T&UC

TUNNELING & UNDERGROUND CONSTRUCTION

THE OFFICIAL PUBLICATION OF UCA OF SME   WWW.TUCMAGAZINE.COM   VOLUME 5 NO 3   SEPTEMBER 2011

Transporting a TBM

Ground support for tunnel boring

Lessons in pump station construction

Special Editorial Section from the publisher of *Mining Engineering*

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COVER STORY

COVER — Moving a tunnel boring machine (TBM) from one shaft to another is a challenge anywhere it is done, but to do it in a large city adds new wrinkles to the already challenging job. In Portland, OR, planners of the East Side CSO Tunnel Project overcame the moving challenge by going to the water and using barges to transport their TBM. See the story on page 44.

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CHAIRMAN'S COLUMN

UCA of SME is on the right path and will continue to improve

The UCA Executive Committee has an established process in which every two years the current chairman passes the gavel on to the Vice Chair and then assumes the duties of the Past President. And 2011 was no exception as Dave Klug officially passed on the gavel to yours truly during the RETC in San Francisco, CA, June 19-22.

Klug briefly discussed this transition in his final chairman's column in the June issue of **T&UC**, and now, I would like to take this opportunity to thank him for his hard work and dedication to the industry and for helping improve the UCA of SME to the place it now is. I look forward to working with Klug in his new role. I also want to take a this opportunity to share my thanks to the outgoing committee members for their dedicated service: Brenda Bohlke, Tom Clemens, Gregory Raines and Mark Kritzer. It was a pleasure getting to know these people while we worked together, and I look forward to that relationship continuing for years to come.

Klug also introduced the new incoming executive committee members, so I will not go into that detail here (the committee members are listed on this page). But I would like to say that it is a privilege to serve as chairman for the UCA Executive Committee and I look forward to working with Bill Edgerton as vice chairman and the entire executive committee team as we continue to develop the organization to better serve the industry.

In recent years, we have seen many changes and improvements in the UCA. During my time here as chairman, I certainly plan to work with our team, as well as many in the industry, to keep that trend going. Since this is my first chairman's column, I thought it would be fitting to share with you the four areas that I would like to see UCA focus on as we move forward.

The first area of focus is to continue to develop our internal working groups and committees to ensure they serve our members in the best possible way while adding value to the industry. For example, under the leadership of Bohlke and Klug, we have made significant progress with the scholarship and education committees and Bob Goodfellow made significant progress this past year with the publishing of the book, *Concrete for Underground Structures; Guidelines for design and construction* (see page 30).

There are many more opportunities for our members to participate and many more ways to help shape and improve all aspects of the work we are involved in. With improved programs and processes within the UCA, we will be able to achieve much more as a team and an industry.

The second area of focus I would like the UCA to develop is in all things safety related. The UCA is made up of people from all walks of life, and the executive committee has four main groups of people represented — contractors, engineers, owners and suppliers. In my opinion, this is a perfect format to ensure that we address safety improvements in all areas of our industry. Unfortunately, underground and tunneling work has a terrible reputation of being unsafe. While it does require us to work in a high-risk environment, I think that with the right engineering, process, control and most important, attitude, our work does not have to be as unsafe as it was in the past. None of our people plan to come to work and get hurt, and we should have the attitude that getting hurt is unacceptable. There is room for

(Continued on page 25)

Jeffrey Petersen,
UCA of SME Chairman

Seattle Tunnel Partners choose Hitachi Zosen for earth pressure balance machine

The tunnel boring machine (TBM) that will be used to excavate the proposed 3.2-km (2-mile) SR 99 bored tunnel that will replace the Alaskan Way Viaduct will be built by Hitachi Zosen Corp.

Seattle Tunnel Partners, the Washington State Department of Transportation's (WSDOT) design-build contractor for the proposed SR 99 bored tunnel, announced that it has selected Hitachi Zosen Corp. to supply the machine that is expected to the be the largest TBM built to date. Hitachi Zosen will design, manufacture, assemble, test and commission the 17.5-m- (57.5-ft-) diameter earth pressure balance TBM and will also be responsible for training Seattle Tunnel Partners' personnel.

"After a decade of debate, we are taking another step toward creating a new waterfront for Seattle, preserving the capacity businesses need to grow and replacing the viaduct," said Gov. Chris Gregoire. "Hitachi Zosen's state-of-the-art proposal exceeded WSDOT's standards and will help Seattle Tunnel Partners deliver this world-class tunnel project."

WSDOT said in a statement that Hitachi Zosen was the best value manufacturer based on overall technical requirements, support capabilities, price and schedule. Located in Osaka, Japan, Hitachi Zosen has successfully built a number of large-diameter tunnels, including the Tokyo Metropolitan Expressway (13 m or 45 ft in diameter) and the Tokyo Bay Highway Tunnel (14 m or 47 ft in diameter). Hitachi Zosen is currently supplying the TBMs for Sound Transit's Capitol Hill Station to Pine Street segment and the Bay Tunnel near San Francisco, CA.

"Hitachi Zosen's state-of-the-art proposal exceeded WSDOT's standards and will help Seattle Tunnel Partners deliver this world-class tunnel project."

**Washington Gov.
Chris Gregoire**

"WSDOT requires Seattle Tunnel Partners to provide and safely operate a machine that could successfully bore through soil conditions in downtown Seattle, that would protect city infrastructure and buildings, and would provide real-time monitoring information to inspectors," said Washington Transportation Secretary Paula Hammond. "We are pleased with the selection of Hitachi Zosen and know they will be a strong partner in delivering this complex project."

Herrenknecht (Germany), Hitachi Zosen (Japan), Kawasaki-SELI

(Continued on page 19)

Barnard Impregilo Healy JV wins San Francisco Central Subway Tunnel contract

The San Francisco Municipal Transportation Agency's (SFMTA) board of directors approved a tunneling contract for the $1.57-billion Central Subway project.

The board approved a $233.6-million contract that will pay for the development of about 2,500 m (8,240 ft) of concrete tunnels and two tunnel boring machines (TBM), according to SFMTA officials. The contract, the largest construction package for the $1.6 billion transit project, was awarded to Barnard Impregilo Healy, a joint venture out of Bozeman, MT.

The project will create a new branch of the San Francisco Municipal Railway's T-Third line that will run north along Fourth Street from Brannan Street before going underground at Interstate Highway 80, with subway stops at Moscone Center, Union Square and Chinatown.

The board approved a $233.6-million contract that will pay for the development of the concrete tunnels and two TBMs, according to SMFTA officials. Barnard Impregilo Healy was awarded the contract after offering the lowest bid.

The Central Subway project has received nearly $96 million in federal funding, including $20 million from the U.S. Department of Transportation's Federal Transit Administration.

"Investing in the Central Subway is an investment in jobs, in the economic vitality of our city, in safer transit and better commutes for San Francisco's workers," U.S. House Minority Leader Nancy Pelosi said in a statement.

"The Central Subway project is vital to connecting our city to our communities like never before," San Francisco Mayor Ed Lee said in a statement.

The Central Subway is expected to open by 2018 and carry 65,000 passengers daily by 2030, according to SFMTA officials. ■


WE DO
BIG.
AND WE DO IT WITH PRIDE.

Contract for Blue Plains Tunnel project awarded

The joint venture of Traylor Brothers/Skanska/Jay Dee (TSJD) secured a $330.5-million contract from the District of Columbia Water and Sewer Authority (DC Water) board of directors for the design and construction of a storage and conveyance tunnel as part of the Clean Rivers project.

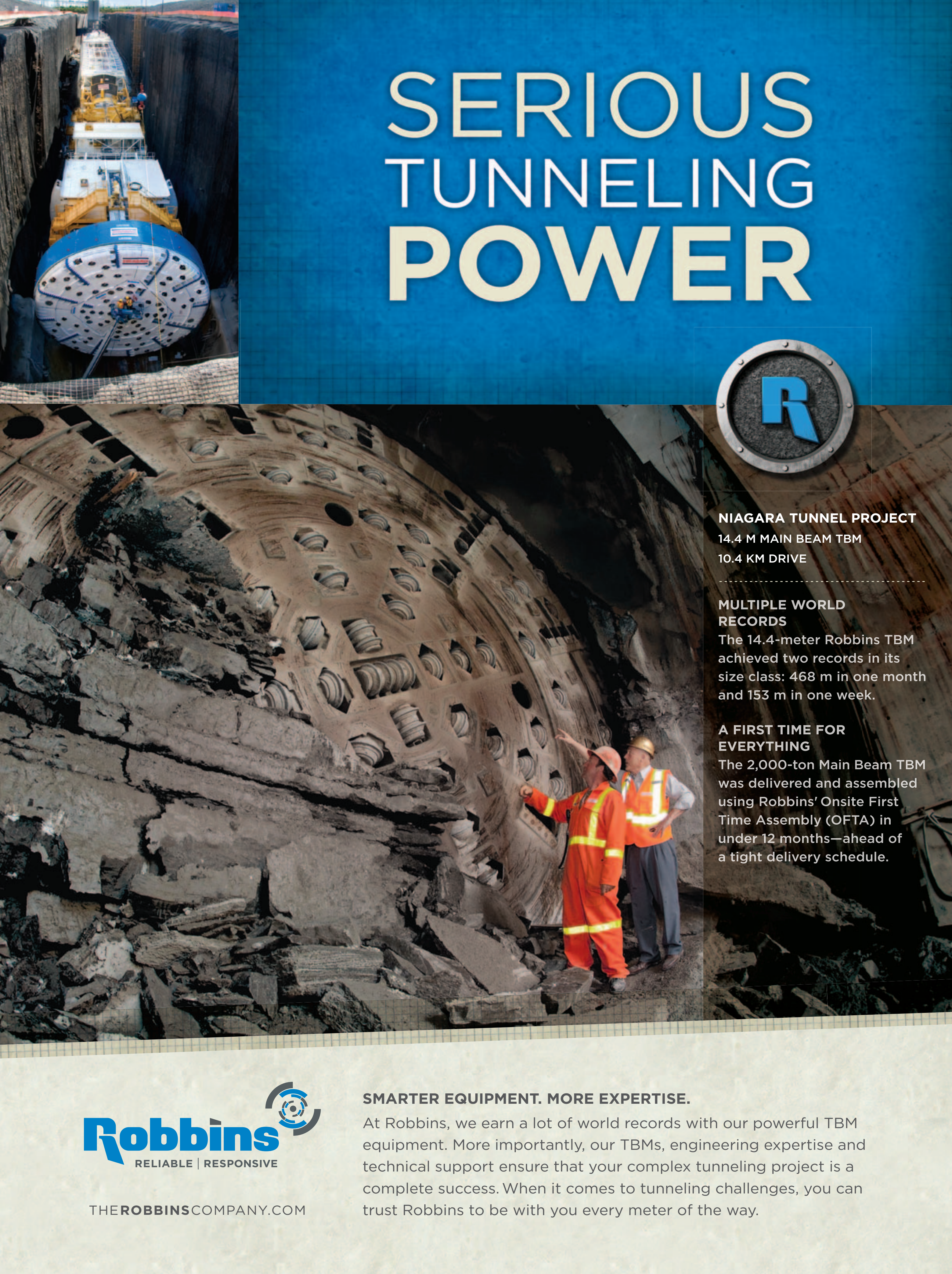
The Clean Rivers project is a 20-year, $2.6-billion program to reduce combined-sewer runoff to the Anacostia and Potomac rivers and Rock Creek by 96 percent. The contract to TSJD is the largest contract to date for the project. TSJD delivered the highest-scoring technical proposal and the lowest price.

"The board's action starts an economic engine that will affect our area for many years," said DC Water Board chairman William M. Walker. "The tunnel contract is also the board's most significant opportunity to date to provide opportunities for minority, local and women-owned contractors. We remain committed to making sure we meet our obligations on that front, and will provide the ongoing oversight a project of this scope demands."

"This contract award means actual shovels in the ground after years of planning," said DC Water general manager George S. Hawkins. "The Clean Rivers project will be the single most important step of a generation in improving the district's waterways."

"TJSD is very excited about the Blue Plains tunnel project," said Traylor Brothers vice president George Williamson. "We have more than 65 years of experience in tunnel design and construction and a tremendous depth in our engineering and management staff. Further, our team is rounded out by some exceptional local professional and construction subcontractors. We are confident in our ability to build an outstanding tunnel at Blue Plains." ■

> **"This contract award means actual shovels in the ground after years of planning."**
>
> **DC Water general manager George S. Hawkins**



SERIOUS
TUNNELING
POWER
NIAGARA TUNNEL PROJECT
14.4 M MAIN BEAM TBM
10.4 KM DRIVE
MULTIPLE WORLD RECORDS
The 14.4-meter Robbins TBM achieved two records in its size class: 468 m in one month and 153 m in one week.
A FIRST TIME FOR EVERYTHING
The 2,000-ton Main Beam TBM was delivered and assembled using Robbins' Onsite First Time Assembly (OFTA) in under 12 months—ahead of a tight delivery schedule.
Robbins
RELIABLE | RESPONSIVE
THEROBBINSCOMPANY.COM
SMARTER EQUIPMENT. MORE EXPERTISE.
At Robbins, we earn a lot of world records with our powerful TBM equipment. More importantly, our TBMs, engineering expertise and technical support ensure that your complex tunneling project is a complete success. When it comes to tunneling challenges, you can trust Robbins to be with you every meter of the way.

Arup signs agreement with China Railway Engineering

Arup announced that it has signed a landmark agreement with the China Railway Engineering Corp. (CREC), one of the world's largest civil engineering groups and tunneling contractors.

Chinese Premier, Wen Jiabao, and British Prime Minister, David Cameron, attended the signing of a memorandum of understanding (MoU) in London as part of a Sino-UK visit.

The agreement forms the basis for closer collaboration between Arup and CREC in bidding for key international projects in the future. The MoU strengthens an already close working relationship between the two groups as they look to exploit growing market opportunities in the Middle East, Africa, South America and Southeast Asia.

Combining the design engineering expertise of Arup with the scale and experience of the Chinese engineering and construction giant is likely to provide a compelling proposition for prospective clients in these expanding markets, according to the signatories.

"This is an excellent agreement that forges a very powerful strategic partnership for future growth across both groups," said chairman of the Arup Group Board, Philip Dilley. "CREC is a very well-known and highly respected company, so we are delighted to be able to work with them even more closely, combining our knowledge and expertise to exploit new business opportunities in fast-growing markets around the world."

"CREC already has many offices around the globe, but this agreement is strategically important for the company. Not only does the agreement reinforce the strong relationship between Arup and CREC, it also puts us in a good position to exchange information on new project opportunities and bid for major contracts as we aim to expand outside China," said CREC vice president, Hui Liu.

The signing ceremony in London was attended by high-level delegates from both groups, alongside representatives from the Ministry of Commerce of the Peoples Republic of China who added their support to the cooperation agreement between Arup and CREC. ■

Sand tunnel contract awarded to Redpath South Africa

The Ghaghoo diamond mine in Botswana will be the site of a first-of-its-kind inclined sand tunnel developed by Redpath South Africa.

The mine, 200 km (124 miles) north of Gaborone in the Central Kalahari Game Reserve, is being recommissioned. The contract for the sand tunnel is valued at approximately C$9.4 million.

The tunnel will descend 112 m (367 ft) vertically below the surface at an inclination of 8°. It is scheduled to be completed in 2012. About 403 m (1,300 ft) will pass through pure sand and another 121 m (396 ft) will pass through the transition from sand to basalt. Workers will be protected from sand collapse by a 50-t (55-st) shield.

About 403 m (1,300 ft) will pass through pure sand and another 121 m (393 ft) will pass through the transition from sand to basalt. Workers will be protected from sand collapse by a 50-t (55-st) shield.

Redpath South Africa mine manager Olaf Iversen said he expects Redpath to face numerous challenges in the upcoming months. "The Ghaghoo diamond mine is extremely remote and isolated, and the majority of the 93 Redpath staff members working on the project will be located on site. In order to maximize productivity and reduce logistical challenges, staff members will be working 14 days on and seven days off."

Iversen said the company expects several additional challenges will be encountered in constructing the inclined sand tunnel at the sand and basalt interface because water could possibly be intersected. He also noted that Redpath's entire scope of the project will have to be undertaken using diesel-powered generators in a region with no electricity.

Redpath South Africa will employ 78 staff members from communities surrounding the project. "The client, Gem Diamonds, held numerous discussions and road shows for the local communities, in order to ensure that we are

(Continued on page 25)


LOVAT

Seattle's East Link light rail route approved

Seattle Sound Transit directors approved the East Link light rail route, a 23-km (14.5-mile) extension that includes a tunnel beneath downtown Bellevue, WA. The project will connect Seattle, Mercer Island, Bellevue and Overlake by 2023. Construction is expected to begin in 2015 or 2016.

Bellevue and Sound Transit staff agreed on the basic terms of what they hope will become a legally binding deal by October. The preliminary agreement called for the city to share the cost of the tunnel, support Sound Transit's rail route through south Bellevue and work cooperatively with the transit agency on permitting and construction. However, the *Seattle PI* reported that the cost of the tunnel, an estimated $329 million, was not part of the original $2.4 billion East Link financial plan approved by voters in 2008. That plan was to run trains at grade.

"I am delighted at what has happened recently and the new spirit of cooperation," said Fred Butler, the Issaquah City Council's deputy president, who successfully urged the Sound Transit board to approve the route plan and the agreement with Bellevue.

The *Seattle Times* reported that strained relations between Bellevue and Sound Transit gave way to intense negotiations after a majority on the city council concluded that their desired rail route across Mercer Slough and along an abandoned freight-rail corridor beside Interstate 405 would cost more than Sound Transit could afford.

Sound Transit agreed in the preliminary deal with Bellevue to evaluate a grade-separated alignment along 112th Avenue Southeast, noise walls and wider landscaping in Surrey Downs and construction of a new southbound lane on Bellevue Way Southeast.

However, many details remained to be worked out before a binding agreement could be reached and the Sound Transit board insisted that Bellevue must share in any tunnel-related cost overruns. The preliminary agreement, as presented to the board, limited Bellevue's obligation to $160 million, or about half the expected cost of the tunnel.

Sound Transit staffers said the tunnel leaves East Link with a $100-million to $200-million funding gap, but they said they hope to narrow the shortfall through a variety of measures before construction begins in 2015.

Seattle Mayor Mike McGinn and Metropolitan King County councilmember Larry Phillips, members of the Sound Transit board, voted against the rail alignment,

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Tutor Perini acquires Frontier Kemper stock

Tutor Perini Corp. has acquired 100 percent of the stock of Frontier Kemper Constructors Inc. from Deilmann Haniel International Mining and Tunneling GmbH. Tutor Perini is a Massachusetts corporation with headquarters in Sylmar, CA, and is a leading civil and building construction company offering diversified general contracting and design/build services to private clients and public agencies throughout the world. Tutor Perini has provided construction services since 1894 and had $3.2 billion in revenue in 2010. Its acquisition of Frontier Kemper stock was effective June 1, 2011.

Frontier Kemper president and chief executive officer W.D. (Dave) Rogstad announced that Frontier Kemper will operate as a subsidiary to Tutor Perini Corp. and will continue to operate in the underground construction and mine development markets. The acquisition of Frontier Kemper will allow Tutor Perini to expand and grow its presence in the underground construction market. Frontier Kemper had $148 million in revenue in 2010 and currently has $290 million in backlog.

"Frontier Kemper management views this as an exciting and positive step forward and welcomes our new shareholder," the company said in a statement. "Frontier Kemper also thanks DHI Mining and Tunneling GmbH, and its parent Aton GmbH, for all of their support over the last five years." ■

East Link: Construction to begin in 2015

(Continued from page 12)

saying it was not clear Sound Transit could afford the downtown tunnel. "By making this commitment we're starting with what is a $100-million to $200-million hole. That's if everything works out," McGinn said.

King County executive Dow Constantine said it was critical to approve the route, including a tunnel he said would improve travel times.

By 2030, East Link trains are expected to move up to 50,000 riders every weekday. ■

Rains fast-track work at tunnel project in Mexico

Components for the 8.93-m (29.3-ft) Robbins EPB, including the cutterhead, were lowered down the 45-m- (148-ft-) deep shaft 5 for assembly prior to launch.

Mexico City's torrential rains and their ensuing floods have fast-tracked commissioning of one Robbins earth pressure balance (EPB) tunnel boring machine (TBM) at the country's most critical infrastructure project, a 62-km- (39-mile-) long waste water tunnel. The 8.93-m- (29.3-ft-) diameter machine was launched on July 13 at Lot 1 — a change from its originally designated tunnel at Lot 5.

Six lots, using three Robbins TBMs and three Herrenknecht TBMs, were planned for the waste water line, but problems with the first TBM on Lot 1 prompted the machine change. "A flood in shaft 0 delayed the Herrenknecht ma-

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Emisor Oriente adds to city's wastewater capacity

(Continued from page 16)

chine for six months. In order to compensate for time lost, we began boring with the Robbins machine at Shaft 5 of Lot 1," said David Juarez, site manager for Lot 1 contractor Ingenieros Civiles Asociados (ICA).

The critically designated Lot 1 site, located in the Ecatepec area outside of downtown Mexico City, has seen widespread flooding during each rainy season. The Gran Canal, an open sewer commissioned in 1910, is the area's main sewer line — a waterway that floods its banks regularly, causing road closures and significant health problems to those living nearby. Due to a loss of slope because of the city's sinking lake clays, the canal now has a positive vertical alignment below Mexico City. The portion of the canal outside the city has not been affected. Increased volumes of water have the potential to overload current pumping stations and send the untreated water back into the city.

"We are currently building a treatment plant and a pumping station at Shaft 5 of Lot 1, to pump the water diverted into Emisor Oriente back into the Gran Canal where the slope has not been affected," said José Miguel Guevara, general supply coordinator for Potable Water and Sanitation at the National Water Commission (CONAGUA). The pumping station will go into service as soon as tunneling is completed at Lot 1 and the finished section is sealed off from the rest of construction.

The Robbins TBM at Lot 1 has started excavation using umbilical cables connected to the surface and a sludge pump for muck removal. Once it has bored ahead 150 m (490 ft), a Robbins continuous conveyor system and vertical belt will be installed for the remainder of the drive in mainly lake clays and sand.

Once the machine reaches the end of its 5-km (3-mile) drive to Shaft 3A at Lot 1, it will be removed and readied for its original 8.6-km- (5.3-mile-) long bore at Lot 5. Two more Robbins EPBs are scheduled for launch later in 2011 on 9.2 km (5.7 mile) and 10.2 km (6.3 miles) bores at Lots 3 and 4, respectively.

When complete in 2014, the Emisor Oriente line will add about 150 m^3/sec (5,300 cu ft/sec) of water to the city's waste water capacity. The project will operate in parallel with the city's other main waste water line, Emisor Central. ■

TBMs ready to launch at Toronto's Spadina project

The first of four tunnel boring machines (TBM) that will be used to extend Toronto's Spadina subway line to the York Region was lowered and launched in June.

"It's really exciting. After 25 years, we're finally building the subway line. It's going to connect York to rapid transit, it's going to open up an entire new area of the city. It's going to link us to our regional neighbors," Toronto Transit Commission chair Karen Stintz told *The Toronto Star*.

Currently, there are 2,000 buses a day that serve York University and the city's planned development of Downsview Park, which will also feed the subway.

The $2.4-billion extension of the subway line, which will extend 6.7 km (4.1 miles) from Downsview station to the Vaughan Metropolitan Centre, is scheduled to open by 2015. So far, construction is on time and on budget, Stintz said. The project will include four tracks.

There are three shafts along the six-stop route into which the machines will be lowered and extracted at various phases.

The first machine will dig northwest, parallel to Keele St. to just south of Finch Ave. About a month later, its twin will begin boring a parallel tunnel. The time gap is necessary to let the ground settle.

Once they reach Finch, the machines will be pulled out through an extraction shaft and returned to Sheppard, where they will begin boring south to Downsview station.

> **"After 25 years, we're finally building the subway line."**
>
> **Toronto Transit Commission chair Karen Stintz**

The second set of tunneling machines will be launched in fall at Steeles West Station, from which they will travel south to Finch West. There they will be extracted and taken up to Highway 407 to dig south to Steeles West. Finally, those machines will be used to tunnel north to Vaughan.

Custom-built by Lovat in Toronto, the machines are assembled at the subway site.

The Spadina tunnel will be 5.4

(Continued on page 19)

Hitachi Zosen: TBM design under way

(Continued from page 3)

(Japan, Italy) and Robbins-Mitsubishi (United States, Japan) submitted boring machine proposals to Seattle Tunnel Partners on May 31. Seattle Tunnel Partners met with the manufacturers numerous times during the evaluation. Some of the factors considered were the teams' ability to meet technical requirements prescribed by WSDOT and established by Seattle Tunnel Partners specifically for this project; management and supervision on the construction site; cost and schedule and warranty and bonding.

"Receiving proposals from four highly qualified and experienced tunnel boring machine manufacturers resulted in a very competitive procurement," said Chris Dixon, Seattle Tunnel Partners executive. "We are confident that Hitachi Zosen will build a state-of-the-art machine that will safely construct the proposed bored tunnel."

Seattle Tunnel Partners issued a letter of intent to Hitachi Zosen on July 15, which allowed them to begin preliminary design until the project receives federal environmental approval. Once approval is issued, WSDOT would direct Seattle Tunnel Partners to proceed with final design and construction and the design-build team will execute a contract with Hitachi Zosen to design and manufacture the boring machine. ■

Spadina project: First TBM launched in June

(Continued from page 18)

m (17.7 ft) in diameter, compared with 5.2 m (17 ft) on the Sheppard line, because of different curves on Spadina and to accommodate new fire rules requiring wider walkways.

The tunnels won't be as wide, however, as the Eglinton light rail, which requires a 6.5-m (21-ft) diameter to accommodate the overhead catenary.

The stations will cost $100 million to $200 million each, including tail track at the north end, where trains will be stored. ■

Big Becky breaks through at Niagara Tunnel

After four years of tunneling beneath Niagara Falls, Ontario, the tunnel boring machine (TBM) named Big Becky broke through to daylight on May 13. The machine is the largest rock TBM in the world.

Ontario Power Generation's (OPG) Niagara Tunnel is one of Ontario's largest clean energy projects. This design/build project is a 10.2-km (6.3-mile), 12.8-m- (42-ft-) diameter water diversion tunnel for hydropower generation and includes associated intake and outlet works. Completion of the TBM's journey beneath the City of Niagara Falls is a major milestone in the project. When the entire project is complete, in 2013, it will provide enough additional water to the existing Sir Adam Beck generating stations to generate clean energy for about 160,000 homes.

Hatch Mott MacDonald, along with Hatch, is providing Owner's Representative services to OPG during the design/build construction of the $1.6-billion Niagara Tunnel project. This has included preparation of design/build contract documents, design review, construction monitoring and contract administration. The design/build contractor is Austria based Strabag AG.

The breakthrough was witnessed by a large number of project staff and dignitaries, including Dalton McGuinty, Premier of Ontario and Brad Duguid, Ontario Minister of Energy. "The breakthrough of Big Becky to daylight is an historic event for Ontario," Tom Mitchell, president and chief executive officer of OPG announced. "Today, we witnessed the completion of one of the largest underground excavations in history. Everyone in this province can take pride in this project. It's important we recognize the employees from OPG, Strabag, Hatch Mott MacDonald, subcontractors and the hundreds of men and women who went deep underground every day to make this project a reality." Mitchell added that, while the project had challenges, this difficult phase was completed safely. "This tunnel was excavated with no fatalities and no serious injuries. That is a tremendous accomplishment and everyone on the project should be proud of this." ■

Sinkhole develops beneath Boston's Big Dig project

The Big Dig tunnel project, the much maligned project in Boston, has another problem to deal with, a 1.2-m- (4-ft-) deep sinkhole that is estimated to be 18 m (60 ft) below the surface and could be as large as 58-m- (190-ft-) long.

The sinkhole is believed to be the result of ground thawing.

Massachusetts state officials signed off on a pioneering soil-freezing technique in the 1990s to avoid having to reroute commuter trains during the problem-plagued project's construction, after rejecting more traditional methods that would have disrupted rail service.

Big Dig engineers have been monitoring soil subsidence that exceeded expectations for the past four years. *The Boston Herald* reported that state officials insist the tunnel — where motorist Milena Del Valle was killed by a falling slab of concrete in 2006 — is safe for traffic and not in danger of collapse

"We're very satisfied that the tunnel structures are not compromised at all."

Frank DePaola, Massachusetts acting highway administrator

"At this point, the engineer consultant is saying no matter how much settlement occurs, they say there's no concern for the tunnel itself," Frank DePaola, the state's acting highway administrator said. "We're very satisfied that the tunnel structures are not compromised at all."

Engineers have not been able to see the sinkhole because of its remote location. They say it poses no threat to drivers because tests show the tunnel could span the gap like a bridge over a river.

They plan to fill the space with concrete, once the area is completely thawed, sometime in late 2013 or early 2014.

The state has spent $15 million to date to monitor the situation, and has budgeted $10 million more for repairs. The money comes from a $485 million fund set up by the Big Dig's contractors, to avoid liability for the fatal tunnel collapse in 2006, leaks, and other problems on the project. ■

Drilling for hydropower in Huoi Quang

Vietnam's cities are growing to support the country's rapidly expanding manufacturing base and so, too, is the need for electricity.

To meet the demand of electricty, construction of a 520-MW hydropower plant is under way at Huoi Quang in northwest Vietnam.

Scheduled to come online in 2014, the plant is expected to produce 1.84 billion kWh of electricity per year.

With ambitious goals for rapid progress, the drill-and-blast teams have chosen Atlas Copco Boomer rigs to handle the drilling operations.

An Atlas Copco Boomer L2 D drill rig at work in Vietnam.

When commissioned, the new plant will make a significant contribution to Vietnam's increasing need for power. It will be one of the four largest hydropower facilities in the country along with Son La, Hoa Binh and Lai Chau.

Huoi Quang is located on the Da River some 450 km (280 miles) northwest of Hanoi, and is initiated and supervised by Vietnam Electricity, the state agency that supplies the country's power. Two main contractors are working on the construction and excavation of the required tunnels – Song Da #10 and Lung Lo Construction Ltd. Company.

A 4.2-km (2.6-mile) headrace tunnel is currently being constructed from three separate portals. Song Da is drilling from opposite ends of the 7.5- x 7.5-m (24- x 24-ft) main tunnel, while Lung Lo, part of the Vietnamese army, was driving a 6- x 6-m (20- x 20-ft) access tunnel to the T-point before continuing in the main tunnel, on two fronts and in opposite directions, to meet Song Da.

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Hydro plant will increase Vietnam's energy capacity

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The 500-m- (1,600-ft-) long access tunnel was being excavated at an incline of 6° on its way to the T-point and more than half of it had been completed. For its drill-and-blast operations, Lung Lo uses two Atlas Copco Boomer L2 D drill rigs, each equipped with COP 2238 rock drills, which provide 22 kW (29.5 hp) of power, as well as Secoroc 45 mm (1.7 in.) ballistic button bits and T38 drill rods.

To drill each round took 2 to 2.5 hours and working in three shifts, the teams achieved two, 4-m (13-ft) advances each day including drilling, charging, blasting and mucking out. The crew drilled 190-195 holes per round. It planned to do the same in the main tunnel.

The plan for support and lining included wire mesh, rock bolts, sprayed concrete with concrete admixtures and steel arches.

Le Tuan Long, Lung Lo's operations manager, pointed out that he has worked with Atlas Copco for many years on various projects and respects the quality of the equipment.

"Atlas Copco makes a quality machine that I can depend on," he said. He emphasized that Lung Lo is paid bonuses for working faster and that it is important to have equipment that can operate consistently at peak performance.

Nguyen Van Tien, vice director of transport and maintenance and onsite operations manager for Lung Lo, has used drill rigs from various manufacturers over the years but said: "The Atlas Copco rigs drill faster and have the easiest controls."

Hard rock challenge

Nguyen Van Tien continued: "The rock is very hard at this site. It is difficult to say exactly how much faster the Atlas Copco rig can drill because of variations in the rock formation, but taken side by side, I would say Atlas Copco's penetration rate is about 20 percent greater than with the previous rigs we used."

The hydropower project in Vietnam is expected to produce 1.84 billion kWh/year when it is completed in 2014.

Van Tien's crew has had no problems with the rigs and he is pleased that they enable the company to meet and exceed production requirements.

Tang Van Chuc, chairman of military assembly, a Senior Lt. Colonel in the Vietnamese army and head of Lung Lo's infrastructure operations, confirms the views of the field crews.

"The Boomer L2 D operates faster and is a longer lasting rig, which translates to a financial bonus in the overall operation," he said. ■

$1.9 billion Virginia tunnel project moving forward

The Downtown Tunnel/Midtown Tunnel/Martin Luther King Extension project connecting Norfolk, VA and Portsmouth, VA, a $1.9-billion project will move forward. Virginia Gov. Bob McDonnell made the announcment on July 20 that the Virginia Department of Transportation (VDOT) and Elizabeth River Crossings LLC (ERC) have agreed on the major business points for project.

The agreement on the major business points paves the way for VDOT and ERC to finalize the detailed terms of the comprehensive agreement and the financing package for the project.

VDOT and ERC were expected to sign the comprehensive agreement and achieve financial close by the end of 2011.

"The construction of the Downtown Tunnel/Midtown Tunnel/MLK Extension project will bring needed improvements to the transportation infrastructure of Hampton Roads, which will connect citizens with their jobs, families and activities. It will also provide easier access to our military bases and the Port of Virginia that will increase security and commerce in the region," said McDonnell. "This critical improvement is long overdue. The innovative public-private agreement will advance this project years before the Commonwealth could afford to complete the work on its own."

The major business points of the transaction were presented to the Commonwealth Transportation Board.

The key aspects of the transaction require ERC to design and construct the project. The scope of this work includes construction of a new Midtown Tunnel facility; rehabilitation and upgrades to the existing Downtown Tunnel and Midtown Tunnel facilities; construction of the Martin Luther King (MLK) extension in Portsmouth and minor upgrades to the Brambleton Avenue interchange in Norfolk.

ERC is also expected to provide a fixed-price, fixed-date, design-build contract; manage and fund all operations and maintenance for a 58-year term and collect tolls at the Downtown Tunnel, Midtown Tunnel and MLK facilities. ■

Chairman's Column: First priority is to serve our members

(Continued from page 3)

improvement in all aspects of our business to make this work from owners, engineers, suppliers and especially contractors.

The third area of focus I would like to see is further development in training and education in our industry. The underground industry continues to grow and I personally think that this will continue in the years to come. Tunnels provide a sustainable future for many solutions we need, but we simply do not have the resources in the industry to keep up — be it construction, engineering, or experts within the owner's team to implement the programs. I believe we can target both the college level education as well as improved training of other experienced people in related industries. The education committee has some great things to start with already and we look forward to working with specific schools and members alike to get the momentum in this important area rolling.

The fourth area of focus I would like to see UCA continue to develop is improved functionality and relationship with the International Tunneling Association (ITA). A better teamwork with the ITA can help us within the U.S. gain valuable lessons learned and best practices for our international colleagues to improve our local results. We can also help shape many of the international trends in the business that many times do not start within the U.S. Let's face it, the world is becoming a more global place, and our industry will not be exempt from this process. The ITA is working on some very interesting aspects of our business, and we might as well take a leadership role in shaping this process in order to get the most benefit to our members.

As you can see, we have some lofty goals to work on in the coming years; and we certainly will not be able to do it with only 16 people on the executive committee (who also have day jobs). If there is an area that you feel passionate about helping with, do not hesitate to contact me or any of the executive committee members.

Again, thanks for the opportunity to serve as the Chairman of the UCA of SME.

Be Safe. ■

Sand tunnel

(Continued from page 10)

able to get the population directly involved in the project, while creating sustainable skills development in the area. What's more, all segments for the sand tunnel will be manufactured in Gaborone, in order to ensure that investment in the project remains in Botswana."

Gem Diamonds purchased the Gope Exploration Co., which owns the rights to the Gope deposit, in 2007. It has since been renamed the Ghaghoo diamond mine, and a mining license was awarded to the company in January 2011. The Gope 25 kimberlite pipe was first discovered in 1981, with drill shafts to date reaching 1,000 m (3,280 ft) into the volcanic rock. Gem Diamonds stated that once the sand tunnel is complete, the decline will be extended to the kimberlite pipe and phase 1 of the mining will commence at 45 kt/month (49,600 stpy) per month. In parallel with this, a bankable feasibility study will be done for phase 2 of the project. ■

Becker Wholesale Mine Supply partners with OTN Systems

Mining communication products expert Becker Wholesale Mine Supply (BWMS) has signed a partnership agreement with global fiberoptic communications developer OTN Systems to bring the latest in fiberoptic network communication technology to the North American mining industry.

The teaming is the another entry for BWMS into the fiberoptic market for the mining industry, again expanding its product portfolio, while also giving it access to a vast network of new and existing OTN Systems customers enjoying the benefits of an open transport network (OTN) design.

For OTN Systems, the new partnership means an enhancement to its customer base in North America, as it has worked for more than 15 years serving and supporting the communications backbone infrastructures of mining companies worldwide.

At the center of this landmark deal is OTN Systems' OTN-X3M, an easy-to-use, open and highly reliable industrial networking solution developed in 2008 that joins multiple applications to support automation, safety and efficiency on one pair of fiber.

Ideal for placement at opencast and underground mines as well as throughout the tunneling industry, the OTN system can transmit all of an operation's critical information – including voice, data, LAN, video, SCADA and process control – between remote locations in the mine and the operations control room.

OTN-X3M includes video features such as analog and IP capabilities; embedded channel switching; integrated video-over-IP streaming; real-time, high-resolution images; an integrated video recording and management solution and open interfaces for third-party products.

The OTN Management Systems (OMS), capabilities include graphical user interface (GUI), client-server architecture with single, multiple or remote clients; hardware management for components including nodes, interfaces and optical connections; connection management, monitoring and error reporting; internal and SNMP alarm forwarding; on- and offline operation and more.

(Continued on page 27)

Robbins TBMs score record advance rates in China

At up to 1,400 m (4,600 ft) of cover and more than 10 hours from the nearest town, China's West Qinling Mountains may not seem like the most hospitable site to build a rail tunnel. However, two Robbins tunnel boring machines (TBM) are turning that notion on its head with world-record advance rates in exceedingly difficult conditions. The first of two 10.2 m (33.5 ft) main beam machines advanced 235 m (771 ft) in one week, and 841.8 m (2,761 ft) in one month during Spring 2011 — rates much higher than any ever recorded for TBMs in the 10 to 11 m (33 ft to 36 ft) diameter range. The previous long-standing rates, from a Robbins machine at Chicago, USA's TARP project, were for 185

(Continued on page 29)

The two Robbins Main Beam TBMs are excavating parallel 16.6-km- (10.3-mile) long rail tunnels under high cover of up to 1,400 m (4,600 ft).

Tunnel under state park challenged

Buckingham Coal Co.'s plans to tunnel under Burr Oak State Park in southeastern Ohio was approved by the state of Ohio, but has since been challenged by the U.S. Department of Justice, which filed a lawsuit against the project.

The lawsuit said that the tunneling could harm the park's reservoir and dam and contends that tunneling is prohibited under a U.S. Army Corps of Engineers agreement that the state signed in 1948 for the construction of the dam and reservoir.

The Ohio Department of Natural Resources struck a deal with Buckingham Coal Co. so that it could tunnel under Burr Oak Park to connect an active coal mine with an untapped coal reserve east of the park.

The Ohio legislature approved the deal in December 2009, giving Buckingham the tunnel and the rights to 63 hm^2 (155 acres) of state-owned coal in exchange for a $210,000 royalty and 99 hm^2 (244 acres) of coal near the park's lake and main entrance, the *Columbus Dispatch* reported.

The lawsuit argues that mining the area presents an unacceptable risk of sinkholes and reduces water flowing into the nearby East Branch of Sunday Creek. ■

Becker Wholesale: OTN technology provides a fast network

(Continued from page 26)

Topping off the broad capacities of OTN-X3M is its delivery of a highly reliable communications network for industrial environments. The OTN Systems communications solution will segregate 100 percent of the traffic for each application running on its backbone, lowering the risk of network issues and complexity as demanding applications, such as high-definition video cameras, require more bandwidth.

Additionally, the OTN-X3M technology provides fast network convergence (less than 50 ms for networks of up to 110 nodes and 1,000 km or 621 miles of fiber) without impact on the service layers.

"We are very excited to be bringing a new world of advanced fiberoptic technology to the mining industry, and the versatile capabilities and top-quality design of OTN's system is unmatched," said BWMS president Bill Hensler.

"We couldn't be happier about our new partnership, and we cannot wait to show the industry everything that this system can do."

"OTN Systems shares the enthusiasm of our new partner Becker Wholesale Mine Supply, as it will bring this highly-capable technology to increase business in the ever-growing mining industry of North America," said Tom Ceunen, sales director for OTN Systems in North America.

"For mines needing an easy-to-use, very reliable communications network for their SCADA, voice, video and data, OTN is the ideal solution, and both BWMS and OTN Systems will work hard to bring it to them." ■

TBMs at work on Chinese rail line

(Continued from page 28)

m (607 ft) in one week and 685 m (2,247 ft) in one month.

"The Robbins machines have a good performance, we are very happy with the weekly rates, and hope for even better monthly rates," said Mr. Xu, chief engineer and vice project manager for contractor China Railway Tunnel Group Co. Ltd. (CRTG). The 18th Bureau of CRTG is managing the Left Line Tunnel, while China Railway Construction Corp. (CRCC) is managing the Right Line Tunnel. The two parallel 16.6-km (10.3-mile) routes are just 40 m (130 ft) apart and are located approximately 1,000 m (3,280 ft) above sea level, about halfway up Qinling Mountain.

The record-breaking Left Line machine at West Qinling also broke through into an intermediate adit tunnel on May 28, 2011 at the 5.5-km (3.4-mile) mark, where it is now undergoing planned maintenance and inspection. Within several weeks the machine will be launched again to bore the rest of its tunnel.

Ground has consisted mainly of phyllite and limestone, often with high quartz content. Crews have also encountered fault zones of breccias and clay, as well as a 600-m- (2,000-ft-) long section of badly broken rock. Despite the conditions, only about 100 cutters have been changed on the Left Line machine so far. The Right Line machine, launched a month later and about 1,000 m (3,280 ft) behind, is also experiencing good cutter wear.

To combat the tough conditions, the machines have been specially designed with adaptable ground support systems that replaced the roof shield fingers in the L1 area. The new roof shield canopy contains mesh pockets, rather than fingers, for installation by workers under the safety of the shield structure. Other design aspects include improved ring beam building, separate roof and probe drills, and materials handling.

"The ring beam erector and the segment hoist have been very successful. Overall, the machine is good," said Mr. Wang, spare parts manager and engineer for CRCC.

The West Qinling tunnels are part of the Chinese government's Lanzhou to Chongqing Railway project, an extensive 820-km- (500-mile-) long scheme that will link the capital of Gansu province (Lanzhou) with southwestern Chongqing, a mega-city of more than 35 million people. The entire railway is expected to open to traffic in 2014. ■

The first of two 10.2 m (33.5 ft) Robbins TBMs has achieved records in its size class, for excavating 185 m (607 ft) in one week and 685 m (2,247 ft) in one month.

NEW MEDIA

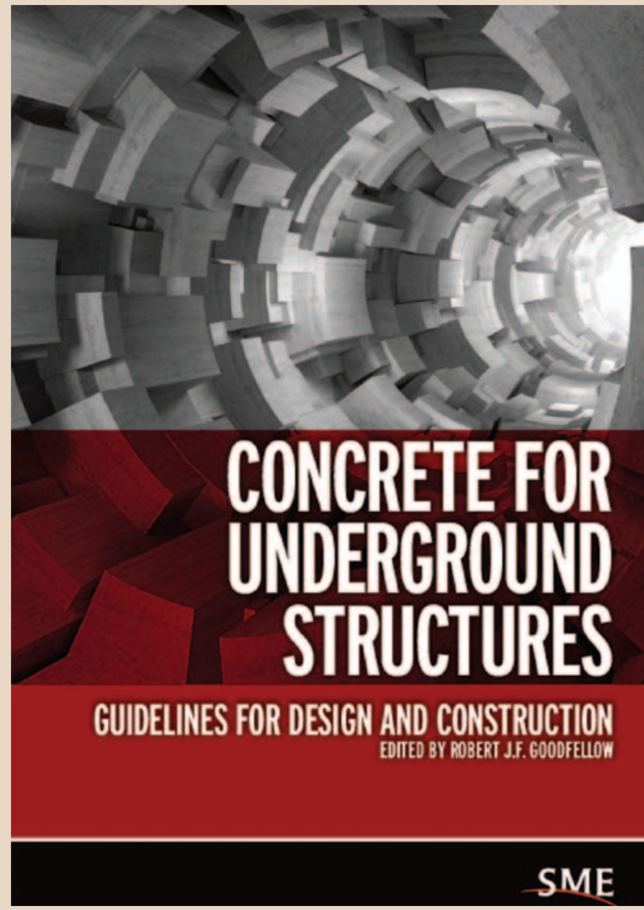
Concrete for Underground Structures

2011, edited by Robert J.F. Goodfellow, SME Customer Service, 12999 E. Adam Aircraft Circle, Englewood, CO 80112, phone 1-800-763-3132, 303-973-9550, fax 303-933-6269, e-mail cs@smenet.org, Web site www.smenet.org. 2011, 176 pages, 2 lbs. ISBN-13: 978-0-87335-346-5. Book Order No. 346-5$79 member / $69 student member / $99 non-member/list. Available as an eBook from www.smenet.org/ebooks.

Concrete is a vital component of almost every underground construction project. Because it significantly impacts both the durability and cost of a project, owners, designers and contractors are constantly challenged with designing and placing the concrete to meet their quality standards in the most cost-effective way.

Concrete for Underground Structures: Guidelines for Design and Construction can make that task a lot easier. Instead of searching pages of scattered reference materials when writing specifications, this book is a one-source guide to help you quickly find the answers you need.

The first resource of its kind, this practical nuts-and-bolts handbook provides an industry voice as well as recommendations for areas of concrete application. You will get valuable insights into current best practices for all aspects of the design and construction of underground structural concrete.



Internationally respected authors examine three key applications: cast-in-place concrete, precast concrete segmental linings, and shotcrete. Each chapter addresses the differences between aboveground and underground use. The various types of concrete admixtures are also discussed, and sample specifications for each are included.

Concrete for Underground Structures is an indispensable resource for industry veterans as well as an educational tool for those who are new to the profession. ■

FEATURE ARTICLE

New developments in ground support technology for open-type tunnel boring machines

Open-type, or main beam, tunnel boring machines (TBMs) can achieve impressive rates of production. This type of TBM typically outperforms other types of TBMs currently in use around the world. In good ground conditions, main beam machines have achieved production rates of more than 1 km/month (0.6 miles/month).

However, installing effective ground support in poorer rock conditions on main beam machines can be a major cause of concern. The design of main beam machines is such that installation of ground support equipment, particularly at the front of the machine in what is commonly known as the L1 support zone, has traditionally been limited to rock drills and basic working platforms. Personnel working in the L1 zone have, until recently, been protected by roof supports and extended fingers, often with restricted access to working areas.

This article discusses the advances and developments of ground support systems currently in use in the L1 support zone on main beam machines. A case study of the benefits and challenges of providing such equipment on a 10-m (33-ft) main beam machine, currently in use on a project in China, is included.

History of TBM ground support

Ground support on open-type, hard rock TBMs is now a much safer, more streamlined process than it once was. The L1 zone, which extends from the face to several meters back from the cutterhead and directly behind the cutterhead support, is a critical area for ground stabilization. Primary ground support should be installed while boring to avoid deterioration of the rock over time and distance from the face.

Steve Chorley

Steve Chorley is international field service manager, Robbins Co., e-mail chorleys@robbins.com.

In years past, crew members typically used hand-held air drills, or stoper drills, to install rock bolts from both the L1 area and from a location behind the TBM. Panels of wire mesh were handled by the crew and positioned in place before bolting. Before wire mesh, tunnel lining often consisted of steel ribs with wooden lagging, a laborious and time-consuming process.

FIG. 1

Historical TBM ground support methods using handheld air drills and shotcrete.

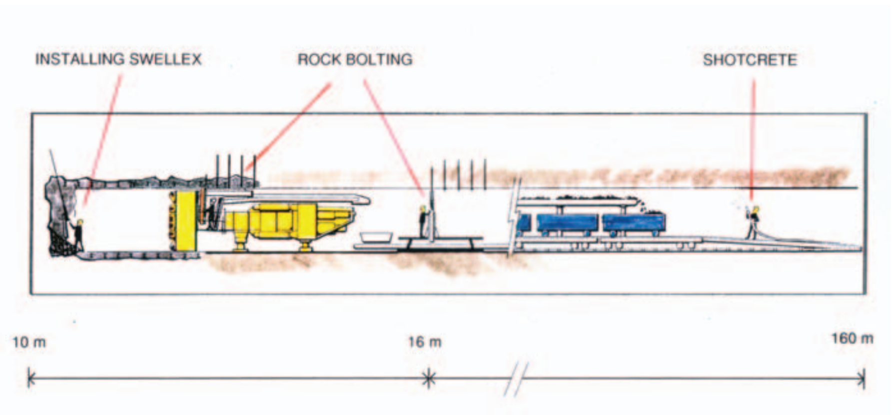


FIG. 2

Liner plate installation at Taiwan's New Wuchieh project (invert plates visible).

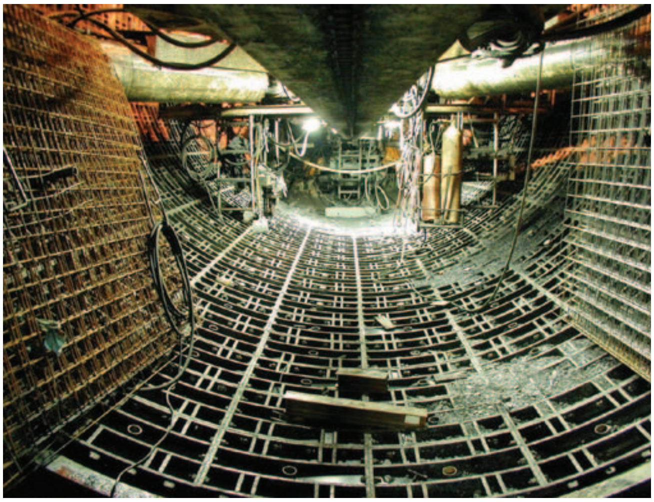


Table 1

Ground support classification system.

Rock mass classification	Rock bolts	Shotcrete	Steel sets
I — Very good rock RMR: 81–100	None needed.	None needed.	None needed.
II — Good rock RMR: 61–80	Localized bolts in the tunnel crown, 3-m-long, spaced at 2.5 m with occasional wire mesh.	50 mm layer in the tunnel crown where required.	None needed.
III — Fair rock RMR: 41–60	Systematic bolts 4-m- long, spaced 1.5 to 2 m in crown and walls with wire mesh in the crown.	50–100 mm layer in crown and 30 mm in sides.	None needed.
IV — Poor rock RMR: 21–40	Systematic bolts 4- to 5-m-long, spaced 1 to 1.5 m in crown and walls, with wire mesh.	100–150 mm layer in crown and 100 mm in sides.	Light to medium ribs spaced 1.5 m where required.
V — Very poor rock RMR: <20	Systematic bolts 5- to 6-m-long, spaced 1 to 1.5 m in crown and walls, with wire mesh. Bolt invert.	150–200 mm layer in crown and 150 mm in sides.	Medium to heavy ribs spaced 0.75 m with steel lagging and forepoling if required. Close invert.

Shotcrete, when used, was applied using a handheld hose and nozzle. Workers often stood in man baskets, on platforms, or in the invert to install various forms of ground support (Fig. 1).

Ground support classification systems

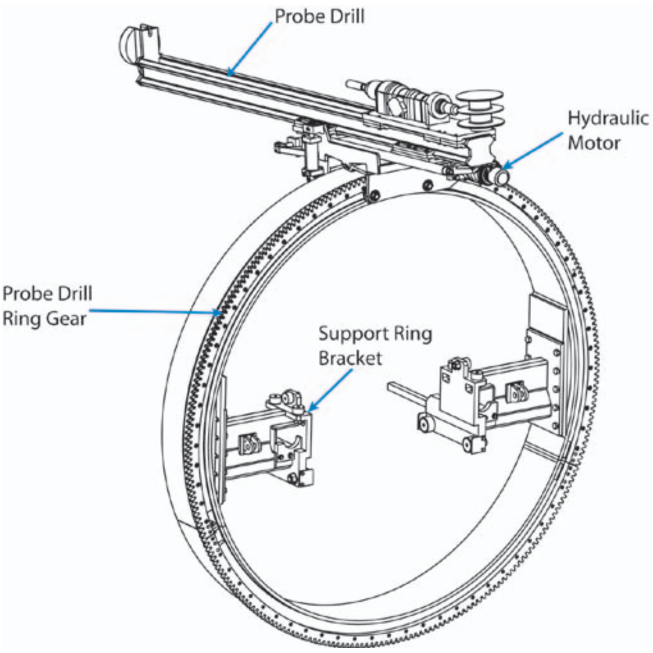
Today's ground support systems are typically classified based on the rock mass rating system (RMR). Current methods are more streamlined and allow for TBM tunneling in difficult, Class IV rock and possibly Class V rock. Many ground support programs follow charts such as the one in Table 1 (Ozbay, 2008).

The amount and type of ground support is somewhat subjective and also varies depending on the TBM diameter. Research has shown, for example, that full ring beams in tunnels more than 8 m (26 ft) in diameter are not adequate in many cases and may require alternative methods of crown support, such as the McNally Support System, combined with steel straps (Khalighi, 2010). In addition, yielding rock bolts and yielding arches can be used in high cover, which often causes squeezing ground. These support methods typically have some give via friction joists or sliding steel bars, allowing the ground to relieve pressure gradually and in a controlled manner.

Even with the wide variations in ground support within the L1 zone, some generalizations can be made regarding ground support equipment and installation.

FIG. 3

360° probe drill assembly mounted on ring.

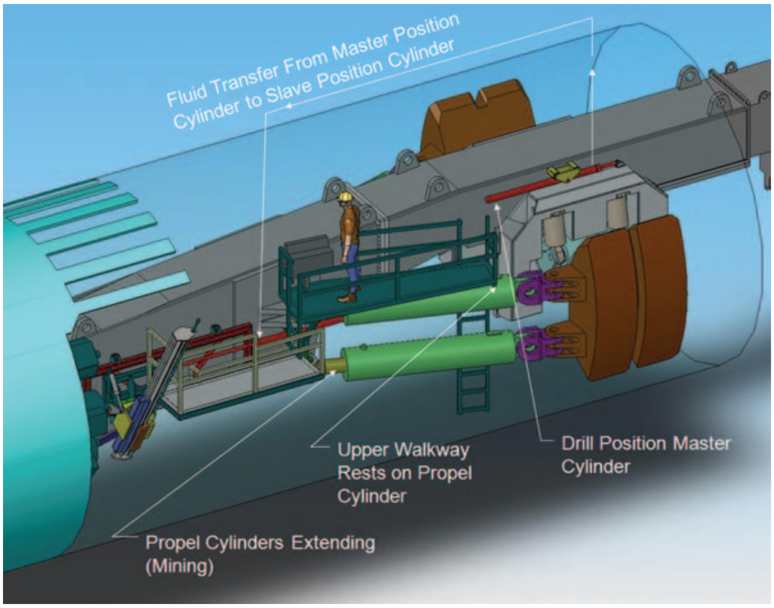


Steel plates: An early lining method in severe ground conditions

In severe fault zones and unstable ground, an early type of lining was developed and successfully used on open-type machines. The method involves 360° steel liner plates installed and attached immediately behind the cutterhead support. The attached liner is then towed forward and new plates are attached until the fault zone is passed.

FIG. 4

Master/slave cylinder system. Figure courtesy of Brian Kelley, Kelley Engineered Equipment LLC.



The liner plates are then detached from the support and grouted in place.

This method has been used successfully at the Butterfly Valley tunnels in Hong Kong and on Taiwan's New Wuchieh project in 2001. At New Wuchieh, a large fault zone required the introduction of the steel plates, which were installed from the cutterhead support to the grippers. The installation of the steel plates freed up the grippers, allowing the machine to move slowly through the zone. Invert steel plates were also installed in case the grippers were not freed and became stuck. The machine would have pushed off using two shove rams installed in the cutterhead support, but this method was not needed (Fig. 2). Despite the method's success, it has not been used on many projects simply because it is a time-consuming and relatively costly method of ground support. Concrete rings used in conjunction with shielded hard rock TBMs are the preferable method if significant sections of unstable ground are expected.

Rock drills

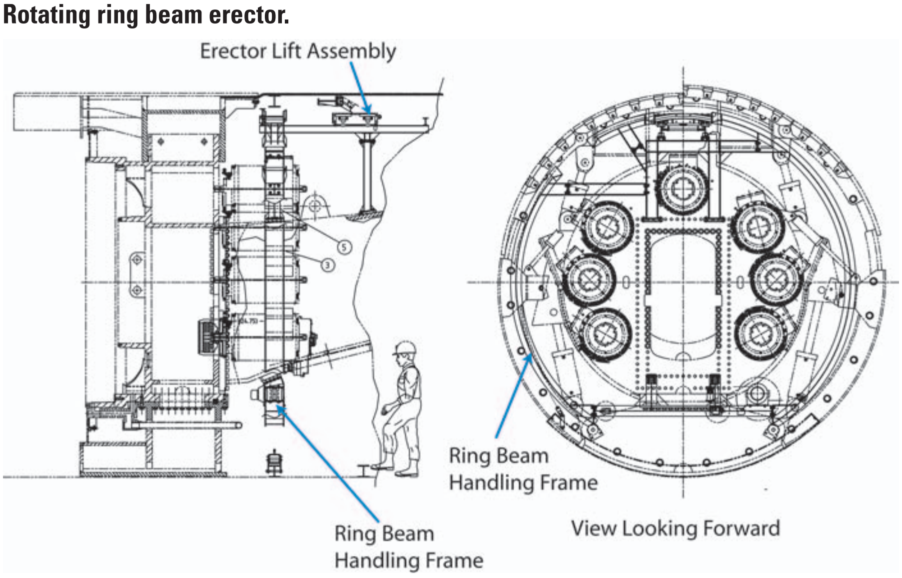
Fixed drills. A substantial improvement from hand held air drills is the fixed drill. Fixed drills are either mounted in a fixed place on the machine, or on slides connected to the gripper. The setup only allows for use as a rock bolt drill, since it cannot be angled forward to probe the face. In addition, drilling cannot occur simultaneously with TBM excavation since the drill is advancing along with the machine.

Later drills were mounted on slides connected to the gripper system, allowing for simultaneous boring. However, this setup still had limitations as far as the angle and position of drilling, due to tilts interference with the main beam.

Floating drills. The most commonly used rock drills today are floating drills, which can be used as both roof drills and probe drills by changing the angle of their position. In this way, the drills can also be used for probing and pre-excavation grouting, both very important components of ground support. The setup is also capable of drilling simultaneously with boring, saving significant time during ground support installation.

FIG. 5

Rotating ring beam erector.



Drills mounted on a drilling ring are capable of 360° probing around the perimeter of the TBM, and through the face if necessary. The TBM shield structures around the cutterhead can contain steel tubes that act as probe guides, leading the drill bit to the tunnel face at a 7° angle from the tunnel centerline (Fig. 3).

Master/slave cylinder technology

The latest designs in rock drills involve master/slave cylinder technology, which allows the drill to stay in position during a push. A fluid transfer system allows the rock drill cylinders to retract as the propel cylinders extend, compensating for the movement.

The system is also advantageous

because it minimizes the risk of positioning cylinder buckling that is common on conventional drilling systems. Standard drill positioning uses long stroke cylinders connected from the drill carriage to the gripper carriage. This setup requires cylinders with strokes that are more than twice the TBM stroke, which are prone to buckling. Mounting locations are also limited and often cylinders are mounted in positions that are unfavorable for cylinder protection.

On a TBM, the master/slave system consists of two cylinder barrels connected to the main beam. The rod end of the slave cylinder is connected to the drill carriage and the rod end of the master cylinder is connected to the gripper carriage. Master cylinder and slave cylinder bore and rod diameters are identical. As the TBM advances, fluid is forced out of the rod end of the master cylinder and forced into the rod end of the slave cylinder.

This transfer of fluids retracts the slave cylinder at the same rate as the master cylinder is extending, which holds the drill carriage still as the TBM advances. The drill carriage is also advanced forward relative to the gripper shoe, which is fixed except for re-gripping. Similarly, the drill carriage retracts relative to the gripper shoe as well (Fig. 4).

Ring beam and channel erectors

Ring beam and channel erectors have several iterations in use today. The most basic model consists of an assembly ring with a winch wire rope and guide channel, which allows each piece to be manually moved into place. A smaller Dutchman piece completes the ring and expands so that the ring beam can be bolted or expanded to the tunnel walls.

Current ring beam erectors rotate ± 200° about the frame using roller supports and a motor (Fig. 5). Ring pieces are attached to the erector, which can either move independently of the TBM or be fixed. Improved ring beam expanders, such as tie rods, can pull the completed ring beam out of the erector at the end of a boring stroke.

Slotted grippers to accommodate ring beams

In order to ensure continuous ring beam builds, a problem had to be solved: How could grippers react against tunnels walls with a ring beam in place? Making the gripper too narrow could potentially crumple the rock — a good rule of thumb is that the pressure against the rock should never be greater than 600 psi.

The answer was a slotted gripper design, allowing space for ring beams along with ample TBM gripper surface area to react against rock. This design has been used on numerous open-type TBMs and can be seen on a 6.3-m (20.6-ft) machine used for China's Chongqing Metro (Figs. 6 and 7). This combination of gripper pads designed to accommodate ring beams, simple ring beam erectors and rock drills, has enabled good rates of production in type III ground conditions that might otherwise be time-consuming to set adequate ground support in.

FIG. 6

Slotted gripper shoes designed for continuous installation of ring beams, Chongqing, China.

Crown support in severely stressed ground

In highly stressed, squeezing or rock-bursting ground, roof shield fingers may not provide adequate protection

FIG. 7

Ring beams installed at the correct spacing for the grippers — Chongqing, China.

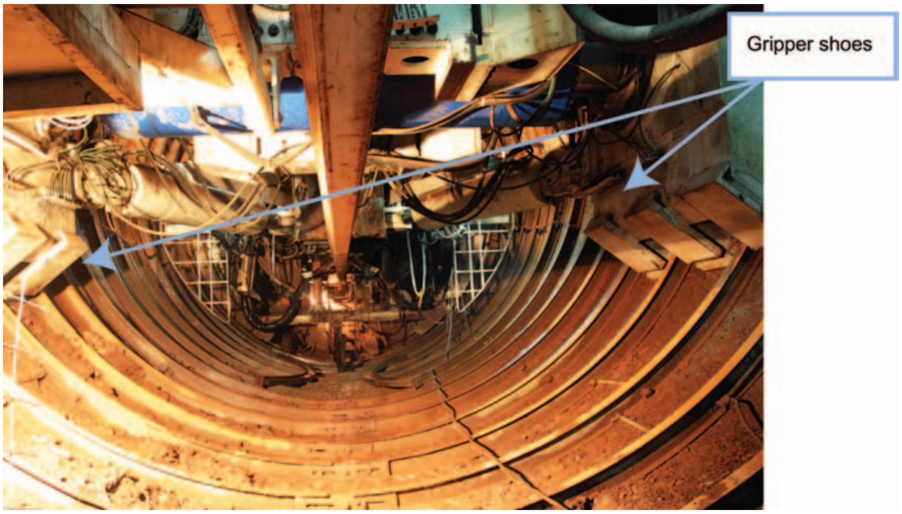
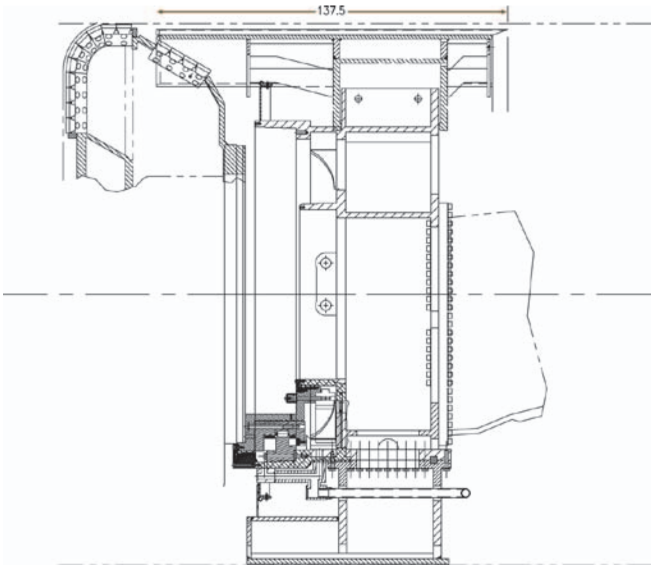


FIG. 8

Crown support system with pockets for slats.



behind the cutterhead support. Rock pressure can shift and bend the roof fingers, resulting in a deformed cross section and possible rock falls.

The McNally crown support system removes roof shield fingers from the equation, opting instead for a system of pockets with extruded slats that support the loose rock above the tunnel and provide safety for the workers under the roof during TBM excavation.

The McNally system works by replacing the curved finger shield plate for a curved assembly of pockets with rectangular cross-sections. The pockets extend axially from the rear side of the cutterhead to the cutterhead support, within the area where roof drills can work. Before a TBM stroke, crews slide slats of metal or wood into the pockets, such that the slats are two rows deep inside each pocket. The ends of the slats protrude from the pockets and are bolted to the roof of the tunnel using a steel strap. As the machine advances, the slats are withdrawn from the pockets and continuously bolted to the roof to support the rock. New slats are loaded and used for the length of the tunnel to prevent deformation and rock falls (Figs. 8 and 9).

Modernized ground support: Mechanized mesh erectors and telescopic man baskets

A recent project using a 12.43-m (40.7-ft) Robbins main beam TBM required specially designed support for high water inflows and difficult ground conditions. Primary rock support activities were performed from platforms on top of the TBM. Ring beams were delivered in the top of the tunnel, through the backup and over the top of the TBM main beam to the ring beam erector.

Moveable steel dams were placed in the invert just behind the TBM, and dewatering pumps were available to relay water from the cutterhead support area to the end of the backup to keep the water level as low as possible under the TBM in the primary tunnel working area.

Rock bolting was done in two locations on the TBM. The L1 zone, located just behind the cutterhead support, had two drills and the L2 zone, on the backup just behind the bridge conveyor, had two more drills. Shotcrete could be applied both in the L1 and L2 areas. In L1, a single robot was used for emergency application of shotcrete.

After encountering difficult ground, the machine was further modified to include invert cleaning mechanisms, mesh windows to install mesh panels beneath the safety of the shield structure and the McNally crown support system to install steel slats 150-mm- (5.9-in.-) wide and 5-m- (16.4-ft-) long (Fig. 10).

Two telescoping man baskets were also added on either side of the main beam, capable of improved access as far forward as possible for rock bolting and shotcreting (Fig. 11).

Novel ground support scheme at West Qinling

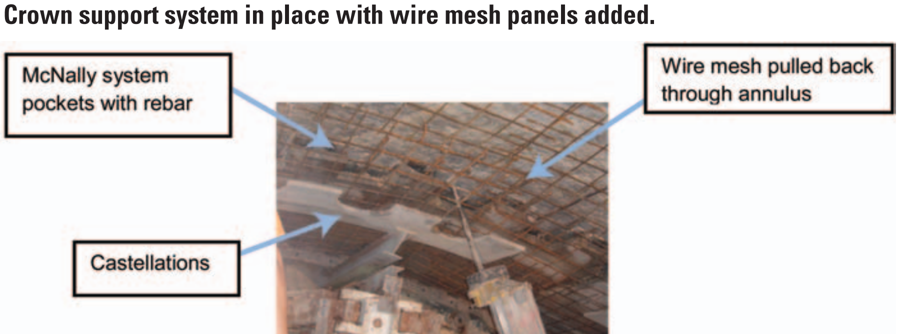
Two 10.2-m- (33.4-ft-) diameter Robbins main beam TBMs are currently excavating twin rail tunnels at China's West Qinling project. The machines were designed for high cover tunneling (up to 1,400 m or 4,600 ft) in relatively weak rock strengths. The two TBMs were the first recent Robbins main beam machines assembled without roof shield fingers. Ground support systems include modified mesh installation, ring beam installation, work platforms and materials handling. During tunneling, primary ground support consists of continuous mesh and rock bolts, with either ring beams or steel straps, for the length of the tunnel. A number of engineering developments and modifications were made to the setup of these machines.

Safer mesh installation

Mesh windows, installed in the roof shield, allow workers to slide panels of mesh in the annular space between the shield and the tunnel

FIG. 9

Crown support system in place with wire mesh panels added.



crown from the safety of the shield structure. The panels are then pinned or secured with rock bolts. Traditional ground support includes no specific provisions for mesh installation and little cover from falling rock.

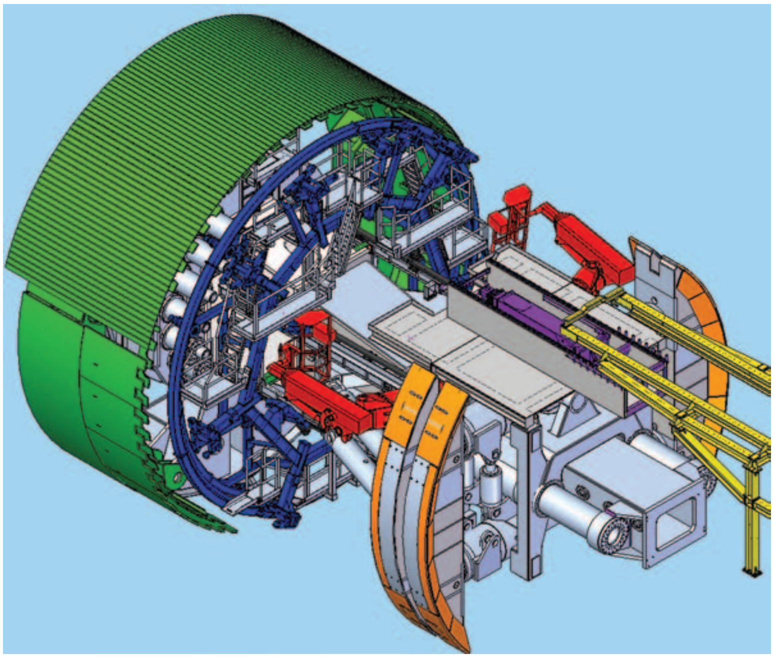
Streamlined ring beam installation

Ring beams are installed using an erector consisting of the assembly ring and expander. The rotating assembly ring is fixed axially and used to loosely assemble five ring beam components. Once the components are loosely assembled and pinned to the assembly ring, the expander, which moves fore and aft, expands the components to a preset pressure against the tunnel wall. A sixth Dutchman piece is installed in the resulting space, and the ring beam with tightened connections is bolted to the tunnel wall. The assembly and expander can also be easily converted for installation of steel straps, rather than full rings.

Previous assembly methods required that the fully assembled ring beam be transported to a pocket before being expanded against the tunnel wall. The method is not as fast and does not give the flexibility often needed in changing ground that may require steel straps.

FIG. 10

Newly designed ground support system, featuring McNally crown support pockets in roof shield, automated materials handling system, telescoping man baskets and new ring beam erector.



A variety of work platforms

Accessible work platforms are located throughout the machine, including two in front of the ring beam erector and under the roof shield for mesh installation. Other work platforms are located at various levels around the circumference of the machine for ring beam and rock bolt installation.

Efficient materials handling

Streamlined materials handling allows the ring beam components to be transported efficiently to the L1 area. The system reduces the number of transfer points, and ultimately reduces the number of crew members required to transport materials.

Ground support components are loaded onto the backup using a crane and placed onto a carriage riding on an electric transport car. The carriage is designed to hold a stack of mesh panels, ring beams, rock bolts and lagging materials for the McNally system. The remotely operated trolley carriage transports the materials to a rack located in front of the ring beam guide rollers where they can be easily placed (Figs. 12 and 13).

Increased range of motion for drills

Instead of a combination roof and probe drill, the setup uses separate roof and probe drill canopies. The system allows a wider range of motion and better access from nearby work platforms.

Optional crown support system

If more difficult ground is encountered, the mesh pockets can be relatively easily converted to use a modified form of the McNally System for heavy duty crown support. Crews would bolt McNally pockets inside the mesh pocket structures, allowing a space to slide short slats of steel or wood into the area where roof drills can operate.

Concepts for the future

One way to solve the problem of limited access to the tunnel walls for ground support would be to move the

FIG. 11

Telescoping man baskets.

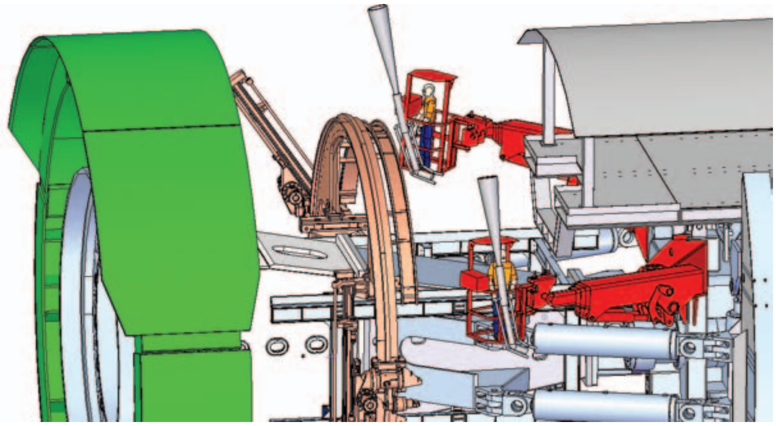
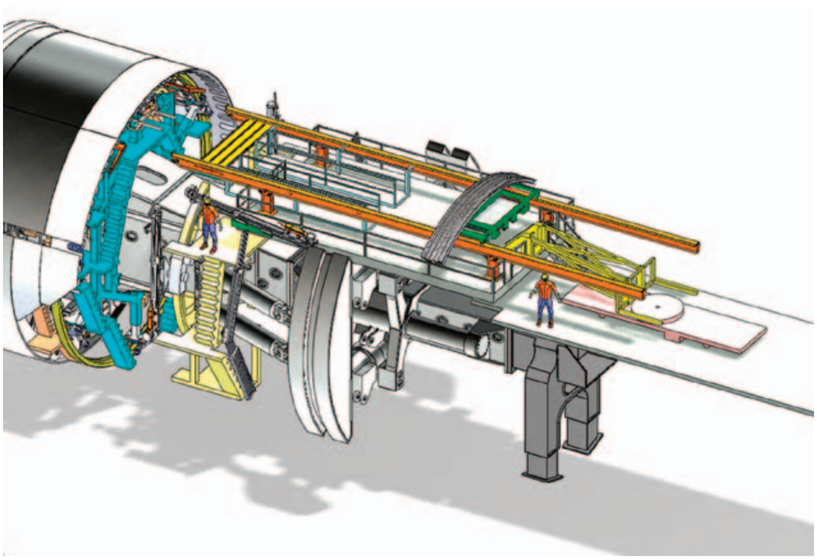


FIG. 12

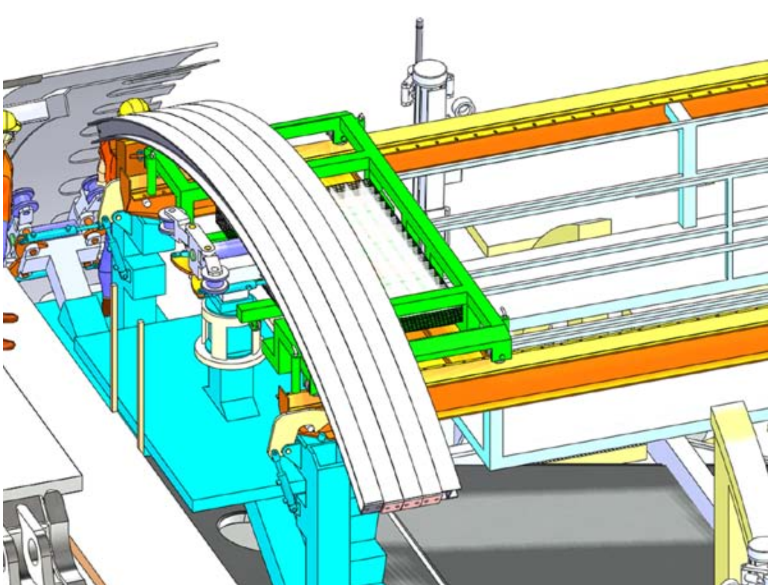
Ring beam being transported on platform.



thrust cylinders to the back of the gripper shoes — effectively "pulling" the TBM forward. The method may offer advantages, as it clears room at the front of the machine for extra ground support. Disadvantages may be that pulling the machine forward, rather than pushing it forward, as with the current configuration, may reduce the TBM's efficiency. The propel cylinders would need to be made stronger in order to overcome the force disadvantage of pulling vs. pushing.

FIG. 13

Ring beams and wire mesh transported to L1 zone.



Conclusions

All of the developments described in this article have contributed to some degree to improved ground support in the L1 zone. The primary goals of the ground support systems should be to ensure safe working conditions for personnel and to provide stabilization of ground to enable tunneling to continue at an acceptable rate of production.

At the West Qinling project in China, the machines are achieving production rates of approximately 500 m/month (19,700 ft/month), while at China's Chongqing Metro project, more than 700 m/month (27,500 ft/month) has been attained. These are exceptional advance rates for the ground conditions encountered.

At other projects, such as the Olmos project in Peru, where ground cover exceeds 2,500 m (98,400 ft), simply being able to advance the machine due to the improved ground support systems is an achievement within itself. Previously, contractors may have considered stopping mechanized tunneling in favor of conventional drill-and-blast methods.

However, it is not just a matter of installing all ground support systems available. Even with large diameter machines, space for ground support equipment is still an issue. Therefore a careful, educated, case-by-case study of the expected ground conditions for any particular project should be undertaken by the designer and contractor in conjunction with the TBM manufacturer with a view to installing the optimum ground support equipment for that particular project. Gathering as much geotechnical information as possible is also critical to providing the most suitable ground support systems.

In some cases, less is more and the more simple a system is designed, the better the ground support and, ultimately, the production. Most recently, three machines were deployed in 2010 to a project in Malaysia. Due to the expected ground conditions, the designer opted for a fiber mortar system in the L1 zone as the principal ground support system with provisions for ring beams, if needed. Fiber mortar is applied for approximately 180° of the tunnel over the crown, and production rates of 20 m/d (787 ft/day) have been seen.

For any of the systems to work, the onus is on operational personnel to ensure the equipment installed is used as designed. Per the mantra of the U.S. Marines, where necessary, designers, contractors and manufacturers should be prepared to improvise, adapt and overcome to ensure the correct ground support equipment is installed for the successful completion of a project. (References available from the author.) ■

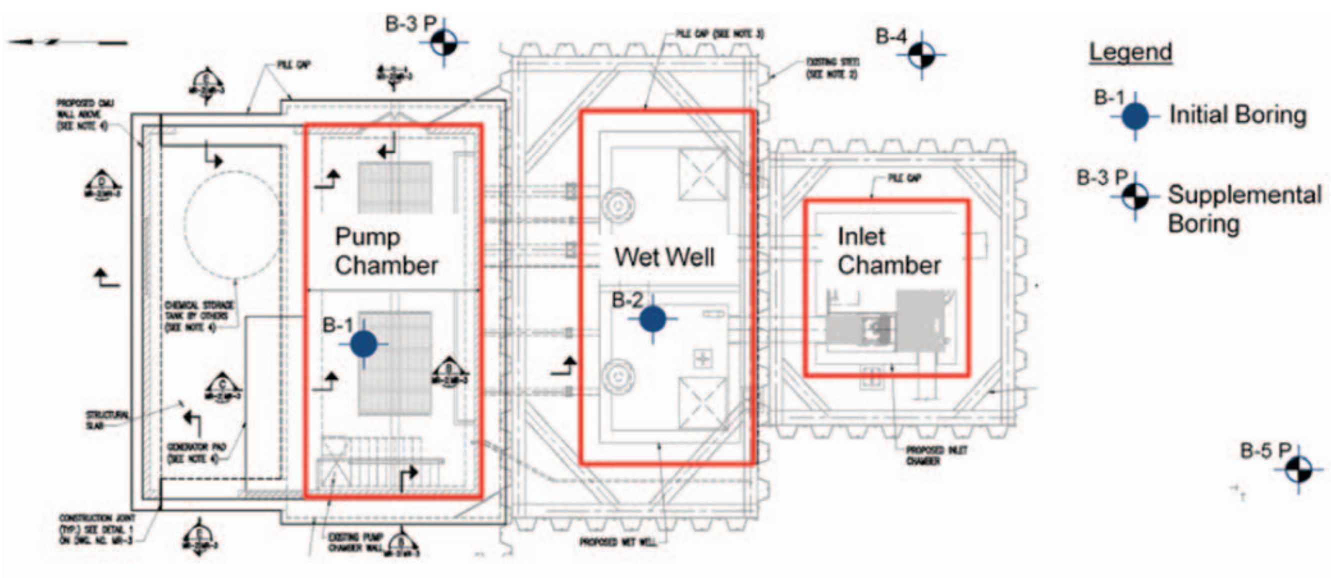
FEATURE ARTICLE

Pitfalls and lessons learned in pump station construction

Construction of a pump station, consisting of an inlet chamber, wet well and pump chamber, required excavation to a depth of 9.7 m (32 ft) below ground surface and more than 7.6 m (25 ft) below the ground water table in a rural, but rapidly developing part of southern New Jersey. Private houses are located within a few hundred feet of the pump station that use shallow wells for water supply. The pump station design anticipated support of the entire pump station on shallow foundations bearing directly on the underlying natural soils. However, during construction, uncontrolled ground water flow caused ground loss and damage to the bearing qualities of foundation soils. As a result, remedial repairs were required including support of the pump station on drilled pile foundations and releveling of the pump chamber that had settled. This case study is an example of where a poor understanding of the significance of upward flowing ground water had a major impact on the cost of construction.

FIG. 1

Pump station layout.



Anticipated subsurface conditions

The pump station layout is shown in Fig. 1 with the locations of two borings made prior to construction superimposed. One of the borings was located within the footprint of the deep wet well excavation. Generally, this is not advisable where a deep excavation is required below the ground water table. This is because there is a history of projects where ground water seepage, or pressure, has broken out into an excavation through an ungrouted borehole and compromised the integrity of foundation soils. Logs of the borings did not indicate that the borings were grouted upon completion.

As shown in Fig. 2, the borings portray a stratified soil profile of interlayered sands and clays overlying glauconitic (green) sands with excavation subgrade for the wet well near the interface with the underlying sands. The sands are described as "silty" with a fines content (percent passing the No. 200 sieve) generally in excess of 19 percent. This would indicate that the sands below subgrade were of relatively low permeability and would not yield significant quantities of water. The investigation did not include the installa-

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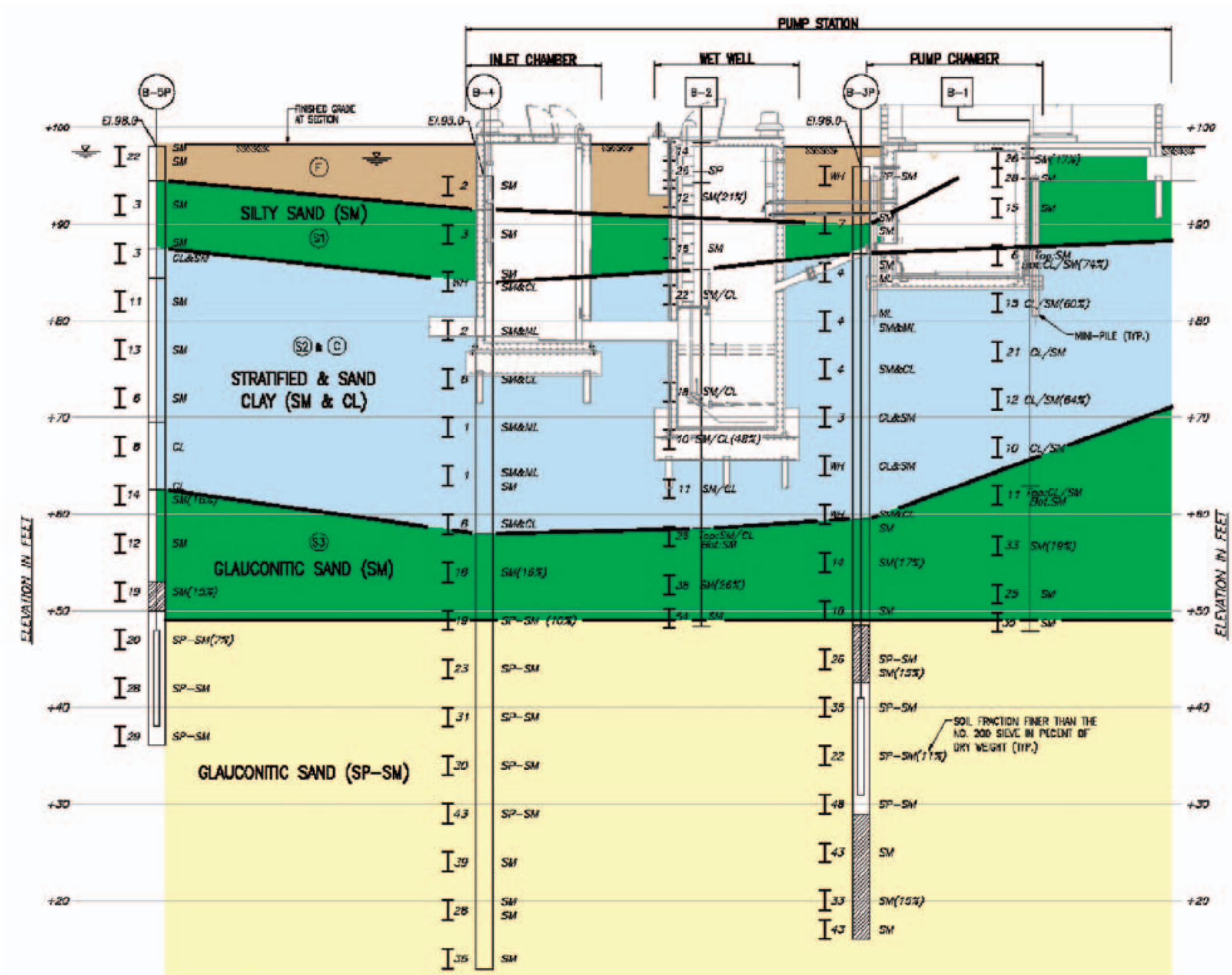
FIG. 2

Geologic section.



tion of a piezometer but instead reported ground water at a depth of 1.2 m (4 ft) based on water levels measured in the borings.

The borings penetrated to a depth of only 15.2 m (50 ft) or about 5.5 m (18 ft) below excavation subgrade for the deeper wet well. For a deep excavation below the ground water table, it is generally recommended to perform at least one boring that extends to excavation subgrade plus a depth equal to one to 1.5 times the depth of penetration of the excavation below the ground water table. This is to evaluate if coarse grained, more permeable deposits exist below subgrade that if not pressure relieved could cause heave or piping in the excavation bottom. Following these guidelines, this would have required a boring extending to a depth of at least 20 to 23 m (65 to 75 ft).

The shallow depth of the borings limited the characterization of the soils below excavation subgrade and resulted in problems during construction.

Initial dewatering, excavation and ground loss

Sheet piling was driven around the perimeter of the pump station with interior dividing walls used to create separate cofferdam enclosures around the central wet well and adjacent pump chamber and inlet chamber. The wet well is the deepest structure and required excavation to a depth of about 9.7 m (32 ft) below ground surface and 8.5 m (28 ft) below the ground water table indicated by the borings.

A single stage wellpoint system was installed around the perimeter of the cofferdam to reduce water pressures on the sheet piling. The wellpoints only extended to the bottom of the wet well. The wellpoints lowered the shallow ground water levels, but since they did not penetrate through the interlayered sands and clays, the original high water pressures remained in the sands beneath the excavation. Apparently, it was anticipated that either the clay soils below subgrade were of sufficient continuity to act as a plug and prevent ground water inflow and heave of the excavation bottom or that the soils below excavation subgrade were of modest permeability such that ground water flow into the bottom of the excavation could be handled by sumping and would relieve water pressure in the underlying sands. This was a risky approach given the indicated subsurface conditions that was made more adverse by the highly permeable sands that were subsequently found below excavation subgrade.

As excavation neared final subgrade, concentrated ground water flow started to enter the bottom of the excavation in the area of the ungrouted borehole (B-2). In response, the contractor installed two 18 m (60 ft) deep wells just outside the wet well cofferdam. Pumping from the wells at a combined rate of 10.7 L/s (170 gpm) did not stop the upward flow of ground water and sumps were used to collect the water that continued to flow into the bottom of the excavation. Given these high flows, it should have been recognized that the sands below excavation subgrade were much more permeable than portrayed by the borings.

However, the importance of the unexpected conditions and its potential impacts on continued construction were not recognized. The upward flow of ground water through the ungrouted borehole was allowed to continue and was collected and handled by sumping from within the excavation. Contrary to good dewatering practice, no piezometer was installed to determine water pressures in the underlying sand. No additional wells were installed to supplement dewatering efforts and stop the upward flow of ground water. Dewatering discharge was not monitored to determine if sump pumping was causing the continuous removal of soil fines. Vertical and horizontal movements of the sheet piling cofferdam were not measured.

Figure 3 shows the upward flowing water brought with it significant fines and led to softening of the excavation bottom. However, excavation was able to reach final subgrade and facilitate construction of the wet well, which consisted of a base mat and stacked precast box sections. During this construction, it was observed that the wet well was settling.

Escalating ground water problems

Due to the disturbance of the underlying soils, support of the wet well on a shallow foundation was no longer considered feasible and driven pipe piles were recommended for continued wet well construction. As a result, the precast box sections had to be removed and the base mat demolished. While the plans for the pile foundation were prepared, construction of the adjacent pump chamber, a heavy cast in place structure, proceeded.

The pile plan consisted of 24 pipe piles driven into the underlying sands for support of the wet well. Although ground loss was likely continuing, the pile plan did not include any requirements for supplemental dewatering to stop the upward flow of ground water into the excavation bottom. A piezometer was not installed to determine the

FIG. 3

Upward flow of ground water despite dewatering efforts.

water pressures or drawdown in the underlying sands prior to pile driving. Without any supplemental dewatering, water pressures in the sands remained high. As a result, during pile driving, a sudden boil developed in the bottom of the excavation when the third pile punctured through the clay subgrade and penetrated into the underlying sands (Fig. 4). This should have been recognized as a dangerous condition and supplemental dewatering efforts implemented immediately or the cofferdam flooded to stop the upward flow of ground water prior to additional pile driving. Unfortunately, continued pile driving resulted in increased water inflow into the cofferdam, ground loss around and beneath the excavation and subsequent settlement of the sheet piling and the adjacent pump chamber. All work was stopped and the cofferdam was flooded.

Problem diagnosis and remedial measures

At this point, Mueser Rutledge Consulting Engineers (MRCE), a geotechnical and foundation engineering consultant, was engaged by the owner to diagnose the cause of the problem and develop remedial measures to allow construction to continue. Three additional borings were made to depths of 19 to 25 m (62 to 82 ft) and revealed that the underlying sands became more permeable with depth (Fig. 2). The presence of these more permeable sands, which are confined by the overlying clays, acted as a reservoir of constant head and sustained upward flow and critical gradients in the overlying soils.

Piezometers installed in the completed borings also indicated that ground water levels in the sands were within a 0.3 m (1 ft) of the ground surface. However, overflow from the flooded cofferdam acted to relieve

FIG. 4

A boil at the bottom of the excavation developed when clay subgrade was penetrated by pile driving.

water pressure and, therefore, ground water levels in the glauconitic sands were likely higher prior to construction. Test pumping of the two existing dewatering wells at the same rate (10.7 L/s or 170 gpm) employed during initial construction produced only about 3 m (9 ft) of drawdown in the sands underlying the wet well. For comparison, more than 9 m (30 ft) of drawdown was actually required to lower ground water levels in the sands below excavation subgrade. Based on these findings, and the records of previous construction, the cause of the problem was diagnosed as unrelieved water pressure in the underlying more permeable sands.

FIG. 5

Timber mats over cofferdams to install mini-piles.

The additional borings also revealed that the natural density/stiffness of the soils surrounding the wet well and for some distance beneath the pump chamber and inlet chamber were significantly reduced down to depths of about 10.6 to 12 m (35 to 40 ft) by the ground loss that occurred during wet well construction. Support of the inlet chamber, wet well and pump chamber on drilled mini-piles was therefore recommended to transfer structure loads to deeper, undisturbed soil and provide uniform support of the pump station. Drilled piles were recommended due to the concern that additional settlement of the constructed pump chamber could occur if driven piles were used.

Moretrench, a geotechnical specialty contractor, was subsequently contracted by the owner to work with MRCE and perform the remedial construction measures. A total of 28 mini-piles were installed beneath the footprint of the wet well and inlet chamber and around the perimeter of the completed pump chamber. Mini-pile installation occurred from near existing ground surface prior to the start of dewatering. Timber mats were used to span across the sheet piling and facilitate access for pile installation within the flooded cofferdam (Fig. 5). This allowed pile installation to occur under a positive head of water and prevent ground water flow and seepage pressures from affecting pile installation. This sequence also reduced the necessary duration of dewatering and consequent effects on the nearby private water supply wells.

The data from the pumping test was used to design a pressure relief system. The system consisted of the two existing wells supplemented by two new wells that penetrated into the deeper, more permeable sands. Excavation and construction of the wet well and inlet chamber was then successfully completed after water levels in the underlying sand were lowered below subgrade.

The final task was to re-level the adjacent pump chamber by jacking and supporting the structure on mini-piles. Re-leveling was accomplished by installing high strength steel threadbar lifting points into the walls of the pump chamber box. A large jacking frame was then assembled with the threadbars passed through center hole jacks and used as lifting points to level the chamber (Fig. 6). A series of 10, 46-t (50-st) capacity hydraulic jacks were connected in a parallel arrangement to a common manifold allowing independent control of each jack. In a clever scheme, Moretrench installed injection wellpoints at the perimeter of the chamber to liquefy the soils and relieve friction on the sides of the box during jacking thereby reducing the required jacking loads. Jacking was performed slowly over a two-day period with the pump chamber lifted from 25 to 305 mm (1 to 12 in.) and leveled to within 12.7 mm (0.5 in.) of its original design elevation. The void space beneath the chamber was then filled with 182 m^3 (600 cu ft) of neat cement grout. Support of the pump chamber was completed by constructing a concrete collar beam and doweling it into the walls of the lifted pump chamber. The jacks were then released to transfer load to the mini-piles.

Lessons learned

1. Geotechnical investigations for projects involving deep excavations below the ground water table require special attention and should include at least the following items:

- Sufficient borings to define the subsurface profile including type, stratification and thickness of soils and rock involved in excavation and dewatering. Particular emphasis should be placed on establishing the continuity of strata and location of interfaces between coarser grained and finer grained soils and their relationship to excavation subgrade as such interfaces can have a significant effect on ground water flow and the difficulty of dewatering.
- At least one boring should extend to excavation subgrade plus a depth equal to one to 1.5 times the depth of penetration of the excavation below the ground water table to investigate the presence of water bearing deposits and uplift pressures beneath the excavation bottom that if not relieved by pumping in advance of excavation could cause heave or piping.
- Piezometers installed in select borings as water levels measured during boring progress may not provide a true indication of the ground water level because of drilling rate or method, addition or removal of water by driller, or mud use in rotary borings. Multiple piezometers, screened and sealed at various depths, may be required in stratified soil deposits that could confine water in layers at higher pressure.
- Tremie grouting of all borings at completion to prevent ground water seepage through an ungrouted borehole from compromising the integrity of foundation soils.

2. Although the construction documents identified the need for dewatering for pump station construction, they did not convey the potential for heave or piping of the excavation bottom if the underlying sands were not pressure relieved by pumping in advance of excavation. Of all the potential problems in excavating below the water table, the possibility of uplift pressures in underlying pervious strata deserves the greatest attention because of the serious or even catastrophic consequences if such pressures are not adequately relieved in advance of excavation. It is, therefore, of utmost importance to identify such conditions before construction as they may not otherwise be anticipated. Where such conditions are suspected, the documents should require the installation of piezometers isolated in the underlying pervious strata to monitor and verify ground water drawdown and pressure relief of the sands in advance of excavation.

FIG. 6

Jacking frame, hydraulic jacks and injection points used for releveling the pump chamber.

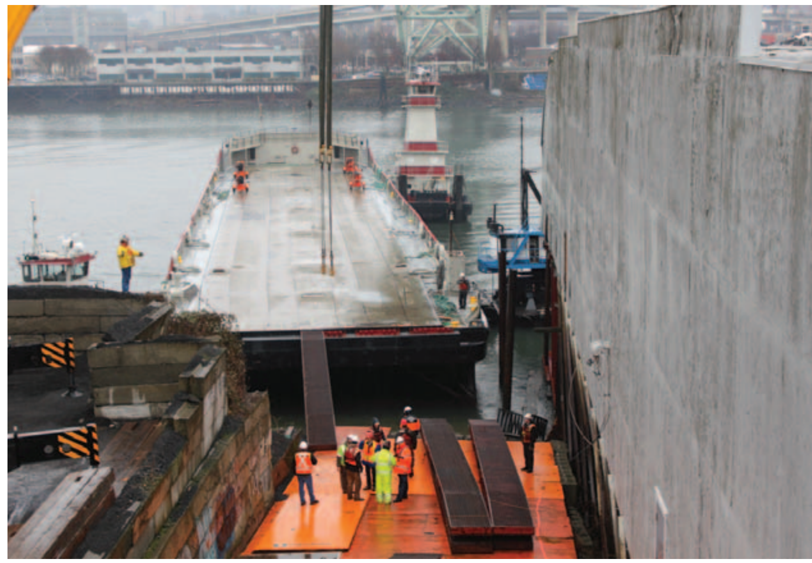
3. The inadequate instrumentation and monitoring plan implemented during construction was unable to reveal the problem and effects of upward ground water flow. Contrary to good dewatering practice, no piezometer was installed to determine water pressures and drawdown in the sands below excavation subgrade. Dewatering discharge was not monitored to determine if sump pumping was causing the continuous removal of soil fines. Monitoring of the sheet piling for settlement and lateral deformation was also not performed. Such measurements would have warned of the high water pressures remaining in the sands and effects of upward water flow on the stability of foundation soils and the sheet piling cofferdam.

4. The decision to install driven pipe piles to remediate the disturbed subgrade failed to address the primary cause of the problem that was unrelieved water pressure in the underlying sands. Without any supplemental dewatering, water pressures in the sands remained high and a sudden boil developed in the bottom of the excavation during initial pile driving. Unfortunately, pile driving did not stop and resulted in increased water flow into the cofferdam, ground loss around and beneath the excavation and settlement of the sheet piling and adjacent pump chamber. A better understanding of the subsurface conditions, and water pressures within the sands below subgrade would have shown that this "solution" to the problem created a more dangerous condition.

A clear understanding of subsurface conditions is critical to successful excavation and construction below the ground water table. This can be achieved through a well conceived and implemented geotechnical investigation. Often a specialty engineering and/or construction firm is required to fully understand conditions that are not generally experienced. ■

FIG. 2

Actual TBM roll-on site about 1.6 km (1 mile) south of the Port Center shaft.



Selecting the means of TBM transportation

Based on the nature of a soft ground TBM, especially a slurry TBM, some components are not only subject to extensive wear, but they are also exposed to ground water pressure and are, therefore, very difficult to access during mining. These components consist primarily of the cutterhead, tailshield and stone crusher. Since the TBM had to be relocated to the Opera shaft upon completion of the North Tunnel drive, KBB planned to refurbish the TBM under atmospheric conditions during this relocation period. This approach would avoid numerous costly and risky compressed air interventions during the mining. The original plan was for the TBM to be taken apart in standard sizes and number of pieces, similar to the manner in which the TBM was originally delivered to the construction site from the manufacturer.

The combination of TBM disassembly, refurbishment and reassembly would have a significant time and cost impact on the project. Parts of the TBM that were not exposed to ground water pressure could be maintained during the mining and were, therefore, not critical to the overhaul/relocation program. However, to break down the cutterhead and the tailshield into the originally delivered sections would require a significant amount of cutting and welding with the highest degree of accuracy. Certified welders would be necessary to perform this structural welding. It was critical that the TBM tailshield reassembly achieve the same roundness it had before it was cut apart at the Port Center shaft. The tailshield roundness would ensure a tight seal with the concrete segmental tunnel lining once tunneling resumed.

During initial TBM assembly, three weeks of specialty welding work was required on a brand new cutterhead and tailshield in order to achieve the quality required for the project. Significantly more welding would be required on the TBM after removing it from Port Center shaft. After considering these aspects, KBB decided to explore options for special TBM transport, at least for the two items listed in Table 1, to allow transport of these critical components in complete units.

Portland is a city with an impressive infrastructure. Eleven bridges cross the Willamette River, which divides the city into a west side and an east side. The Opera shaft (the launching shaft for both tunnel drives) and the Port Center shaft (the receiving shaft for the North Tunnel drive) are both located close to the Willamette River. A railroad yard, private property and main traffic roadways run along the river. This existing infrastructure led KBB to consider three means of transportation for the TBM: by road, by rail and by water.

All means of transportation have their challenges and opportunities. Bridges, for example, present more of a problem due to the TBM dimensions and the weight of the TBM components. Utilities would also have to be relocated and traffic restrictions would have to be coordinated. While hauling the TBM on the roadways was possible, it was not an ideal solution.

After evaluating the risks of TBM disassembly and

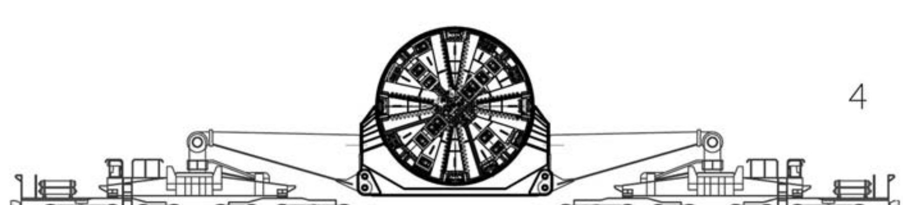
Table 1

Critical TBM components.

Component	Dimension	Weight
Cutterhead	7.72 m (25.4 ft)	100 t (110 st)
Tail shield	7.67 m x 4.3 m (25 ft x 14.1 ft)	75 t (83 st)

FIG. 3

BBCX 1,000 with the custom TBM Schnabel car.



FEATURE ARTICLE

Transporting a TBM through a large city on the East Side CSO Tunnel project in Portland, OR

Upon completion of the 6,200 m (20,340 lineal ft; lft) North Tunnel drive for the Portland East Side Combined Sewer Overflow (CSO) Tunnel project in Portland, OR, the slurry tunnel boring machine (TBM) had to be returned from the Port Center shaft at Swan Island to the Opera shaft at the main mining site for the 2,700 m (8,860 lft) South Tunnel drive.

At the Port Center shaft, the main 513-t (565-st) TBM and TBM tailshield were hoisted out of the shaft in two pieces using four 200-t (220-st) strand jacks mounted on a 635-t (700-st) hydraulic boom gantry system supported by Emmert International's custom gantry tracks designed to span the shaft. After lifting the TBM components out of the shaft, the gantry system loaded the TBM components onto two Goldhofer platform trailers, which then transported the TBM and tailshield to a barge using a roll-on/roll-off method.

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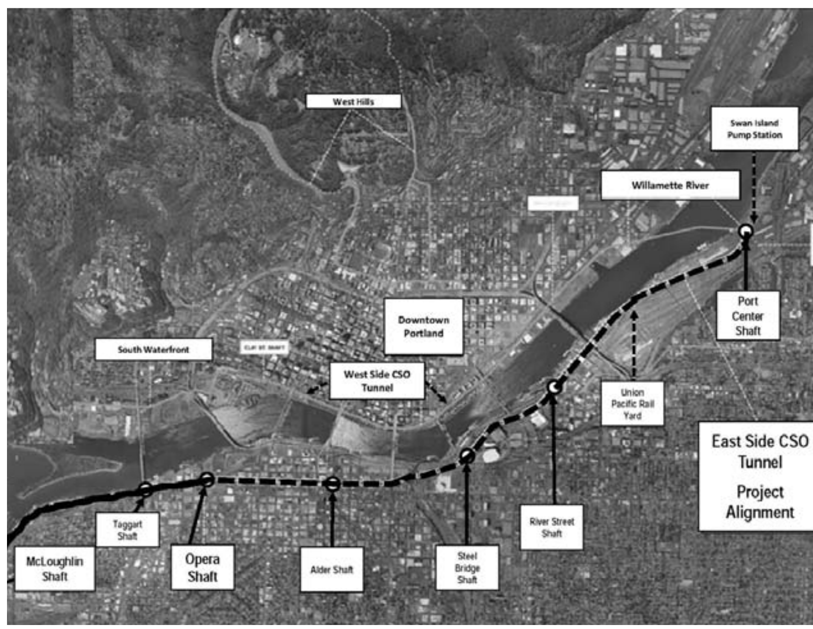
Niels Kofoed, is project manager, Kiewit Infrastructure Group, Inc., **Terry M. Emmert** and **Mark S. Voss** are vice president and Ph.D, P.E., M.ASCE, Emmert International, Engineered Transportation and Rigging, 11811 SE Hwy 212, Clackamas, OR, 97015, **Christof Metzger** is senior project manager Bilfinger Berger Civil, Inc. and **Gary Irwin**, member UCA of SME, is supervising engineer, City of Portland, Bureau of Environmental Services, e-mail gary.irwin@portlandoregon.gov.

The barge transported the TBM and tailshield up the Willamette River back to the Opera shaft site where the process was repeated in reverse for re-installation of the TBM inside the Opera shaft. This article discusses the considerations for selecting the means of transportation, the engineering and planning of the TBM transport, and the lessons learned from this successful operation.

FIG. 1

Alignment of the ESCSO project.



Portland East Side CSO Tunnel project

The Portland East Side CSO Tunnel project (ESCSO) is part of the Willamette River CSO program in Portland, OR, with a required completion date of December 2011. The project owner is the City of Portland, Bureau of Environmental Services and the contractor is Kiewit-Bilfinger Berger, AJV (KBB). Construction started in March 2006.

The scope of work for the ESCSO tunnel project includes a deep tunnel about 8,900 m (29,200 ft) long and 6.7-m (22-ft) finished diameter; seven main shafts; about 2,316 m (7,600-lft) of microtunneled pipeline; 792 m (2,600 lft) of opencut pipeline; and 13 diversion structures (Fig. 1).

The slurry TBM for the ESCSO project was fabricated by Herrenknecht in Germany in 2006 and delivered to the site in Portland during the first quarter of 2007. The machine was assembled and launched from the Opera shaft in early June 2007. The first of two tunnel drives — the 6,200-m (20,340-lft) North Tunnel drive — was completed in late October 2009 with hole-through at the Port Center shaft. The TBM was then transported back to the Opera shaft, refurbished and re-launched in early March 2010 for the second of two drives — the 2,700 m (8,860 lft) South Tunnel drive. The South Tunnel drive was completed in October 2010 with hole-through at the McLoughlin shaft.

FIG. 4

Actual TBM roll-off site with double ramp system.

methods and commercial approaches to the TBM transport. KBB compared the advantages and disadvantages of each proposal with the original plan of disassembling the TBM for lifting and relocation.

Project scheduling was the most important criteria in the selection process since the tunnel construction and TBM relocation were both on the critical path of the project. It was important that the TBM was relocated, refurbished and relaunched as soon as practical. Emmert International's proposal allowed for the TBM to be lifted and transported as a complete unit. This presented a significant advantage to the overall project. A crane was also available in town with sufficient capacity to make this lift. While space constraints at the Port Center receiving shaft required that the tailshield be disconnected from the TBM for removal, the tailshield could be lifted as a complete unit as well. For these reasons, KBB accepted Emmert International's proposal to transport the TBM from the Port Center shaft back to Opera shaft.

reassembly, KBB concluded that the two major TBM components — the cutterhead and the tailshield — should be transported in one piece without disassembly. The next step was to plan the critical lift of these two large components out of Port Center shaft and the transport back to Opera shaft. Table 2 provides the key dimensions of the TBM.

Local "special transportation" companies were contacted and asked for proposals to transport the TBM from Port Center shaft to Opera shaft. Several proposals were received offering a variety of technical means and

Table 2

Key TBM dimensions.

Component	Dimension	Weight
TBM	7.72 m x 10.73 m (25.4 ft x 35.2 ft)	514 t (565 st)

Engineering and planning

In preparation for the TBM transfer, Emmert performed an extensive analysis of the transportation route, the means of transportation and the lifts required in the transportation. The engineering and planning for the TBM transportation included stability analyses and load distribution analyses at each step of the process.

Transportation plan

Given the size of the TBM and tailshield, an overland

FIG. 5

Actual barge layout with the TBM and tailshield on deck.

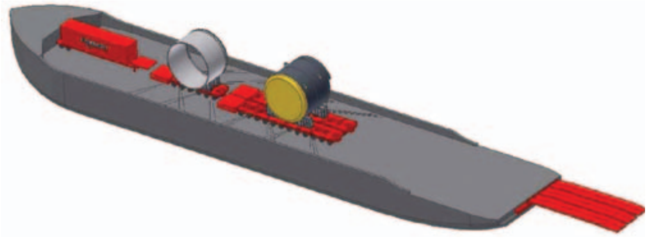
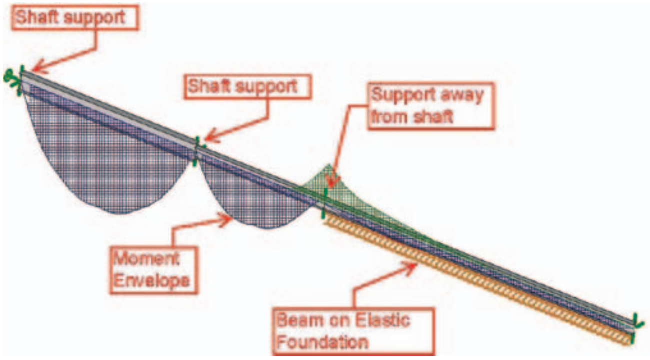


FIG. 6

Gantry track-beam on elastic foundations.



route was ruled out due to the impact the move would have on the traveling public and the cost of relocating numerous utilities along the route. An over-water route on the Willamette River was the more logical choice for the majority of the route. The only real problem with the over-water option was finding a way to get the TBM loaded onto a barge near the Port Center shaft site and a suitable location to offload the TBM from the barge when it arrived near the Opera shaft site. There was a dry dock facility near the Port Center shaft, about 1.6 km (1 mile) north of the site. This was the first consideration for the TBM roll-on. However, scheduling complications with the facility owner led Emmert to investigate other options for the roll-on. Emmert identified a second location about 1.6 km (1 mile) south of the Port Center shaft that, if the existing dock was improved, could serve as the TBM roll-on point. This alternate roll-on location was selected. Emmert used a 16.7-m (55-ft) barge ramp system and designed a custom hinge support to connect the ramp to the barge (Fig. 2).

The first site considered for the TBM roll-off was an existing offload area near a private railroad line that was approximately 1.6 km (1 mile) south of the Opera shaft. A preliminary engineering study was conducted by Emmert to determine if its 20-axle Schnabel car (the BBCX-1,000) could be outfitted to carry the TBM on the private rail line (Fig. 3).

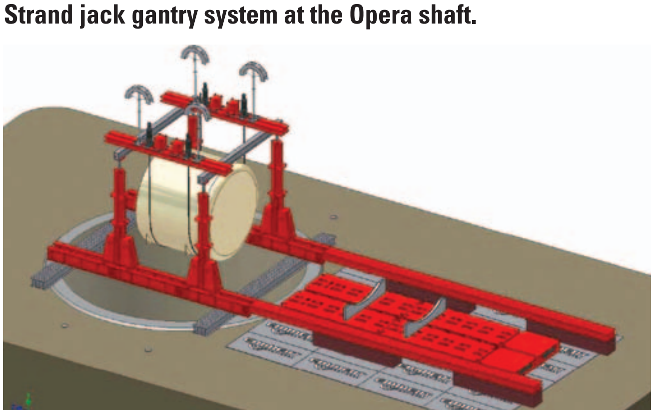
While Emmert was investigating the Schnabel rail car option, preliminary engineering studies on a new offload ramp closer to the Opera shaft were also being conducted. The property for this new ramp was available and permits had already been taken to develop this site. As such, the new ramp was a viable option. The costs to develop this new ramp were compared to the costs to transport the TBM on the private rail line. Schedule durations were also compared. Ultimately, the new offload ramp was selected for the TBM roll-off point. Extensive geotechnical and structural engineering was completed on the offload ramp area. Emmert plated and compacted the TBM's path of travel with a specified maximum grade. At this location, a double ramp system was employed to accommodate the difference in elevation from the barge to the offload ramp. The TBM offload is illustrated in Fig. 4.

FIG. 7

Actual gantry track layout at the Port Center shaft.

FIG. 8

Strand jack gantry system at the Opera shaft.



Marine engineering

Along with the geotechnical and structural engineering analyses, the TBM transporter also evaluated the structural capacity of the barge deck and performed ballasting and stability calculations for each step of the TBM transport. The engineering assumptions and the operation plans were coordinated and checked independently to ensure that all aspects of the critical TBM transport were compatible. One complicating factor in the marine calculations was the uncertainty in predicting the tidal highs and lows during the planning stage several months ahead of time. Emmert's final marine engineering analysis provided a flexible solution that accommodated a range of potential offload geometries that would be dictated by the actual water levels on the day the TBM was moved. Figure 5 is a three-dimensional schematic of the TBM and the tailshield tied down on the barge.

Strand jack gantry system for picking/setting the TBM

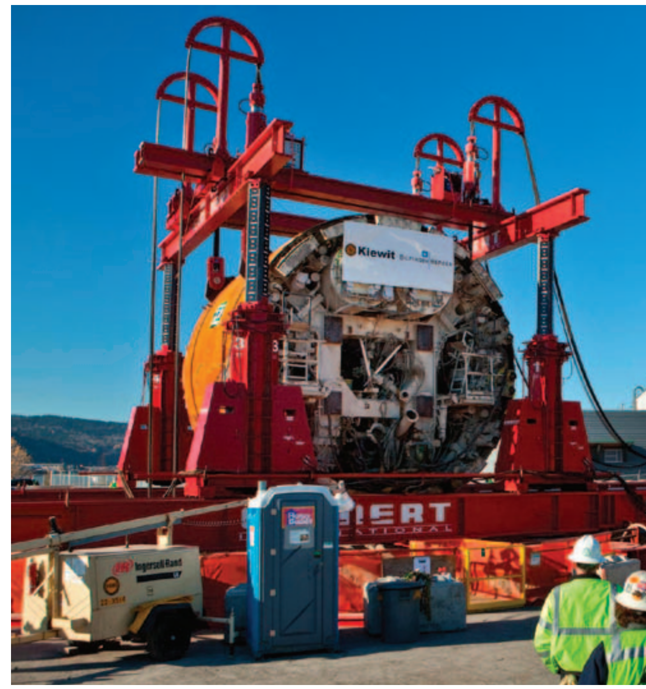
Transporting the TBM from the Port Center shaft back

FIG. 9

Lifting the TBM out of the Port Center shaft.

FIG. 10

Actual 635-t (700-st) gantry used to lift and set the TBM.



to the Opera shaft was only half of the challenge. The TBM had to be lifted out of the Port Center shaft and then set down inside the Opera shaft. A strand jack gantry system had to be designed, which could not only span the shaft, but also span a distance away from the shaft to prevent side loading of the shaft wall. A preliminary engineering study determined that a custom designed long-span gantry system would adequately solve this problem. Emmert employed RISA-3D to model the gantry beam system on elastic foundations using a moving load analysis to create a design envelope (Fig. 6).

KBB's and Emmert's engineering teams determined the maximum vertical wall loading that the shaft would be able to support, resulting in a minimum distance for the first gantry track support outside the shaft wall. The engineering teams also worked together for the gantry supports located on the top of the shaft walls, resulting in a shimmed beam support system that would distribute the shaft loading across an acceptable area. The actual installation of the gantry system required the temporary removal of the shaft utilities and the safety handrail around the perimeter of the shaft collar. Final checks of the gantry support beam were performed by both engineering teams. The upper gantry beam and strand jack support systems were designed in parallel with the gantry beam layout. The final gantry and strand jack designs were checked and reviewed independently for the Port Center shaft and the Opera shaft. The strand jack and gantry crane system are illustrated in Figs. 7 and 8.

It is important to note that one of the design constraints confronting the design teams was that access to the Port Center shaft site was severely restricted by a nearby railroad yard and further complicated by the design requirement that the gantry tracks be perfectly level. The decision was made to remove the TBM perpendicular to its path of travel at the Port Center shaft and then set the TBM parallel to its path of travel at the Opera shaft. This required that the TBM be rotated 90° at some point between the Port Center shaft and the Opera shaft. Emmert designed custom lifting links for lifting the TBM from the Goldhofer transporter, allowing placement of the W14•311 beams below the saddles, which were supported on staging stands. The staged TBM allowed the TBM to be rotated 90° and had the added benefit of facilitating the removal of the TBM cutterhead at the Opera shaft. Here again, collaborative teamwork between the Emmert and KBB personnel resulted in a more efficient outcome. The Goldhofer trailer was set 90° from the offload position to deliver the TBM to the Opera shaft strand jack gantry system for installation.

Lifting links for picking/ setting the TBM

Four 200-t (220-st) strand jacks mounted on a 635-t (700-st) hydraulic boom gantry system were employed to lift the TBM (Fig. 8). A critical design component to this system was the load connections, specifically the lifting lugs on the TBM, the lifting links that connected the TBM lugs to the strand jack lugs and the strand jack lugs themselves. The TBM lifting lugs were designed by KBB and consisted of four, 7.6-cm- (3-in.-) thick steel pad eyes welded to the TBM body. The locations of the four lifting lugs were determined based on the center of gravity of the TBM. The strand jack lugs were designed by the strand jack manufacturer. Emmert designed the linkage between the TBM lugs and the strand jack lugs.

FIG. 11

Transportation of the TBM and tailshield on the Willamette River.

Sequence of TBM transportation

After welding the lifting lugs to the TBM at the bottom of the Port Center shaft, it took just one week to complete the transport operation previously described. The TBM was lifted out of the Port Center shaft on Dec. 10-11, 2009 and was followed by the removal of the tailshield three days later. The TBM and tailshield were then transported from the Port Center shaft site to the roll-on loading ramp on two Goldhofer trailers and loaded onto the barge on Dec. 15, 2009. The TBM was pushed up river on Dec. 16, 2009. The TBM was then offloaded and transported to the Opera shaft site the following day on Dec. 17, 2009. The execution of the TBM transport is best described with photos. Figures 9 through 12 illustrate the successful transportation of the TBM on the ESCSO tunnel project in Portland.

FIG. 12

Unloading the TBM and the tailshield from the barge at the roll-off site.

Conclusion

The transport of the TBM and tailshield from the Port Center shaft to the Opera shaft involved every aspect of heavy haul marine/land transport and rigging. State-of-the-art transporters, strand jacks, gantry systems and computer modeling assisted in the planning. But it was the human element that made this TBM transport such a success. Teams of highly skilled engineers and craft workers cooperated during the planning and execution stages to solve the numerous complex, interconnected problems that arose. The TBM transport in Portland raised the bar for what can be accomplished using a fully engineered transport and rigging solution. The cost of this final solution was comparable to other approaches that were considered. But ultimately, this final solution allowed the TBM to be re-launched almost six weeks earlier than originally planned. This schedule savings was critically important to the overall success of the project. ■

Acknowledgments

The authors would like to acknowledge Dave Anderson, P.E. from Kiewit Engineering Co., and Jasbir Singh, P.E. from Kiewit Infrastructure Group Inc., for their valuable input during the planning stage and for their independent engineering checks and on-site inspections during the work.

FEATURE ARTICLE

Health of the underground construction industry evident at RETC

In spite of a global economy that continues to seesaw and a U.S. Congress that is at odds with the president and themselves, cities around the world are still spending billions on their infrastructure. And that bodes well for the underground construction and tunneling industry and the professionals who work in it.

In June, 1,405 of those professionals gathered in San Francisco, CA for the Rapid Excavation and Tunneling Conference (RETC). In addition to the first rate technical programming, attendees were able to see first-hand the latest in tunneling technology from 127 exhibitors who occupied 152 booths. Two short courses preceded the conference and two field trips were offered following the conference.

Technical programming

The technical programming at the RETC included 115 papers in 21 sessions. The 1,608-page proceedings volume of the 2011 conference is available from SME Customer Service, 12999 E. Adam Aircraft Circle, Englewood, CO 80112, USA, phone 800-763-3132, 303-948-4200, e-mail cs@smenet.org, www.smenet.org, member $139, student member $139, list $179.

The following is a sampling of the papers presented at RETC. Each is included in the proceedings volume.

Roadheader excavation in hard rock — a case history from Midtown Manhattan. Roadheader technology has made some significant advances in recent years. So much so that planners at New York's East Side Access project were able to consider roadheaders as an alternative to conventional drill-and-blast techniques. A group of authors, headed by E. Jordan of Hatch Mott MacDonald, presented a case history of roadheader use at the East Side Access project.

The unique geometries of the main station below Grand Central Terminal were excavated using roadheaders that were capable of mining strong, resistant rock. The excavations were mapped by a team of geologists and geotechnical engineers. The authors provided an overview of the ESA roadheader excavations to date, a summary of geotechnical characteristics and the strength of rock types encountered, and a description of the benefits and limitations of using a roadheader in the crystalline rock of the Manhatten Formation.

Steve Kral, Editor

High pressure EPB tunneling under sensitive buildings. The Rome Metro Line B1 is an extension of the existing B line. The project includes two 6-km (3.7-mile) tunnels and three stations. A paper written by five members of the project team described some of the technical challenges involved, along with some solutions. They described the technologies and the tunneling boring machine (TBM) operation parameters applied to boring the tunnel that minimized the impact on surface settlements and avoided damages to the buildings above. The earth pressure balance (EPB) TBMs used in the project had cutting diameters of 6.79 m (22.3 ft), and were designed to work with a face operating pressure of up to 5.5 bar.

Among the challenges faced by project planners was the close proximity of ancient and sensitive buildings with foundations as close as 6 to 8 m (20 to 26 ft) from the tunnel's route. And the tunnel was planned to run below the Aniene River at a depth of 30 to 35 m (98 to 115 ft) below the water level. In addition, the complex vertical and horizontal alignment had a minimum radius of 130 m (425 ft).

RETC hosted 1,405 attendees this year.

Tunneling in the Andes in Chile by drill-and-blast and TBM. Pacific Hydro is developing a series of cascading, run-of-river hydro electricity projects located in Chile's Cachapoal Valley at the foot of the Andes Mountains. The projects, about 100 km (330 miles) south of Santiago, will involve extensive tunneling and underground work.

The first of the projects, now under construction is called Chacayes, with an installed capacity of 110 MW. It involves 6 km (2.7 miles) of tunneling with diameters between 5 and 7 m (16 and 23 ft). About 2.5 km (155 miles) of the tunnel will be bored by a TBM.

A group of authors from Pacific Hydro described the project and factors involved in deciding between conventional drill-and-blast and TBM tunneling techniques. They also discussed the issue of swelling rocks that were discovered during the tunneling process and the implications this had on the design of the permanent concrete liner.

Brian Olson's Art in Action was display of painting and music.

Summary of the first TBM drive at the Hallandasas project. The first of two drives at the Hallandasas project in Sweden was completed in August 2010. A group of project members presented a discussion of the challenges that drive presented. The engineering, geological conditions and hazards required advanced methods, flexibility, and adaptation of equipment and working methods in order to keep the TBM moving.

The main issues, according to the authors, were controlling the wear of the cutterhead due to blocky ground, and limiting ground water ingress by extensive pre-excavation grouting from the TBM and through the segmental linings. Workers also had to control the outwash of backfill material using a combination of pea gravel and mortar, and using ground freezing methods to stabilize the very poor rock in the Molleback fault zone.

Innovative approach for oil production based on subsea tunnels and caverns. A feasibility study conducted by Acona Wellpro and NTNU/SINFEG compared tunneling for oil development with traditional development strategies. According to authors who conducted the study, the concept includes three tunnels descending from the terminal facility on land to a base station at the low point under water. From the base station, three tunnels would be TBM bored to the large production caverns that would need to be established for drilling equipment. The caverns would need to provide sufficient confinement and safety measures for worst-case accidents.

The authors concluded the tunneling concept is feasible compared with traditional development techniques. The costs are competitive for oil fields that are about 30 km (19 miles) from shore. Tunneling reduces environmental risks, they said, and provides a solution to improve the use of the oil field better than traditional solutions. Critical issues include grouting, advance rates and uniform performance for tens of kilometers.

Risk management and relationships overcome challenges. The WRCT Tunnel in northern Kentucky has been holed through, but construction continues. The design, procurement and construction of this tunnel included technical and construction-related risks as well as political challenges. Members of the project team presented a discussion of the challenges facing the project and how teamwork overcame them.

A few of the challenges included methane gas, low cover, internal corrosion, creek crossings, strong public opposition, the rejection of bids and the use of a 40-year-old TBM. The authors described the design and construction methods used on WRCT Tunnel to mitigate these challenges. And they described the collaboration between the owner, engineer and contractor that led to a successful project.

Blasting the Sykesville formation in the national capital area. Blasting in urban and suburban environments is a source of conflict between the public, contractors and project owners. However, the increasing availability of smaller and more lightweight seismographs has significantly improved the quality and ease of blast data gathering. S. Lipfosky, of J.F. Shea Construction, and L. Jennemyr, of Skanska USA Civil, presented two case studies of projects in the Washington D.C. area that involved blasting. Both were in the same geologic formation.

The first project was surface excavation for the Silver Spring Transit Center. The other was a subsurface excavation that included shafts and horseshoe-shaped TBM starter and tail tunnels for the Washington Suburban Sanitary Commission. Both projects are located in the Piedmont physiographic province northwest of the Fall Line.

Cal Park tunnel rehabilitation project. The Cal Park Tunnel in Marin County, CA was built in the 1880s as a single-width railroad tunnel. In 1924, it was widened to a

The exhibition at RETC attracted 127 companies occupying 152 booths.

double track tunnel and then closed in the 1970s. The tunnel is now being refurbished as multimodal transportation tunnel for passenger rail and a pedestrian-bicycle pathway.

However, while closed from the 1970s to the present, the tunnel suffered from vandalism, fire, tunnel timber support decay and multiple collapses. Four members of the project that is rehabilitating the Cal Park Tunnel presented a paper on the challenges encountered during the upgrade. Because of uncertainty surrounding the tunnel's condition and its proximity to a major freeway, the tunnel required a variety of ground support modification schemes, the author said. These included final lining approaches and unique risk management strategies by the owner and contractor.

Ground freezing for Manhattan Tunnel TBM establishes technology breakthrough. The Manhattan Transit Authority, in December 2007, awarded a $1.15-billion contract to build tunnels and a station for the Number 7 Subway Line Extension Project. A part of the contract required the design and installation of an appropriate ground improvement method for a 90-m (300-ft) section of the two 6.7-km (22-ft) tunnels. Three members of the joint venture group that are building the tunnel discussed this aspect of the project.

Ground freezing was selected as the technically superior approach to converting soft, unconsolidated soils to a rock-like structural and waterproof material. They said that this project was the first time that TBMs have mined through artificial frozen ground. The paper examined the design and how factors such as soil properties, ground water flow and salinity effect freeze development time. They also described innovative components used, including aluminum pipes and monitoring devices.

Construction of the Dulles Corridor Metrorail project NATM tunnels at Tysons Corner, Virginia: a case history. A pair of 520-m- (1,700-ft-) long tunnels are being constructed in Tysons Corner, VA as part of the $3.1-billion Phase 1 Silver Line passenger rail service to Dulles International Airport. The twin tunnels, owned by the Metropolitan Washington Airports Authority, are being built beneath the major traffic arteries of Routes 7 and 123. Tysons Corner is one of the busiest and most congested retail, commercial and residential areas in the Washington D.C. area.

The contractors selected the NATM, or sequential excavation, method for boring the two tunnels. Three authors involved with project discussed the method used to build the tunnels in soft ground conditions with shallow heading cover. The tunnel drive is pregrouted with a continuous overlapping pipe arch canopy, the authors said, and excavated in 13-m (42-ft) "saw tooth" increments. The initial ground support consists of a 255-mm- (10-in.-) thick layer of steel fiber reinforced shotcrete. The final liner includes PVC waterproofing and a 305-mm- (12-in.-) thick cast-in-place liner.

Ground challenges for the Thames Tunnel. London Tideway Tunnels is building a 7.2-m- (23.6-ft-) diameter, 32-km- (20-mile-) long tunnel beneath the Thames River in London, UK. The capture will capture up to 39 m^3/a (1,380 cu ft/year) of untreated sewage from the city's sewer system that is currently discharged into the river during heavy rainfalls.

T. Newman and N. Hadlow said in their paper that ground investigations has shown that the tunnel will encounter the London Clay, Lambeth Group and chalk, requiring different tunneling techniques for each deposit. In addition, the authors said that the presence of several regional geological structures would add to the complexity. They indicate hazardous changes in geology and ground water conditions along the alignment. The authors described the challenges that needed to be overcome to satisfy the health and safety and build quality standards that were imposed.

Tunel Emisor Oriente in Mexico, the world's most challenging EPB shield tunneling project. The proposed 62-km (38-mile) Emisor Oriente sewage tunnel near Mexico City has presented many challenges for six EPB shields that will be used, according to project managers. These shields, with boring diameters of 8.74 and 8.93 m (28.6 and 29.3 ft), will excavate mostly soils with overburden up to 140 m (46 ft). The soils comprise very soft settlement-prone clays of the Mexico Valley, the authors said, along with deep consolidated clayey and sandy sediments and water pressures up to 7 bar.

These conditions represent an extension of the typical applications ranges for an EPB. The authors described the efforts that are being made to adequately adjust the process technologies, enhance the process controlling tools and perform additional measures aimed at optimizing key success factors for the project. A few of those factors include advance speed, ground conditioning, minimizing tool wear, and muck transport and disposal. In addition, the design and calculation of the segmental lining has exceeded conventional load cases and calculation methods.

The exhibit area was the place to meet with old friends.

Short courses

The 2011 RETC also featured two one-day short courses, "Grouting in Underground Construction" and "Large Diameter Tunneling Technologies."

Sixty-eight professionals attended the "Grouting in Underground Construction" short course, which presented an overview of the materials, equipment and grouting methods that are used in underground construction in soils and rocks. Content included an introduction and overview, cements and admixtures, equipment, jet grouting, compaction and permeation grouting, backfill and contact grouting, cellular grouts, chemical grouts, grouting to protect pre-existing structures, and probe hole drilling and pre-excavation grouting.

"Large Diameter Tunneling Technology" attracted 77 attendees. The course provided an overview of the technological developments involving large diameter tunneling, 14 m (45 ft) in diameter. Conventional and mechanical tunneling methods were covered. Some of the course topics included site investigations for large tunnels, selection of excavation methods, tunnel boring machine (TBM) operation and design, tunneling under high water pressures, and machine advance rates and tool life estimations.

Field trips

In addition to the technical sessions and short courses, two field trips to San Francisco area underground construction projects took place. One tour was of the San Francisco Public Utilities Commission's New Irvington Tunnel project. This tunnel is being driven parallel to the existing Irvington Tunnel at a depth of 9 to 213 m (30 to 700 ft). The 5.6-km- (3.5-mile-) long tunnel will have an internal diameter of 2.6 m (102 in.).

Southland/Tutor Perini is the contractor. It is using conventional mining methods including several roadheaders and controlled detonations. The tour focused on the Alameda West Portal, one of the project's three main tunneling locations.

The second tour was to the Sunnydale Auxiliary Sewer Project. This tunnel is designed to prevent flooding of residences near San Francisco Bay during storm events. The 2.4- to 3.7-m- (8- to 12-ft-) diameter tunnel is 1.2 km (4,000 ft) long. It will require a single-pass, segmentally lined earth-pressure-balance drive, a microtunneled drive, a jacked-shield and a short cut-and-cover section. The tunnel crosses through a variety of soft ground and highly variable Franciscan Formation bedrock.

Upcoming UCA of SME meetings

The UCA of SME's 2012 North American Tunneling Conference is scheduled for June 24-27 at the J.W. Marriott Indianapolis Hotel in Indianapolis, IN. The biannual meeting includes technical programming, a proceedings volume and an exhibit.

The annual George A. Fox Conference will once again be held at the Graduate Center, City University of New York. This one-day technical paper conference is set for Jan. 24, 2012. For information on both conferences, contact SME Meetings Department, phone 800-763-3132, 303-948-4200, e-mail sme@smenet.org. ■

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Gateway Tunnel project	Amtrak	Newark	NJ	Subway	8,000 x 2	24.5	2014	Under study
2nd Ave. Phase 2-4	NYC-MTA	New York	NY	Subway	105,600	20	2012-20	Under design
Water Tunnel #3 bypass tunnel	NYC-DEP	New York	NY	Water	20,000	15	2015	Under design
Water Tunnel #3 Stage 3 Kensico	NYC-DEP	New York	NY	Water	84,000	20	2017	Under design
Cross Harbor Service Tunnel	NYC Reg. Develop. Authority	New York	NY	Highway	95,000	38	2014	Under design
Cross Sound Link Highway Tunnels	Sound Link	Long Island	NY	Highway	190,000	55	2014	Under design
Clinton CSO Tunnel	City of Syracuse	Syracuse	NY	CSO	2,000	17	2011	Kiewit/Jett low bidder
Silver Line Extension	Boston Transit Authority	Boston	MA	Subway	8,400	22	2013	Under design
Hartford CSO program	MDC	Hartford	CT	CSO	32,000	20	2013	Under design
East-West Subway Extension	Baltimore MTA	Baltimore	MD	Subway	32,000	18	2012	Under design
WASA CSO Program Anacostia River Tunnel Northeast Branch Tunnel Northeast Boundry Tunnel	DC Water and Sewer Authority	Washington	DC	CSO CSO CSO	12,500 11,300 17,500	23 15 23	2013 2018 2021	Under design Under design Under design
North/South Tunnel	Georgia DOT	Atlanta	GA	Highway	77,000	41	2015	Under design
ISCS Dekalb Tunnel	Dekalb County	Decatur	GA	CSO	26,400	25	2013	Under design
Lockbourne Interceptor Sys. Tunnel	City of Columbus	Columbus	OH	Sewer	10,000	12	2012	Under design
Olentangy Relief Sewer Tunnel	City of Columbus	Columbus	OH	Sewer	58,000	14	2012	Under design
Alum Creek Relief Sewer Tunnel	City of Columbus	Columbus	OH	Sewer	74,000	10 - 18	2014	Under design
Black Lick Tunnel	City of Columbus	Columbus	OH	Sewer	32,000	8	2013	Under design
Dugway Storage Tunnel	NEORSD	Cleveland	OH	CSO	16,000	24	2014	Under design
Lower Mill Creek CSO Tunnel	M.S.D. of Greater Cincinnati	Cincinnati	OH	CSO	6,350	30	2015	Under design
Black River Storage Tunnel	City of Lorain	Lorain	OH	CSO	5,700	19	2011	Advertise Oct. 2011
Water Treatment Plant #4	City of Austin	Austin	TX	Water intake	45,000	7 to 9	2010	Obayashi/ Manson
Jollyville Water Trans. Main	City of Austin	Austin	TX	Water intake	25,000	12	2011	Southland low bidder
St. Louis CSO Expansion	St. Louis MSD	St. Louis	MO	CSO	47,500	30	2014	Under design

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Deep Rock Connector Tunnel	City of Indianapolis DPW	Indianapolis	IN	CSO	40,000	18	2011	Bid date 08/11/ 2011
Pogues Run Tunnel	City of Indianapolis DPW	Indianapolis	IN	CSO	11,000	18	2013	Under design
Drumanard Tunnel	Kentucky DOT	Louisville	KY	Highway	2,200 x 2	35	2012	Under design
North Link Light Rail Extension	Sound Transit	Seattle	WA	Transit	34,000	21	2013	Under design
East Link Light Rail Extension	Sound Transit	Seattle	WA	Transit	12,000	21	2015	Under design
Central Subway Tunnel	S.F. Municipal Trans. Authority	San Francisco	CA	Subway	16,600	20	2011	Barnard/ Impregilo/Healy
San Francisco DTX	Transbay Joint Powers Authority	San Francisco	CA	Transit	6,000	35 to 50	2012	Under design
L.A. Metro Regional Connector	Los Angeles MTA	Los Angeles	CA	Subway	20,000	20	2012	Under design
LA Metro Wilshire Extension	Los Angeles MTA	Los Angeles	CA	Subway	24,000	20	2013	Under design
LA Metro LAX to Crenshaw	Los Angeles MTA	Los Angeles	CA	Subway	12,200	20	2013	Under design
SVRT BART	Santa Clara Valley Trans. Authority	San Jose	CA	Subway	22,700	20	2011	Under design/ delayed
BDCP Tunnel #1	Bay Delta Conservation Plan	Sacramento	CA	Water	26,000	29	2014	Under design
BDCP Tunnel #2	Bay Delta Conservation Plan	Sacramento	CA	Water	369,600	35	2016	Under design
Kaneohe W.W. Tunnel	Honolulu Dept. of Env. Services	Honolulu	HI	Sewer	15,000	13	2012	Under design
Spadina Line Extension - South Tunnel	Toronto Transit Commission	Toronto	ON	Subway	11,000	18	2010	McNally/Kiewit/ AECON
Spadina Line Extension - North Tunnel	Toronto Transit Commission	Toronto	ON	Subway	11,000	18	2010	OHL/FCC JV
Eglinton West Tunnel	Toronto Transit Commission	Toronto	ON	Subway	10 km	6 m	2011	Under design
Yonge Street Extension	Toronto Transit Commission	Toronto	ON	Subway	15,000	18	2013	Under design
Downtown LRT Tunnel	City of Ottawa	Ottawa	ON	Transit	10,000	20	2013	RFQ 3Q 2011
Port Mann	Greater Vancouver Regional District	Vancouver	BC	Water	3,300	10.5	2010	McNally/ AECON JV
Evergreen Line Project	Trans Link	Vancouver	BC	Subway	10,000	18	2012	Under design
UBC Line Project	Trans Link	Vancouver	BC	Subway	12,000	18	2014	Under design
Kicking Horse Canyon	BC Dept.of Trans.	Golden	BC	Highway	4,800 m x 2	45 x 32	2012	Under design
LRT Expansion North	City of Edmonton	Edmonton	BC	Subway	370 m x 2	6 m	2011	Bid date 08/26/11

NOMINATIONS AND AWARDS

UCA calls for Executive Committee nominations

The UCA Division seeks recommendations and nominations from all UCA members for interested individuals to serve on the UCA Executive Committee beginning in 2012. Currently, the UCA bylaws allow a 19-person Executive Committee. The members of the executive committee are made up of three officers, chair, vice chair and past chair, and four directors from each of the following areas: engineers, contractors, owners and suppliers.

Ideally, the UCA Executive Committee seeks a balanced representation from the four categories. But the committee has the option to have more members serving in one or more categories, while having fewer representatives in other areas.

If you would like to nominate someone for consideration, please forward your recommendation to Mary O'Shea, oshea@smenet.org, at SME headquarters by Nov. 1, 2011. Staff will compile all nominations for the UCA Nominating Committee's consideration. The Nominating Committee requests the following information to help with the committee's consideration.

- 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.
- Remember that the individual must be a member of the UCA of SME. ■

Send in your nominees for UCA awards

The UCA of SME will present the UCA Awards at the 2012 North American Tunneling Conference in Indianapolis, IN. The awards are: Outstanding Individual, Project of the Year, Outstanding Educator and the Lifetime Achievement Award.

The nominees for the awards will be reviewed by the UCA Executive Committee during the January 2012 UCA Executive Committee meeting. The committee will then vote and approve award nominees.

The recipients' photos and biographies will appear in the March 2012 issue of *T&UC*. Guidelines and nomination forms are available on the UCA of SME website, www.uca.smenet.org.

Please submit your nominations by Jan. 3, 2012 to Mary O'Shea at oshea@smenet.org. ■

PERSONAL NEWS

DANIEL A. LOUIS (SME) P.E., G.E. has joined Samsung C&T, the global construction arm of Samsung Group, as vice president and technical director for the Civil Engineering Division. Louis will focus on tunneling and underground projects worldwide and will be responsible for developing new projects and opportunities in the Americas, Australia, New Zealand and related markets. He has more than 26 years of experience, including design and construction work on several mega-projects in the United States and overseas. He will be based in Seoul, South Korea and will provide support to Samsung's offices in California and Texas.


LOUIS

ROBERT GOODFELLOW (SME) P.E. has joined Aldea Services, a new tunneling and geotechnical engineering firm, as senior vice president. The new company will offer national and international expertise in the management of risk and delivery of underground projects at all stages. Goodfellow will work with vice president **MOHAMED YOUNIS**, P.E., and president **GINA GOODFELLOW** who offer combined expertise in design, construction management and consulting services for all types of trenchless and underground construction techniques.


GOODFELLOW

NICK CHEN (SME) P.E. has joined AECOM as vice president and manager of its North Ameri-

(Continued on page 58)

UCA OF SME SCHOLARSHIP

Gharahbagh receives the first UCA of SME scholarship

Ehsan Alavi Gharahbagh is the first recipient of the new UCA of SME scholarship. Gharahbagh is a graduate student and research assistant in the Energy and Mineral Engineering program at The Pennsylvania State University. He is currently doing research in mechanized tunneling machinery to improve the life and performance of excavation surfaces as part of his Ph.D. research. He is a teaching assistant in mining classes, such as mine surveying and introduction to mining engineering. He currently holds an internship position as a tunnel engineer with the JayDee/Collucio/Michaels U-Link joint venture in Seattle, WA, working on the excavation of the light-rail tunnel by EPB TBM.

Gharahbagh has a B.S. in mining and an M.S. in mineral and geotechnical engineering from the New Mexico Institute of Mining and Technology. He has worked on the numerical modeling of porous media to evaluate various failure forms in materials, such as rock. He is currently working on a project to develop a soil abrasion index for application in the tunneling industry.

Gharahbagh has attended SME meetings, as well as NAT/RETC meetings and participated in the NAT student paper competition last year, wining second prize. His research will benefit the tunneling industry and soft-ground tunneling. His study can also lead to the development of wear-resistant material for longer life and higher efficiency in soft ground tunneling.

Yaw D. Yeboah (l), head of the John and Willie Leone Family Department of Energy and Mineral Engineering at Penn State, presented the scholarship check to Ehsan Alavi Gharahbagh (r).

Scholarship guidelines

The UCA of SME scholarship was established to encourage the introduction of undergraduate and graduate academic pursuits and careers in the field of tunneling and underground construction. The scholarship will be awarded annually to one or more promising college students who desire to develop their skills in tunneling and underground mining. Up to $10,000 in scholarships may be awarded each year. The scholarship will be awarded based on an evaluation by the UCA Scholarship Committee and approved by the Executive Committee of UCA of SME. The recipient(s) will be announced each spring in anticipation of the next academic year, and the scholarship(s) will be presented at either the North American Tunneling or Rapid Excavation & Tunneling Conference held in June each year. The deadline for applications is Dec. 1.

A UCA of SME scholarship may be awarded to students attending any college or university in the United States that provides curricula in academic disciplines associated with planning, design, and construction of tunnels as well as underground construction, and leading to a bachelor's, master's or Ph.D. degree.

Before awards are authorized, candidates may be interviewed by one or more members of the Scholarship Committee to determine the nominee's desire for a career in tunneling and underground construction and the applicant's likelihood for success.

Nominees must be a student member of UCA of SME. Other rules and procedures can be found on the UCA of SME website, www.uca.smenet.org. ■

PERSONAL NEWS

(Continued from page 57)

can tunneling practice. He will be located in Boston, MA. Chen, a specialist with more than 30 years of experience, is an expert in developing cost saving construction methods and applying synthetic fiber reinforced shotcrete as a permanent lining of underground facilities. He is a member of the American Concrete Institute's Subcommitee for Underground Shotcrete. ■

RETC SCHOLARSHIPS

RETC awards scholarships at June meeting

The Rapid Excavation & Tunneling Conference (RETC) annually awards one or more scholarships to promising college students who desire to develop their skills in the rapid excavation and tunneling field. The amount of the scholarship, approximately $2,500, is awarded at the discretion of the RETC Executive Committee.

The scholarship application can be found on the UCA of SME website, www.uca.smenet.org under member benefits.

Three students received RETC scholarships at the 2011 RETC in San Francisco, CA.

ANDREW TANGSOMBATVISIT is a senior at the University of Illinois Urbana-Champaign pursuing an M.S. in geotechnical engineering. He is the treasurer for the student chapter of the Deep Foundations Institute and was a co-captain of the student competition, GeoChallenge, for GeoFrontiers 2011 in Dallas, TX.

Tangsombatvisit worked as an intern at Parsons Brinckerhoff (PB) in its San Francisco office from June 2007 through June 2008. He then joined the company as a full-time staff engineer after graduation from San Francisco State University. He left the company to pursue a masters degree. At PB, he performed engineering calculations for settlement, liquefaction and slope stability and prepared geotechnical design reports and design drawings. He was also a field engineer for the Bay Area Rapid Transit Warm Springs Extension in Fremont, CA, a 2.25-km (1.4-mile) cut-and-cover tunnel. He prepared daily inspection records for the installation of jet grout columns, cement-deep-soil mixed walls and sheet pile walls. Before joining PB, he was a lab technician for Geo Grout. He has attended a North American Tunneling Conference during which he made presentations at the PB booth.

TANGSOMBATVISIT

DANIEL E. MAJESTIC, a senior at the State Univerity of New York, Delhi will receive a B.S. in construction management. He has worked in the construction industry since he was 16. He was also able to observe and work with his father in developing a small underground mine in the hills of Walker Valley in Prescott, AZ . He participated in the drill-and-shoot excavation.

In the summer of 2010, Majestic worked with Peter Kiewit's tunnel crew at the Devils Slide tunnel project in California. There, he was able to work on the bull-gang crew supporting the excavation at the face. He also worked on the southbound tunnel excavation and learned how to properly install the ground support. He then worked with the concrete crew pouring the invert and side benches to support the final concrete arch and with the maintenance crew.

Currently, Majestic is working on the 72nd Street subway station cavern for the Second Avenue subway in New York, NY. He is serving as an intern under the field engineers, performing quality control checks for the permanent installations, as well as supervising the overall underground operation.

His goal is to work in a supervisory position on an underground project and to continue the family heritage in tunneling, which has existed for more than 70 years.

JEREMY R. STENSLIE is a senior at Washington State University majoring in mechanical engineering. After high school graduation, he took a job with Herrenknecht Tunneling Systems while simultaneusly pursuing an associates degree in mechanical engineering from Greenriver Community College. Upon receiving the A.S. degree, he was promoted to a mechanical engineering intern in the cutter department. He helped design and manufacture cutters and cutter-related parts for tunneling machines. In July of 2010, he visited the company headquarters in Germany for three weeks to learn a new parametric modeling software called Onespace.

In 2010, he transferred to Washington State University to finish the last two years of a bachelor's degree in mechanical engineering while continuing to work as an intern. During his career at Herrenknecht, he has worked on the U-link project in Seattle, WA and the Queens project in Long Island City, NY. His current research interests include improving the life of cutters and cutter heads on tunneling machines. He plans to attempt to improve the overall function of tunneling machines, which should lead to less machine downtime. ■

RETC ATTENDANCE SCHOLARSHIPS

Seven students received RETC Attendance Award Scholarships

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 increase their exposure to career opportunities and networking opportunities. The scholarship pays the travel expenses of a student wishing to attend the RETC, which then provides the student with comprehensive and practical information on the underground industry.

The application form can be found on the UCA of SME website, www.uca.smenet.org under member benefits. The seven students who received these awards to attend the 2011 RETC in San Francisco, CA are:

- **DANIEL MAJESTIC,** SUNY, Delhi.
- **APRIL C. SHEN**, University of Washington.
- **ERIC SMILEY**, Colorado School of Mines.
- **JEREMY R. STENSLIE**, Washington State University.
- **ANDREW TANG-SOMBATVISIT**, University of Illinois at Urbana-Champaign.
- **ARTHUR VIDALES JR.**, University of Texas at Austin.
- **CHAD WILLIAMS**, Virginia Tech. ■

CALENDAR PHOTOS

UCA issues call for calendar photos

We know you have some wonderful tunneling photos, and we want to see them. The UCA of SME is putting together its 18-month calendar, July 2012 to December 2013. Please submit your best tunneling photos as high-resolution jpg files and include a brief description of what is pictured. Send all files to Mary O'Shea at oshea@smenet.org by Oct. 7, 2011. The committee will review the submitted photos and make a final selection by Oct. 31, 2011.

If you would like to guarantee your spot in the UCA of SME calendar, you can sponsor a month for $1,000 or sponsor the front or back cover for $3,000.

For more information about sponsorship opportunities, contact Liz Jones at jones@smenet.org or 303-948-4216. ■

Three of the photos that were featured in the 2011 UCA of SME calendar were submitted by Hatch Mott MacDonald (above), Jacobs Associates (bottom right) and Bradshaw Construction (bottom left).

Mine Mate provides a low-profile shotcrete solution

The Mine Mate from Blastcrete Equipment Co. is an innovative machine designed to mix and pump concrete material for underground mine sealing and stabilization, grouting and various other shotcrete applications. The Mine Mate enhances safety in underground mining and tunneling applications, and is a convenient solution when readymix concrete is not an option.

The Mine Mate uses the wet-mix shotcrete process that minimizes dust emissions and improves visibility, making it much safer, particularly for underground use. The machine features a compact and low-profile configuration and is designed for operation within a 1.2-m (4-ft) ceiling.

The Mine Mate includes Blastcrete's X-10 76-mm (3-in.), high-pressure swing tube pump, and a high-shear continuous mixer. The unit is capable of mixing and pumping 9 m^3/h (12 cu yd/hour), and can handle aggregate up to 9.5 mm (0.375 in.) diameter. Offering the highest piston face pressure in the industry at 2,200 psi, it can pump material in excess of 152 m (500 ft), horizontally and vertically. Additionally, the hydraulic pump can run in reverse to eliminate line pressure from the delivery line should a hose plug.

Blastcrete's Mine Mate.

The X-10 provides easy access for cleaning and maintenance. The receiving hopper of the pump is mounted with a heavy-duty hinge so that it can easily swing away from the swing tube section. The flat pack is held in place by four heavy-duty bolts so that the spare flat pack can quickly and easily be replaced. This assures that downtime will be minimized. An optional hydraulic pressure washer is available for quick and easy cleaning of the mixer and the pump.

Available power options include a V3600, 49-kW (66-hp) Kubota water-cooled diesel engine or 37-kW (50-hp) electric motor with starter and disconnect. The machine can also be equipped with a material screw conveyor, with bin indicator for charging the continuous mixer.

The Mine Mate's X-10 is CE certified, and meets European Union safety standards for equipment operation. Blastcrete offers the option to customize the machine to suit the end-user's specific needs.

www.blastcrete.com

US Radar introduces subsurface penetrating radar system

Featuring a technologically advanced, yet simple touchscreen operating system and a variety of antenna frequency options, the Seeker SPR from US Radar is an easy-to-operate, subsurface penetrating radar system that is able to infiltrate numerous surfaces such as soil, clay, concrete and brick. The Seeker integrates a complete imaging system into one portable, user-friendly unit, making it a convenient and practical solution for a variety of industries, including general and underground construction.

By transmitting energy pulses through a variety of mediums, the system is able to display an image of the subsurface on the operator interface. Users have the ability to set a variety of parameters prior to each unique survey for maximized efficiency. Parameters include soil settings, algorithms and color palette. Furthermore, the system can be set to focus on a particular depth range.

To accommodate a broad range of detection needs, from high resolution for small items such as fine wires at a depth of 0.45 m (1.5 ft) to large soil disturbances at 31 m (100 ft), five antenna frequency options are available and are easily interchangeable for those with multiple antenna needs.

The system features an internal memory with data storage capacity of more than 15,200 m (50,000 lineal ft). For convenience, data may be viewed immediately on the large, bright screen. Also included are two USB ports and a serial port for data transfer or to allow the use of external GPS and other data collectors. The Seeker is a Windows-based operating system and includes basic acquisition software. Additional software is available for advanced users and applications requiring greater filtering and data processing capabilities.

The Seeker is a nondestructive method of testing. It is both safe and environmentally friendly. ■

www.usradar.com

September 2011

19-21, Colorado School of Mines Tunnel Short Course, Golden, CO. Contact: Office of Special Programs and Continuing Education, Colorado School of Mines, 1600 Jackson Street, Suite 160A, Golden, CO 80401, phone 303-279-5563, fax: 303-277-8683, e-mail: space@mines.edu, website www.csmspace.com.

February 2012

19-22, SME Annual Meeting, Seattle, WA. Contact: Meetings Department, SME, 12999 E. Adam Aircraft Circle, Englewood, CO 80112 USA, phone 800-763-3132 or 303-979-3461, e-mail sme@smenet.org, website www.smenet.org.

March 2012

27-29, INTERtunnel 2012, Lingotto Fiere, Turin, Italy. Contact: Romeland House, Romeland Hill, St Albans, AL3 4ET, Great Britain, phone 440-1727-814-400, fax 440-1727-814401.

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

14-16, International Symposium on Tunnel Safety and Security 2012, Roosevelt Hotel, New York, NY. Contact: SP Technical Research Institute of Sweden, Box 857, SE-501 15 Borås, phone +46 10-516 50 00, e-mail info@sp.se, website www.istss.se/en/Sidor/default.aspx.

27-31, NASTT's 2012 No-Dig Show, Gaylord Opryland Resort and Convention Center, Nashville, TN. Contact: Michelle Hill, Benjamin Media Inc., 1770 Main St., P.O. Box 190, Peninsula,OH 44264-0190 USA, phone 330-467-7588, fax 330-468-2289, e-mail mmagyar@benjaminmedia.com, website www.benjaminmedia.com.

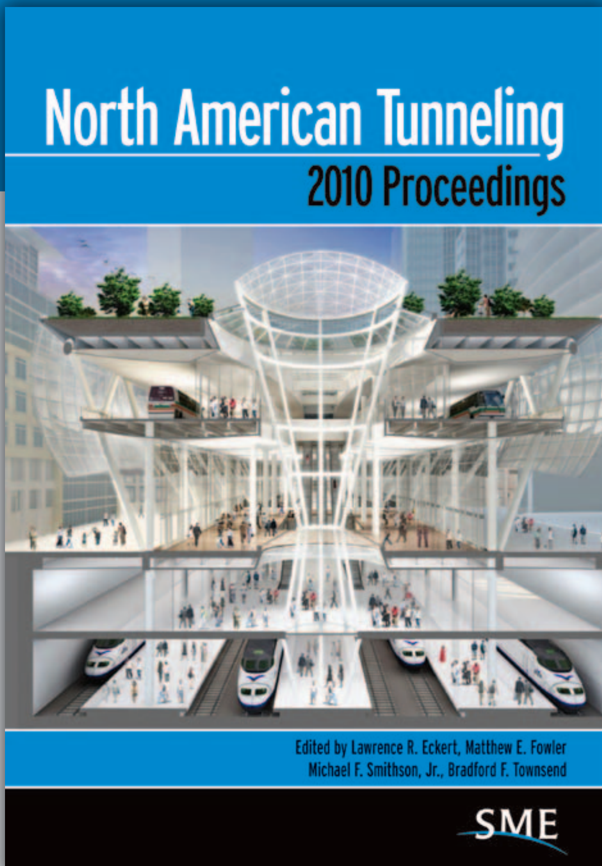
May 2012

18-23, ITA World Tunnel Congress, Bangkok, Thailand. Contact: Thailand Underground & Tunnelling Group (TUTG), e-mail: info@wtc2012.com, website www.wtc2012.com.

June 2012

24-27, North American Tunneling Conference, JW Marriott Indianapolis, Indianapolis, IN. Contact: Meetings Department, SME, 12999 E. Adam Aircraft Circle, Englewood, CO 80112 USA, phone 800-763-3132 or 303-979-3461, e-mail sme@smenet.org, website www.smenet.org.

North American Tunneling
2010 Proceedings



North American Tunneling 2010 underscores the important role that the tunneling industry plays worldwide in the development of underground space, transportation systems, conveyance systems, and other forms of sustainable infrastructure.

The proceedings describe the evolving nature of underground work, methods, and technology. This book documents the challenges faced and the lessons learned while advancing projects in support of a sustainable future. The contributions reflect the ability to adapt and excel in the environment of continual evolution that characterizes the tunneling industry today.

Taken from a collection of papers presented at the prestigious 2010 North American Tunneling Conference, the authors take you deep inside projects from around the world:

- Advancements in technology and sustainability, pressurized face tunneling and tunnel lining, and remediation
- Design considerations, including design validation, optimization and alignment, and strength and stability assessment
- Project planning, from estimating cost and project risk to delivering your project on time
- Case histories of small-diameter and conventional tunneling, and lessons learned while operating under difficult conditions

Whether it is building a subway extension under the streets or New York City or dealing with microtremors and rock bursts during construction, you will learn from the successes and failures of some of the most challenging construction projects undertaken in this rapidly evolving industry.

North American Tunneling 2010 Proceedings

Edited by Lawrence R. Eckert, Matthew E. Fowler
Michael F. Smithson, Jr., Bradford F. Townsend

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