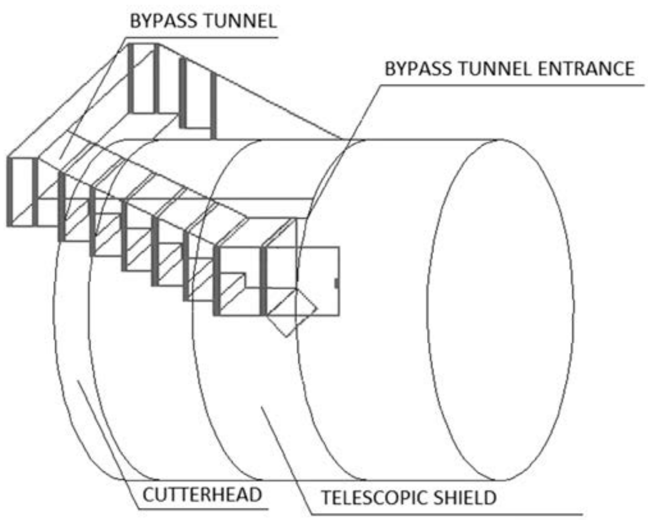
Jim Clark and **Steve Chorley** are project manager and field service director, respectively, with The Robbins Co. email chorleys@robbinstbm.com.

Kargi Kizilirmak hydroelectric project

The Kargi Kizilirmak hydroelectric project is located on the Sakarya River, near the Beypazarı district of Ankara province in Turkey. The Robbins Company supplied a 9.84-m- (32.2-ft-) diameter double shield TBM and continuous conveyor system to Gülermak for excavation of the 11.8-km (7.3-mile) head race tunnel (Fig. 1). The tunnel is being driven through a mountainside with up to 600 m (1,970 ft) of overburden. The geology consists of volcanic rock and softer limestone for the first 3 km (1.8 miles), followed by harder rock including marble and basalt for the remainder of the tunnel alignment. Due to the variation in geology, the ground support regimes range from precast segmental lining for the first 3 km (1.8 miles), transitioning into ring beams, rock bolts and shotcrete as the tunnel moves into more competent geology. Several unique features were

FIG. 2

Bypass tunnel.



incorporated into the TBM design to facilitate installation of the various ground support regimes.

Issues encountered (trapped cutterhead). The machine was launched in the spring of 2012 and almost immediately encountered geology that was substantially more problematic than was described in the geological reports. The geology consisted of blocky rock, sand and clays. As a countermeasure that was immediately put into place to avoid the cutterhead becoming stuck in the blocky material, crews began boring half strokes and half resets. This ensured that there was always the option of rapidly retracting the cutterhead in the event that torque reached critical levels. After boring through 80 m (262 ft) of these difficult ground conditions, the machine encountered a section of extremely loose running ground with high clay content. A collapse occurred in front of the cutterhead and the cathedral effect resulted in a cavity forming that extended more than 10 m (32 ft) above the crown of the tunnel. The weight of the collapsed material trapped the cutterhead. After several unsuccessful attempts to clean out and restart the cutterhead, consolidation of the ground above and in front of the machine was carried out. Injection of polyurethane resins via lances inserted through the cutter housings and muck buckets was the method utilized for consolidation operations.

However, injection locations were restricted to the available openings and subsequent attempts to restart the cutterhead proved to be unsuccessful.

Bypass tunnel. After assessing all of the available options, it was decided that a bypass tunnel would be required. Robbins field service assisted Gülermak with bypass tunnel design and work procedures to free the cutterhead and stabilize the disturbed ground. Blasting techniques were ruled out due to concern over further collapses caused by blast induced vibration. Hence, the excavation was undertaken using pneumatic hand held breakers. Details of the bypass tunnel can be seen in Figs. 2 and 3.

Upon completion of the bypass tunnel, further stabilization of the collapsed material above the machine and the ground ahead of the machine was carried out. The injection process this time was far more comprehensive due to the vastly improved access provided by the bypass tunnel. The area around the cutterhead was able to be cleared of material and the cutterhead was freed, allowing boring to recommence.

At this point, it was believed that the collapse was an isolated event and that the geology would improve as the overburden increased.

However, material for a second bypass tunnel was stored at the site. Unfortunately, this measure proved to be prudent planning. Although the machine passed through several weak zones successfully, a further five bypass tunnels were required to free the cutterhead during the first 2 km (1.2 miles) of boring. Robbins and Gülermak analyzed the bypass tunnel excavation procedures and implemented improvements that resulted in a reduction in the time taken for bypass operations from 28 days to 14 days. One of the main aspects of the improved procedures was the implementation of breaking out for the bypass tunnel through the telescopic shield area of the TBM rather than the accepted norm of breaking out from the tail shield. This modification resulted in reducing the length of each bypass tunnel by more than 4 m (13 ft).

Pipe roof canopy. The possibility of installing ground support such as fore-poles or a pipe roof canopy ahead of the tunnel face was investigated and, after consultation with Gülermak, a custom design canopy drill was installed in the forward shield for installation of a tube canopy (Figs. 4 and 5). The space in the forward shield area is limited. Hence, the extension section of each tube is only 1 m (3.2 ft) in length. However, the advantages of drilling closer to the tunnel face more than compensates for the time spent adding extensions to the tube length. The location of the canopy drill reduces the length of each canopy tube by more than 3 m (10 ft) when compared to installation using the main TBM probe drills. Apart from the obvious savings in drilling time, the extra 3 m (10 ft) of drilling length can result in a significant increase in hole deviation. The diameter of the canopy tubes is 90 mm (3.5 in.), each canopy typically extends up to 10 m (33 ft) from the tunnel face and the drill positioner, carriage and slew ring provide 130° of coverage.

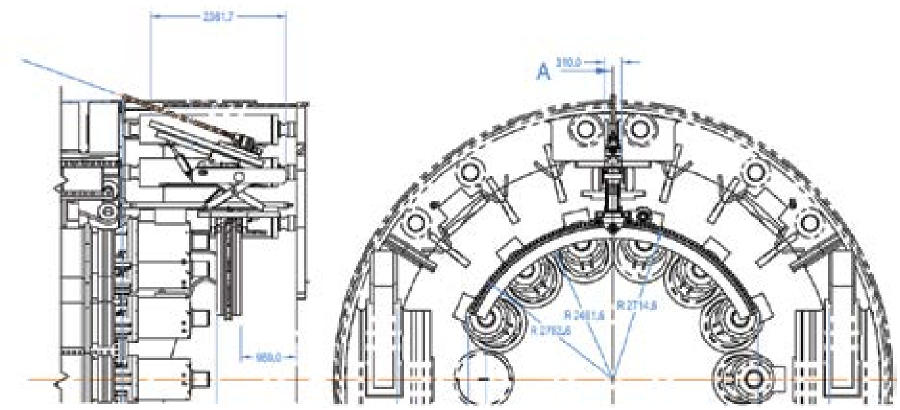
FIG. 3

Bypass tunnel excavation.

Squeezing ground. The time dependency of ground behavior is due to the creep and consolidation processes taking place around the tunnel (Anagnostou & Kovári, 2005). In many cases, the convergence can be a gradual process taking place over a period of days, weeks or even months. On several stretches of the Kargi Tunnel, rapid

FIG. 4

Custom canopy drill.



convergences occurred in the space of a few hours. The geology at the time of these rapid convergences consisted of Serpentine with high content of swelling clay. The convergence was of a radial nature, and distributed relatively evenly around the profile of the TBM.

Probe drilling ahead of the tunnel face identified the majority of the areas considered to be at risk from squeezing conditions. As it is generally accepted that there is a direct relationship between TBM advance rates and problems caused by squeezing ground, it was essential that TBM downtime was minimized while boring through these stretches. On the occasions that squeezing ground had been identified, all outstanding maintenance works, repairs and replacement of worn cutters was completed before boring through the zone of concern commenced. Inevitably, even after taking these precautions, there were unscheduled stoppages. On many occasions, the only successful means of restarting the machine after stoppages in convergence zones was to utilize single shield mode boring. In this mode, the TBM gripper shoes are retracted, the main thrust cylinders are closed up and the auxiliary thrust cylinders are utilized to propel the machine forward by thrusting off the segmental lining. The typical thrust force for standard boring operations using the main thrust cylinders on the Kargi machine is approximately 21,000 kN. On several occasions, thrust force up to 136,000 kN was applied through the auxiliary thrust system before the machine could be freed from squeezing ground. Generally after boring 1 - 2 m (3.3 - 6.6 ft) in single shield mode, the TBM was freed and it was possible to return to double shield mode.

On several stretches of tunnel, the rate of convergence, coupled with the comparative softness of the ground, caused the gripper shield to act as a plough and force muck into the telescopic shield area. The buildup of material became so severe that a mucking system had to be installed in the telescopic shield area. The system consisted of two electric hoists mounted on a running beam that allowed muck kibbles to be placed, lifted, and emptied directly onto the TBM conveyor.

Another measure used to combat the effects of the squeezing ground was the application of a polymer-based, biodegradable lubricant to the extrados of the TBM shields. Eight injection ports were installed around the perimeter of the forward shield and lubrication was injected when boring through convergence zones. It is difficult to quantify the advantage obtained as there was very little consistency in ground conditions and associated thrust pressures. However, it is clear that the application of lubrication reduced the frictional forces between the shields and converging ground.

Solution (gear reduction). To further mitigate the effects of squeezing ground or collapses, custom-made gear reducers were ordered and retrofitted to the cutterhead motors as a solution. They were installed between the drive motor and the primary two-stage planetary gearboxes. During standard boring operations, the gear reducers operate at a ratio of 1:1, offering no additional reduction and allowing the cutterhead to reach design speeds for hard rock boring. When the machine encounters loose or squeezing ground, the reducers are engaged, which results in a reduction in cutterhead speed but the available torque is increased. Figure 6 shows the torque curves for both standard and reduced gearing.

Since the installation of the canopy drill and the increase in available cutterhead torque, the TBM has traversed several sections of adverse geology including stretches of severe convergence without becoming trapped. As of November 2013 more than 4,250 m (13,900 ft)of boring had been completed.

Los Olmos

The Los Olmos Tunnel is a 12.5-km- (7.7-mile-) long water transfer tunnel that was bored through the Andes Mountains in Peru. Odebrecht was the main contractor and the tunnel was driven using a 5.3-m- (17.3-ft-) diameter Robbins main beam TBM. It is the world's second deepest civil works tunnel after the Gotthard Base Tunnel, with overburden of up to 2,000 m (6,560 ft). The tunnel alignment is through complex geology consisting of quartz porphyry, andesite, and tuff with rock strengths ranging from 60 to 225 MPa. The machine crossed more than 400 fault lines including two major faults of approximately 50 m (164 ft) wide.

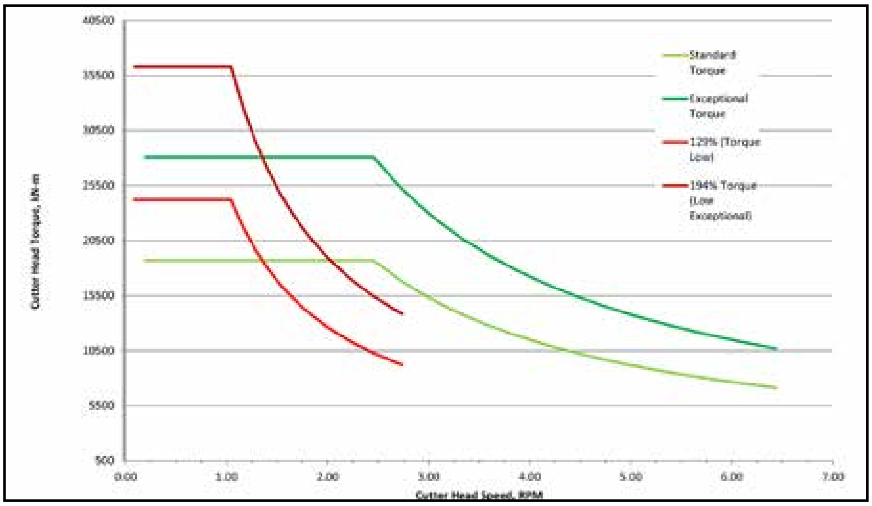
The machine was launched in March 2007, and by February 2008, it had bored more than 4 km (2.4 miles). The geology over the first 4,000 m (13,100 ft) of boring was far more challenging than was anticipated. As the height of the overburden increased, the geological conditions became gradually more severe and long stretches

FIG. 5

Canopy tube drilling.

FIG. 6

Cutterhead torque curves.



of extremely loose, blocky ground were encountered. The rock stresses caused by the high overburden also resulted in more than 16,000 recorded rock bursting events. TBM utilization was as low as 18.7 percent of working time because rock support installation was requiring a very high 43.5 percent of the working time (Roby & Willis, 2008). One of the main problems faced was ground deterioration and the resulting falls of blocky ground. The majority of these events occurred during the time taken for the newly excavated bore to pass behind the rear fingers of the roof shield, where ring beams and mesh are installed.

McNally roof supports system. During consultations between Robbins and Odebrecht, a decision was taken to modify the machine to facilitate the installation of the McNally roof support system, which allows support to be installed directly behind the main roof shield. The main components of the initial modification consisted of removing the shield roof fingers and forming rectangular pockets with a length of 1.4 m (4.6 ft). The pockets run from the rear side of the cutterhead to the trailing edge of the roof support. At a later stage, when the ground conditions worsened, these pockets were extended to cover the profile of the side supports. Figure 7 shows details of the modifications that were implemented to enable use of the McNally system.

The procedures for installation of the McNally roof support system were as follows:

1. Two slats, formed from 6 mm (0.2 in.) rebar, are loaded into each of the pockets.
2. The upper slats in each pocket are drawn from the pocket and pinned to the tunnel wall by means of ring beams or rock bolts.
3. As the machine advances, the slats are held in place and extruded from the pockets.
4. When the leading edge of the upper slat is completely withdrawn, it is fixed to the trailing edge of the lower slat, with an overlap of 200 mm (7.8 in.). Additional slats are then loaded.

The main advantage of the McNally support system is that it is installed closer to the face than other ground support methods used on TBMs, which reduces the required standup time of the excavation. It holds loose rock in place (Fig. 8) which in turn helps to mobilize the strength of the rock mass and maintain the inherent strength of the tunnel arch. When used correctly, the system can significantly reduce the time taken to provide adequate support and can also offer reductions in the level of support required.

Incorporation of the McNally support system and various other modifications to the TBM resulted in a steady increase in production rates in spite of continuous rock bursting events. The machine broke though in December 2011 having achieved production rates in excess of 670 m (2,200 ft) a month.

Parbati hydro electric project stage II

The Parbati hydroelectric project stage II is located in the Kullu district of Himachal Pradesh in India. A 9-km (5.6-mile) section of the head race tunnel is being driven by a 6.8-m- (22.3-ft-) diameter open gripper type TBM through a highly stressed mountain range at the foot of the Himalayas. Overburden along the TBM section of the headrace tunnel reaches as high as 1,400 m (4,600 ft). The geology consists of granite/gneissose and quartzite with bands of biotite schist and talc. Rock strengths are expected to exceed 270 MPa.

The contractor, Himachal joint venture (HJV), purchased a refurbished Robbins-Atlas Jarva TBM from Norwegian company NCC. The machine was launched in May 2004 and, after the completion of 500 m (1,640 ft) of boring, NCC handed over the machine to HJV. HJV operated the machine up to chainage 1,300 m (4,265

FIG. 7

McNally support system.

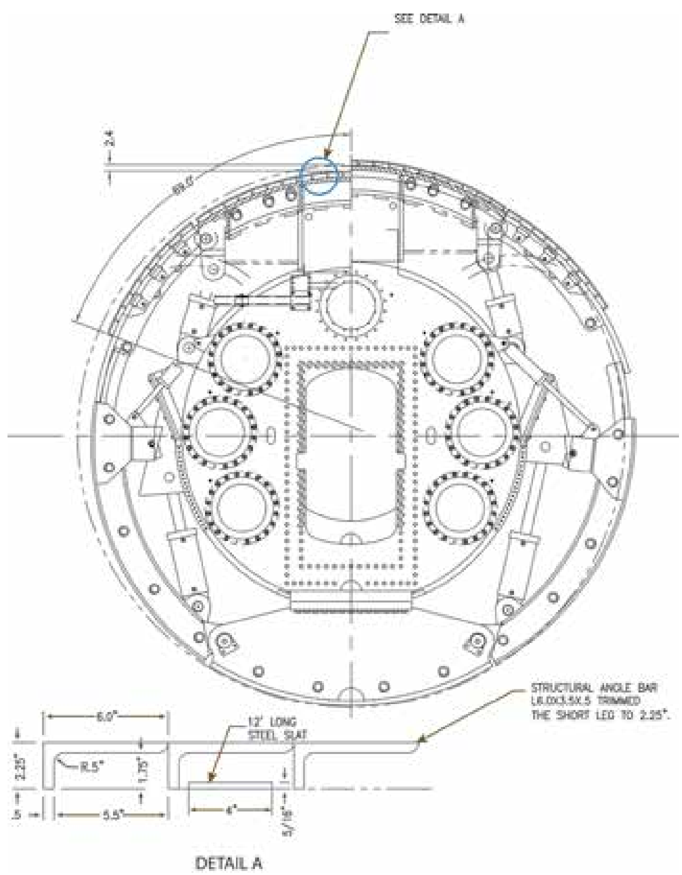


FIG. 8

Loose rocks held in place by the McNally system.

ft). But, due to technical difficulties associated with the machine and relatively slow progress, they approached Robbins for assistance. Robbins provided a field service team to supervise repairs, maintenance and operation of the TBM. Repairs were carried out, the machine restarted and, despite crossing several minor fault zones, operations went smoothly with productions rates of up to 526 m/month (1,725 ft/month). Tunnel support ranged from spot bolting through to complete ring beams, mesh, shotcrete and rock bolts.

Rock bursts. By mid-October 2006, with more than 4 km (13 ft) of boring completed and overburden of more than 1,100 m (3,608 ft) several major rock bursting events occurred. The rock bursting was accompanied by moderate to severe loss of ground, so the support regime was upgraded to include ring beams, rock bolts, lagging sheets and concrete backfilling. During the following 50 m (165 ft) of boring, the incidences of rock bursting events increased to the point that at times they were almost continuous.

Probe drilling. The Parbati project is typical of many hydroelectric projects in that it is located in a mountainous area where there is limited access and high overburden above the alignment of the tunnel. These factors resulted in limited availability of detailed geological information. Bearing this in mind, geological investigation ahead of the tunnel face was essential and was achieved by maintaining a strict regime of probe drilling.

A routine probe hole (P1) was drilled at chainage 4,056 m (13,307 ft) at the 11 o'clock position on the face. The depth of the hole was 27 m (88.5 ft) and minor ingress of water and silt was observed from probe chainage 4,066.5 m (13,341 ft) up to 4,077.3 m (13,376 ft). A decision was made to drill a second probe hole (P2) at the 1 o'clock face position in order to gain further information on the geology/hydrology ahead of the face. During the night shift of Nov. 18, 2006, the P2 probe drilling operations were underway when the crew heard several cracking sounds emanating from the surrounding rock mass. Shortly after these events, the initial probe hole (P1) was observed to be discharging water and silt under high pressure. It took the crew almost 2.5 hours to seal the 51-mm (2-in.) hole using a mechanical packer attached to the probe drill. During these 2.5 hours, approximately 180 m³ (6,356 cu ft) of silt and 125,000 l (33,021 gal) of water were discharged, and continuous rock bursting was occurring.

Inundation. Due to the high pressure and high volume of the discharge, it was decided that the best course of action would be to drill drainage holes to relieve the pressure ahead of the tunnel face, before consolidation grouting could be undertaken. Both drainage holes and grout holes were to be drilled via standpipes. The design of the standpipe arrangement consisted of drilling a 75-mm (3-in.) hole 5 m (16 ft) deep, inserting a 6-m- (20-ft-) long, 64-mm (2.5-in.) steel pipe with a threaded section on the trailing end, and anchoring the pipe in place by cement grouting. A ball valve and pressure gauge were attached to the threaded end of the pipe.

A third probe hole (P3) was drilled, utilizing the standpipe arrangement, to a depth of 38 m (125 ft). Although the location of the P3 probe hole was adjacent to the P1 probe hole location at the 10 o'clock face position, it did not encounter silt or high-pressure water. The next course of action was to attempt drilling a fourth hole that would intersect probe hole P1 to facilitate drainage operations.

FIG. 9

Drilling through stand pipe at Parbati.

The hole was drilled though a standpipe, which was subsequently fitted with a valve to enable regulation of flow, a pressure gauge and a length of 75 mm (3 in.) hose to allow drainage of material directly into the tunnel muck cars (Fig. 8).

On Nov. 24, probe hole P1 was successfully intersected

FIG. 10

Parbati TBM buried in silt.

and drainage operations were underway when several rock bursting events occurred. The pressure in probe hole P1 gradually increased until it exceeded the 25 bar capacity of the pressure gauge and minor inflows of silt and water began to flow through fissures in the rock mass close to the face. Further rock bursting fractured the rock mass surrounding the collar of probe hole P1, causing the rock to fall away and expose the hole behind resulting in an inrush of water and silt under massive pressure. The crew tried unsuccessfully for several hours to insert a packer into P1 to stem the flow of material but at 7 am, with silt levels rising rapidly and rock bursting continually occurring, the tunnel was evacuated for safety reasons.

On Nov. 25, it was deemed impractical and unsafe to enter the tunnel. Water ingress was measured at the portal throughout the day and flow rates gradually increased until they exceeded 7,000 L/min (247 cu ft/min). On Nov. 26, flow rates stabilized, so a team entered the tunnel to assess the situation. They observed that the inundation had almost completely buried the TBM (Fig. 9) and that silt and water were still flowing from the probe hole. However, the pressure of the discharge had reduced and a crew was mobilized and managed to seal the probe hole by inserting a mechanical packer. The total amount of silt deposited during this event was more than 14,000 m^3 (49,440 cu ft) and the cleanup operation took more than two months.

TBM refurbishment and modification. Robbins was awarded a refurbishment contract for the TBM, as many parts and assemblies had been damaged due to being submerged for a prolonged period of time. Once the refurbishment was complete, cement grouting with OPC was carried out to consolidate the ground in front of the TBM. The project was then held up due to contractual issues until January 2010 when Robbins was awarded a contract to modify the TBM. The main components of the modifications included installation of pockets for the McNally support system, upgrading the cutterhead support system and an improved probe drilling system. The existing probe drilling system accommodated drilling from two fixed positions only. The modified system provides 110° of coverage.

After the modifications were completed, further consolidation grouting was carried out before the machine advanced. A system of boring in increments of 8 m (26 ft) advances, interspersed by extensive consolidation grouting, proved to be successful and the machine successfully crossed the geological feature that had caused the inundation. 50 m (164 ft) of boring was completed before the project was again held up due to contractual issues. The project was retendered early 2013 and work resumed in November 2013, although boring will not commence immediately as remedial works to ground support are required in several sections of the tunnel.

Conclusions

TBMs are often the only viable option for the excavation of long tunnels with high overburden due to the impracticalities of opening several faces via adits to enable the application of traditional tunneling methods. As with the three case studies outlined in this article, geological surprises are frequently encountered in long and deep tunnels. Due to cost constraints, contractors often decide to procure a TBM that is suited to the geological baseline reports rather than opting for additional features that ensure against geological anomalies. It is more often than not possible to retrofit additional features, but TBM down time for preparatory works, installation, and component lead times is usually substantial. The actual cost of the additional features applied to the machines described in this paper would have been a fraction of the costs involved had they been installed during the manufacturing process. When compared to the overall cost of a project, additional features installed during manufacturing become almost insignificant.

Technical features on the TBM are not the only insurance required when faced with geological uncertainties. The contractor should have an action plan in place to cover all eventualities. Ground treatment materials and equipment, as well as bypass tunnel materials and equipment should be available at site. Again, the cost of these items is almost insignificant when compared to the cost of the project, and their availability will provide substantial reductions in project delays should they be required. ■

(References are available from the authors.)

FEATURE ARTICLE

Industry turns its focus to California during 2014 NAT Conference

The former mayor of Los Angeles, CA is a believer in public transportation but thinks neither his city nor the entire country is spending enough on basic infrastructure. In fact, the United States has fallen behind most other developed nations in improving public transportation, the former mayor said.

Antonio R. Villaraigosa was the keynote speaker at the North American Tunneling (NAT) conference, held June 22-25 in Los Angeles, CA. The event, held every two years, is sponsored by the Underground Construction Association of SME (UCA). This years' conference attracted 1,091 underground construction professionals from around the world. The accompanying exhibition continues to grow, attracting 142 exhibiting companies occupying 162 booths.

Steve Kral, Editor

As always at NAT, registered attendees received the proceedings volume of the conference, which contains 132 papers. The proceedings volume, including a CD of the papers, is available from SME for $149 member, $139 student member and $189 nonmember. The book can be ordered from SME, NAT item #400-4, phone 303-948-4225, 1-800-763-3132, or online at www.smenet.org/store.

Keynote session

Villaraigosa was mayor of Los Angeles from 2005 through 2013. During that time, he was a strong proponent of building a first class bus system to connect with its rail system, the goal being to "lose the addiction to single passenger cars," he said.

To that end, Villaraigosa helped persuade Los Angeles County voters in 2008 to pass Measure R, a half-cent sales tax that would be used for transportation projects in the area. It was estimated that the tax would bring in about $40 billion during the next 30 years. The Los Angeles area has three transportation projects, funded through the half-cent sales tax, that are either under construction or about to begin, he said. They are the Crenshaw/LAX project, the Regional Connector Transit project and the Westside Purple Line Extension project.

Villaraigosa is very critical of the U.S. Congress' inability to pass a long-term infrastructure bill. In an interview with **T&UC** following his keynote address, he said that artisan politics has stalled any progress on surface transportation issues. "America has to catch up. Professionals are working overseas but not in the United States," he said. "The world is moving while we're standing still." China is building high-speed rail, for example, and 16 other countries are either building them or considering doing so, he said. "It is critical that America start building again," he said. "We need to invest to improve our infrastructure."

Because of the Congress' inability to pass a long-term infrastructure-funding bill, Villaraigosa said it's up to cities and states to figure out ways fund projects — he favors public-private partnerships. "Cities have to take the lead in a world where the Congress does nothing," he said.

To get projects built, coalitions have to be formed between cities, states and other interested parties to decide which projects get built, Villaraigosa said. "This is not a perfect world where you get to pick the project you want."

Antonio R. Villaraigosa, former mayor of Los Angeles, was the keynote speaker at the North American Tunneling conference, held June 22-25 in Los Angeles, CA.

Technical presentations

A major reason NAT is always successful and respected industry event, attracting the number of professionals that it does, is a strong technical program. The following is a small sampling of abstracts.

Planning for what could go wrong, when in fact it could go right — The importance of risk management on tunneling and underground construction projects, J. O'Carroll, Parsons Brinckerhoff — Regardless of whether a tunneling program or project is in the planning, design or execution phase, tackling risks early on is more time- and cost-effective than responding to problems. From inception, projects carry more risk than anticipated, resulting in missing target dates and cost increases. As projects unfold, new risks arise, and they become problems if not identified and acted on immediately. This paper outlines key risk management strategies for owners, tunnel designers and constructors that eliminate, or lessen the severity of, as much risk as possible from the earliest project planning and design stages.

The 2014 NAT Conference attracted 1,091 people and 142 exhibitors. More than 130 papers were presented.

Tunnel boring machine selection for the Baltimore Red Line downtown tunnel, H. Cordes, R. Flanagan and M. Ciancia, Parsons Brinckerhoff — The Baltimore Red Line project involves the design and construction of a 4.8-km- (3-mile-) long tunnel through downtown Baltimore, MD, enabling light rail service between residential and business areas. This paper focuses on the considerations for the selection of an appropriate tunnel boring machine methodology for the downtown tunnel contract procurement. Design challenges of tunneling beneath downtown Baltimore include a tight right-of-way, close proximity to historic and modern high-rise buildings and pre-existing underground tunnels and utilities. Challenging ground conditions consist of soil and rock in full-face and mixed-face conditions. A comprehensive assessment and comparison of state-of-the-art tunnel face support, including innovative hybrid machine techniques with earth pressure balance, slurry face control and open-mode capabilities, was performed to determine the most suitable approach for the project.

The next level: Why deeper Is better for TBMs in mining, R. Gratias, C. Allen and D. Willis, The Robbins Company — Diminishing surficial mineral deposits, increasing environmental regulation and advanced geological exploration techniques are ushering in a new era of mining. Unconventional technology must be adopted to ensure that safe, efficient and responsible access to minerals is possible, as prospecting continues to push the mining industry deeper. This paper discusses why competitive mining operations will become increasingly dependent on tunnel boring machines (TBMs) for mine development and expansion, and explores the implications of TBMs in a drill-and-blast dominated industry.

Design/build a panacea-not, T. Smirnoff, Parsons Brinckerhoff — The current trend of large and small public properties to build major infrastructure is to do so through design/build. Owners believe the design/build approach will shorten the time from preliminary engineering and environmental clearance to delivery while saving money. For design/builders and their engineers, this seems to be a false economy and saves neither money nor time and, in many cases, leaves the owners lacking. This paper examines some of the myths in design/build and shifts of risks to the design/builder as they go through the protracted and expensive process of developing design to meet project requirements and assume contractual risks that are often either attainable or economical. For the responsible final design engineer, it forces many compromises in design to attain the sometimes unattainable low bid.

Other NAT events

The UCA of SME handed out four awards at its banquet on the final night of the conference (**T&UC**, June 2014, page 28). Herbert H. Einstein was presented the Outstanding Educator Award. Ronald E. Heuer was given the Lifetime Achievement Award. Lok Home earned the Outstanding Individual Award. The Project of the Year Award was presented to the Tom Lantos Tunnel project, commonly known as Devils Slide.

Four short courses were presented on Sunday preceding the meeting. They included Tunnel construction ventilation planning and design, surveying in the tunneling industry, Hyperbaric operation in earth pressures balance tunneling: Current standards and operational requirements, and Grouting in underground construction.

Upcoming conferences

There are three conferences in which UCA is heavily involved with coming up. For meeting updates and registration information, go to www.smenet.org. Cutting Edge: Ground Water Control is set for Nov. 2-5, 2014 in New York City. The annual George A. Fox Conference will take place Jan. 27, 2015, also in New York City. And the 2015 Rapid Excavation and Tunneling Conference will be held in New Orleans, LA June 7-10, 2015.

The next NAT will be held in conjunction with World Tunnel Congress April 22-27, 2016 in San Francisco, CA. The UCA will be hosting both conferences. ■

Twin tunnels completes blasting: Project to be completed in December

In December 2013, the Colorado Department of Transportation (CDOT) completed the widening of the eastbound tunnel on Interstate 70 (I-70) from two lanes to three. Work on the westbound tunnel began earlier this year and is scheduled for completion in December.

The Twin Tunnels project is located in the mountains about 55 km (35 miles) west of Denver. They were bored during the 1960s when I-70 was being built and became the main access to Colorado's growing number of ski areas and the state's Western Slope.

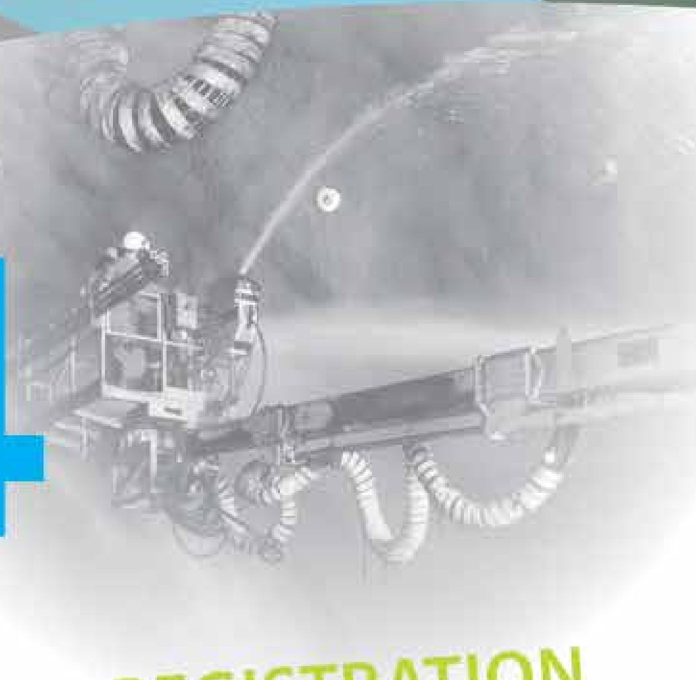
Throughout the decades following their construction, traffic on I-70 continued to increase and now the tunnels have a major bottleneck. Commutes to and from the mountain resorts, particularly on weekends, have become long and slow. Adding a third lane through the tunnels will help alleviate the congestion. (A complete report on the project can be found in **T&UC**, December 2013, page 61.)

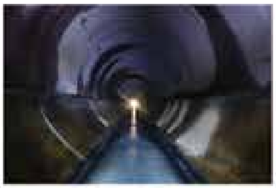
Once the eastbound tunnel was completed late last year, CDOT authorized the funding to begin work on the westbound side. That made economic sense, as the equipment used on the eastbound tunnel needed to only be shifted across I-70 to begin work on the westbound side, rather than removing it in December and bringing it back in March when construction began on the westbound tunnel.

Work on the westbound tunnel uses essentially the methods that were used on the eastbound tunnel — removal of the existing concrete lining and using drill-and-blast methods for tunneling widening. The main difference between the two tunnels is that the westbound side requires more blasting on both ends to widen I-70 to three lanes. ■

Steve Kral, Editor

Crews work in the westbound tunnel of the Twin Tunnels Project in Colorado. Blasting was completed in August.





Compiled by Jonathan Klug, David R. Klug & Associates

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Gateway Tunnel	Amtrak	Newark	NJ	Subway	14,600	24.5	2016	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	Prequals underway
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
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	Bid date 01/09/15
Northeast Branch Tunnel Northeast Boundary Tunnel	DC Water and Sewer Authority	Washington	DC	CSO CSO	11,300 17,500	15 23	2018 2021	Under design Under design
Olentangy Relief Sewer Tunnel	City of Columbus	Columbus	OH	Sewer	58,000	14	2016	Under design
Blacklick Creek San. Interceptor Tunnel	City of Columbus	Columbus	OH	Sewer	24,000	10	2015	Under design
Alum Creek Relief Tunnel Phase 1 Phase 2	City of Columbus	Columbus	OH	Sewer	30,000 21,000	18 14	2016 2017	Under design Under design
Dugway Storage Tunnel	NEORSD	Cleveland	OH	CSO	16,000	24	2014	Bid date 09/10/14
Doan Valley Storage Tunnel	NEORSD	Cleveland	OH	CSO	9,700	17	2017	Under design
Westerly Main Storage Tunnel	NEORSD	Cleveland	OH	CSO	12,300	24	2020	Under design
Shoreline Storage Tunnel	NEORSD	Cleveland	OH	CSO	16,100	21	2021	Under design
Southerly Storage Tunnel	NEORSD	Cleveland	OH	CSO	17,600	23	2024	Under design
Big Creek Storage Tunnel	NEORSD	Cleveland	OH	CSO	19,500	20	2026	Under design
Ohio Canal Interceptor Tunnel	City of Akron	Akron	OH	CSO	6,170	27	2015	Under design
Northside Interceptor Tunnel	City of Akron	Akron	OH	CSO	6,850	24	2021	Under design
Continental Rail Gateway	CRG Consortium	Detroit	MI	Rail	10,000	28	2015	Under design
ALCOSAN CSO Program	Allegheny Co. Sanitary Authority	Pittsburgh	PA	CSO	35,000	20	2016	Under design

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Lower Pogues Run	Indianapolis DPW	Indianapolis	IN	CSO	9,700	18	2018	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
Three Rivers Protection/Overflow	City of Fort Wayne	Fort Wayne	IN	CSO	26,400	12	2017	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
East Link Light Rail Extension	Sound Transit	Seattle	WA	Transit	30,000	22	2016	RFQ underway
L.A. Metro Regional Connector	Los Angeles MTA	Los Angeles	CA	Subway	20,000	20	2014	Skanska-Traylor JV Awarded
L.A. Metro Westside Extension Phase 1 Phase 2 Phase 3	Los Angeles MTA	Los Angeles	CA	Subway	42,000 26,500 26,500	20 20 20	2014 2015 2017	Skanska/Traylor, Shea awarded Under design Under design
Speulvada Pass Corridor	Los Angeles MTA	Los Angeles	CA	High/Trans.	55,500	60	2017	Under study
Northeast Interceptor Sewer 2A	LA Dept. of Water and Power	Los Angeles	CA	Sewer	18,500	18	2014	RFQ underway
River Supply Conduit - Units 5 and 6	LA Dept. of Water and Power	Los Angeles	CA	Water	8,608	12	2014	W.A. Rasic low bidder
River Supply Conduit - Unit 7	LA Dept. of Water and Power	Los Angeles	CA	Water	13,500	12	2015	Under design
JWPCP Effluent Outfall Tunnel project	Sanitation Districts of LA	Los Angeles	CA	Sewer	37,000	18	2015	Under design
Freeway 710 Tunnel	CALTRANS	Long Beach	CA	Highway	26,400	38	2016	Under design
BDCP Tunnel #1 BDCP Tunnel # 2	Bay Delta Conservation Plan	Sacramento	CA	Water	26,000 369,600	29 35	2017 2018	Under design Under design
Iowa Hill pumped storage project	Sacramento Muni. Utilities District	Sacremento	CA	Water	3,500	20	2018	Under design
Coxwell Bypass Tunnel program	City of Toronto	Toronto	ON	CSO	35,000	12	2015	Under design
Yonge St. Extension	Toronto Transit Commission	Toronto	ON	Subway	15,000	18	2016	Under study
Combined Sewer Storgage - East-West	City of Ottawa	Ottawa	ON	CSO	14,400	10	2015	Under design
Combined Sewer Storgage - North-South	City of Ottawa	Ottawa	ON	CSO	5,300	10	2015	Under design
Second Narrows Tunnel	City of Vancouver	Vancouver	BC	CSO	3,600	14	2013	Under design
UBC Line project	Trans Link	Vancouver	BC	Subway	12,000	18	2015	Under design
Northern Gateway Clore Tunnel Hoult Tunnel	Enbridge Northern	Kitimat	BC	Oil Oil	23,000 23,000	20 20	2014 2014	Under design Under design

RAPID EXCAVATION AND TUNNELING CONFERENCE

Mark your calendars!

RETC 2015 ♦ June 7-10, 2015 ♦ Sheraton, New Orleans, LA

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

Exhibit and sponsorship opportunities are now available at: www.retc.org.

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www.smenet.org, **meetings@smenet.org**

www.retc.org

UCA Executive Committee issues call for nominations

Members of the UCA Division are encouraged to nominate interested individuals to serve on the UCA Executive Committee, beginning with the 2015 term. Members serve for four years.

UCA bylaws allow a 19-person Executive Committee. The committee consists of three officers, chair, vice chair and past chair, and four directors, one from each of the following areas: engineers, contractors, owners and suppliers. Ideally, the UCA Executive Committee would have three additional representatives in each of the four categories. But the committee has the option of seating more representatives in one area and fewer in another.

If you would like to nominate someone for consideration, please e-mail your recommendation to Mary O'Shea at oshea@smenet.org by Nov. 25, 2014. Staff will compile all nominations for the UCA Nominating Committee's consideration.

To assist the committee:

- Identify which of the four areas the individual(s) should be considered for service — engineer, contractor, owner or supplier.
- Include a brief biography or résumé outlining the person's industry experience and service to UCA and other professional organizations.
- Remember, the individual must be a current member of the UCA Division. ■

Highlights of the 2014 UCA Executive Committee meeting

By Mary O'Shea, SME Executive Assistant

The UCA Executive Committee met on June 25, 2014 during the North American Tunneling Conference (NAT) in Los Angeles, CA. The committee welcomed two new members, Mike Mooney and Lonnie Jacobs, who will be serving a four-year term.

Young Tunnelers Committee — Anthony Bauer, Erin Clarke and Shannon Goff presented a proposal to create a UCA Young Tunnelers Committee (YTC). The committee would be comprised of industry professionals and university students under the age of 35. The Executive Committee approved the following proposals:

- Create the Young Tunnelers Committee as a UCA standing committee.
- Distribute materials to young members of UCA and encourage them to attend the YTC monthly meetings. UCA members are encouraged to sponsor young members' attendance at the RETC/NAT conferences and to participate in the YTC annual meeting.
- Create a YTC website in the UCA community.
- Sponsor an online webinar host for monthly meetings.
- Sponsor the YTC meeting with a meeting space and refreshments.

Chemical Grouting Committee — Britt Babcock presented a proposal to develop a UCA Cementitious and Chemical Grout Committee. The purpose of the committee would be to provide a collective framework of like-minded, underground construction professionals to promote the understanding, expertise and responsible application of cementitious and chemical grouts and grouting techniques in underground space and facilities.

The UCA Executive Committee agreed that the Cementitious and Chemical Grout Committee would become a task force.

Proposal for UCA to support the Associated Research Centers for Urban Underground Space (ACUUS) — Sanja Zlatanic presented a proposal for UCA to support the ACUUS as a member organization. The ACUUS is an international, nongovernmental association promoting partnerships among all of those in the fields of planning, management, research and uses of urban underground space. It strives to bind these public, private and university levels into a cohesive network of mutual cooperation for the benefit of all parties involved.

The annual membership fee for an institutional member is $500. The UCA Executive Committee agreed to pay the $500 ACUUS membership fee annually. The committee also agreed that Nasri Munfah would be its liaison and that Zlatanic would be the voting delegate.

UCA strategic plan — Chair

EXECUTIVE COMMITTEE

Edgerton sent a letter to the UCA membership in May 2014 requesting volunteers to serve on one of the three strategic committees. The committees will provide their first reports to the executive committee in January.

Strategic Committee One: Become the primary resource for underground construction issues and information requests. Members are: David Klug, Paul Headland, Ray Brainard, Nik Sokol, David Field, Steve Hunt, Derek Zoldy and Nasri Munfah.

Strategic Committee Two: Improve the image of underground construction in the minds of the public, government, owners and all key constituencies. Members are: Paul Gribbon, Stephen Liu, Artie Silber, Jon Klug, Mike Vitale, Mark Johnson, Heather Ivory, Kellie Rotunno, Krishniah Murthy and Brian Zelenko.

Strategic Committee Three: Improve the effectiveness and efficiency of the underground construction industry. Members are: Gregg Davidson, Darrell Wilder, Zachary Jones, Jon Hurt, Dave Young, Steven Fradkin and Dan Ifrim.

Meeting dates

Cutting Edge 2014: Groundwater Control — Nov. 2-4, 2014 New York, NY.

George A. Fox Conference — Jan. 27, 2015, New York, NY.

UCA Executive Committee meeting — Jan. 28, 2015, New York, NY.

SME Annual Meeting — Feb. 15-18, 2015, Denver, CO. ■

OBITUARIES

GLENWAY "BOOTS" MAXON III

Glenway "Boots" William Maxon III, founder of Maxon Industries of Milwaukee, WI, died in Door County, WI May 26, 2014.

He was born in Milwaukee in 1932 and attended engineering school at the Massachusetts Institute of Technology. He served in the U.S. Army before returning to Milwaukee to work with his father. Together they developed and patented numerous products that were instrumental in the rapid concrete paving of the new Dwight D. Eisenhower National System of Interstate and Defense Highways (better known as the Interstate Highway System). Products introduced included the Maxon side dump carrier and Maxon spreader for the transportation and rapid placement of concrete. When larger projects necessitated long haul times from the central mix plant to the placing site, they patented the Maxon agitor — an open-top concrete haul body with an agitation shaft that kept concrete from segregation during transit. The agitor was hugely successful not only in the paving industry, but also in the civil construction industry. In one of the last programs for the atomic power industry, the federal government, through the Tennessee Valley Authority, used 50 agitors to place concrete for its new atomic energy program.

In 1972, after his father retired, Maxon built a factory for the production of concrete equipment on the north side of Milwaukee, where it has expanded multiple times. During the next four decades, he took his extensive knowledge of concrete paving equipment and expanded into new domestic and international markets. Maxon Industries equipment was instrumental in the success of many important international infrastructure projects for bridges, tunnels, highways and dams, including the Chicago Deep Tunnel Sewer Project, the New York Water Tunnel, the Bay Bridge, the Toronto subway and, most recently, the expansion of the Panama Canal.

He grew Maxon Industries into a multifaceted construction equipment manufacturer, acquiring multiple product lines. These included Seaman Travel Mixer, Parsons Trencher and Rexworks Pulvimixer. He was an active member of the American Concrete Paving Association (where he served as past president of the Equipment Division), ACI and ASCM. He retired in 2005, and the company continues on today under the leadership of the next generation of Maxons.


MAXON

Throughout his life, Maxon was active in numerous civic and philanthropic organizations. He was an avid tennis player, playing into his 80s, and was a lifelong automobile aficionado. He raced sports cars in SCCA for many years, more recently working as a docent at the Collier Automobile Collection near his winter home in Florida.

Maxon was a great husband, father and grandfather and will be missed by his wife of 56 years, his three children and eight grandchildren. ■

PERSONAL NEWS

Eisenhower Tunnel superintendent retires

Nearly 3.2-km (2-miles) long and at an elevation of about 3,350 m (11,000 ft), the Eisenhower Tunnel on Interstate 70 in the mountains of Colorado is the highest elevation vehicle tunnel in the world, one of the longest tunnels in the United States and, in its 41-year history, there has never been a fatality in the tunnels.

One of the primary reasons for the impeccable safety record was the efforts of Mike Salamon. More than 300 million vehicles have gone through the tunnel.

Salamon, 62, of Silverthorne, CO, retired last month after serving as tunnel superintendent for the last 22 years. And during his nearly 40 years at the tunnel at the top of the world, safety was always his primary concern. Steep grades and extreme weather set the tunnel apart from all others. "Because of the remoteness we've had to be very self-reliant, even in the areas of fire response," Salamon said. "We maintain all the systems." Three crosscuts connect the two tunnels. In the event of fire and heavy smoke people can use the crosscuts to get into the other tunnel.

"The video surveillance is probably the most important feature from a safety perspective. We can see any event that occurs and respond immediately." That quick response has been tantamount to maintaining such a good safety record.

The dilemma of eastbound traffic jams on Sunday afternoons has also been an issue for decades. Salamon noted, "For about 10 years, from 1990 to 1999, we'd do reversible lanes in the tunnel. On Sunday we'd put three lanes eastbound. It was a complicated reroute. But eventually the westbound volumes became so high we couldn't do it anymore because it started backing up westbound traffic as well. But it helped alleviate a lot of traffic for years." The traffic issues predated the tunnel's existence. Widening the tunnel itself would require the creation of a third bore. A study found the project would cost at least $1 billion.

Salamon has worked at the tunnel almost the entire time it's been open. The town he lives in traces its beginnings to the boring of the tunnels. The miners, who precariously blasted their way through the nearly impenetrable rock, created settlements in what would eventually become Silverthorne. Seven of those miners died during the dangerous process. The now westbound Eisenhower tunnel opened in 1973. Six years later the eastbound Johnson tunnel was completed.

"It was almost like going to moon for miners back then — working at that high altitude in those extreme temperatures, Salamon said. "Construction required 1,500 workers using dynamite to blast through the rock. The first bore doubled the estimated budget. They ran into real bad rock, and they had to go to a very labor-intensive form of tunneling called multi-drifts. Essentially they reinforced the mountain with solid concrete in those bad areas, called the Loveland Fault."

The tunnel was funded 90 percent by the federal government and 10 percent by the state of Colorado. In return, the tunnel would be 100 percent maintained and operated by the state. It was obviously a tremendous boon for travel and leisure in the high Rockies. The opening of the tunnel allowed easier and quicker access to old mining towns, some of which, like Breckenridge, transformed into wealthy resorts. "I think it's the lifeblood to Summit County and the Western Slope," Salamon said. "We see 45,000 vehicles go through a day on the weekend. No way Loveland Pass could have ever handled those totals." ■

Jacobs Associates has added the following five employees to the position of principal with the company.

DAVID CORKUM (UCA) has more than 35 years of experience in the heavy civil and underground construction industry, specializing in geology and geotechnical engineering. Corkum is based in Washington, D.C. and is part of the DC Clean Rivers project team, where he will oversee the design and construction activities.


CORKUM

KARL ASSI, CP.Eng, has more than 20 years of experience in tunneling and structural engineering on a range of transportation, water and waste water projects. He currently manages the Melbourne office.

JOEL KANTOLA, P.E., has more than 25 years of experience working as a program manager, contractor, designer, construction manager and geotechnical engineer on soft ground and hard rock tunnel projects for storm water, sewage, water, subway and highway tunnels. Kantola is serving as a project manager on the DC Clean Rivers' Northeast Boundary Tunnel.

BLAKE ROTHFUSS, P.E., has more than 30 years of engineering experience on heavy civil projects. He is based in the Walnut Creek office and currently serves as project manager and owner's engineer for Sacramento Municipal Utility District's underground pumped storage project.

KENT WINGER, P.E., has more than 25 years of experience providing construction dispute resolution, scheduling and contractor performance analysis consulting services. He is based in the San Francisco, CA office and is involved in the preparation for arbitration and trial of general contractor claims involving building construction projects. ■

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