T&UC

TUNNELING & UNDERGROUND CONSTRUCTION

THE OFFICIAL PUBLICATION OF UCA OF SME WWW.TUCMAGAZINE.COM VOLUME 4 NO 3 SEPTEMBER 2010

Large diameter TBMs

Single bore transit tunnels

Waterproofing linings

Special Editorial Section from the publisher of *Mining Engineering*

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COVER STORY

CONTENTS — A 15.2-m (50 -t) Herrenknecht earth pressure balance-shield tunnel boring machine excavated 3,650 m (12,000 ft) of ground for the M-30 highway tunnel in Madrid, Spain. The breakthrough was achieved on July 17, 2006 – 4.5 months ahead of schedule. An average of 100 lining segments were installed every day. Cover photo courtesy of Herrenknecht.

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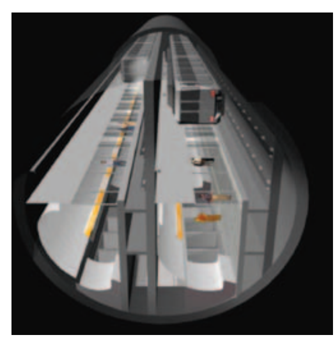

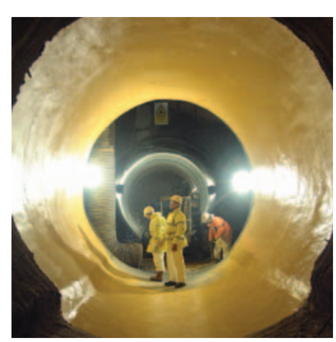

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CHAIRMAN'S COLUMN

Thanks to those who made NAT such a success

On behalf of the Executive Committee of the UCA, I would like to thank all of you that attended the North American Tunneling (NAT) conference 2010 in Portland, OR, June 20-23, 2010. Mark Ramsey, NAT 2010 conference chairman and his committee members created a very interesting and educational conference. The UCA sold 108 exhibitor spaces and had 803 registered attendees. Because of the strong attendance, the conference was a financial success for our organization and will enable us to advance some of our programs that are critical to the future of our industry — programs such as our scholarship program. I would also like to give a special note of appreciation to the staff at the SME office in Denver, CO. They worked very hard to create an event that was well organized and operated in a seamless manner.

A special note of appreciation from the executive committee to the various NAT 2010 awardees; Ed Plotkin for Lifetime Achievement, Refik Elibay for Person of the Year, Levent Ozdemir for Educator of the Year and the Metro Gold Line East Extension for Project of the Year. I was chairman of the awards dinner and it was most interesting to listen to Plotkin and Elibay as they gave their acceptance speeches. Both gentlemen have been involved in the industry for many years. But the proverbial "light at the end of the tunnel" still burns for each of them as after dedicating their lives to the tunnel industry they still have a passion to participate and to transfer their knowledge to the next generation. Due to a health problem with his father, Ozdemir was not able to give his acceptance speech, but his efforts in educating students and industry personnel at the Colorado School of Mines is nonetheless an important contribution to our industry. Ray Henn accepted the award for Ozdemir.

I would also like to extend our congratulations to all of the people involved in the planning, design and construction of the Metro Gold Line East Extension project. This was a team effort of dedicated and competent people. The Gold Line project has become a model for future projects to emulate.

There were three full-day short courses on various subjects applicable to tunnel construction and two workshops — one in the morning on obtaining better tunnel industry specifications and one in the afternoon on legal issues impacting the industry. I want to thank the people who gave up a Sunday and attended the various sessions and to the people who took the time to prepare and conduct the various short courses and workshops. This takes a lot of time and effort, frequently done on personal time, to prepare the material required to conduct such an event. I worked with Mike Bruen on the "Creating Better Specifications" workshop and would like to thank Mike for his planning and for doing most of the organizational work. This is an important industry issue that was well attended. The discussions were quite lively as we antagonized every aspect of the industry to stimulate debate. Mike and I will be creating a white paper on this subject based on the information and input received during the workshop. I hope that the other workshop and short course attendees will continue on what was gleaned from these venues as we must educate and advance as an industry.

From the attendance of NAT 2010, it is clear that our industry is still quite strong and active in all

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David R. Klug, UCA of SME Chairman

TBM sets world-record pace at Niagara project

One of the world's largest tunnel boring machines (TBM), a 14.4-m- (47.2-ft-) diameter Robbins main beam TBM, is setting world records at Canada's Niagara Tunnel project.

The TBM had excavated 6.8 km (4.2 miles) of the 10.4-km- (6.5-mile-) long conduit for Canada's Niagara Tunnel project in Queenston, Ontario in June. Geologic conditions have largely determined the project's advance, from periodic stoppages to a world-record month of 467 m (1,535 ft) in July 2009. The advance rate is a landmark achievement for TBMs in the 14 to 15 m (46 to 49 ft) diameter range, Robbins said in a statement.

"We also raised the tunnel alignment by 45 m (150 ft) to bring the tunnel out of the Queenston shale and into more competent rock, in order to reduce overbreak," said Ernst Gschnitzer, project manager for contractor Strabag AG. Much of the tunnel face is now in whirlpool sandstone and conditions are improving. "We are happy with the current rock conditions and ground support system, as we haven't been short of challenges in the past."

Conditions in the tunnel have been variable, with significant over-break occurring within the first 200 m (650 ft) of tunneling in Queenston shale. Crews scaled down the loose rock and adopted a newly redesigned ground support program consisting of 9-m- (30-ft-) long grouted spiles, 4-m- (13-ft-) long rock bolts, wire mesh, steel straps and a layer of shotcrete.

Four different processes are currently being done from the single tunnel opening. Crews are excavating the tunnel, performing repairs in sections of overbreak, laying invert concrete, and conducting arch lining for the upper two-thirds of the tunnel.

The finished 12.8-m- (42-ft-) diameter tunnel will be fully lined with 600 mm (24 in.) thick continuously poured concrete and a polyolefin waterproof membrane to prevent leakage. The tunnel is being lined behind the TBM using separate invert and arch lining systems as well as a membrane laying machine. By May 2010, invert concreting had reached 4.8 km (3 miles) into the tunnel, while arch lining had started up recently.

The Niagara Tunnel project was initiated in June 2004 by provincially owned company Ontario Power Generation. The tunnel is the third headrace under Niagara Falls, and will add up to 500 m^3/sec (17,700 cu ft/sec) for hydroelectric generation by 2013 — enough power to service 130,000 Canadian customers

Progess at East Side Access project

The joint venture of Dragados/Judlau completed a series of short rail tunnels as part of East Side Access project in New York City. A Robbins main beam TBM was the first of two machines to finish the rail tunnels below Grand Central Station in Manhattan.

The Robbins main beam was the first ever TBM initially assembled at the jobsite using OFTA.

The completion, on June 2, was an important milestone for the East Side Access project, which was stalled in the 1970s due to lack of funding. Altogether, the Robbins machine excavated 5.2 km (3.2 miles) of tunnel since its 2007 launch, averaging 16 m/d (52 ft/day) in the final month of boring.

A second double shield TBM was preparing to embark on its third of four tunnels. The short tunnels, four to each TBM, will ultimately lead to the upper and lower departure and arrival platforms of two main stations currently under construction.

The Robbins machine was retracted at the end of each tunnel heading using specially designed, hydraulic side and roof supports to move past installed ring beams and rock bolts. "The bolted cutterhead, in five sections, was the best possible design for boring multiple tunnels and retracting back through the ring steel," said Kerry Clark, Robbins field service superintendent. The hydraulic extensions, combined with the removable cutterhead pieces, allowed the entire machine diameter to be reduced from 6.7 m (22 ft) to just 6 m (20 ft).

Crews maintained good advance rates despite difficult project conditions. At one point, the parallel TBM excavations were separated by a slim 1.5 m (5 ft) thick pillar of rock, requiring the Robbins machine to operate at 45 to 50 percent gripper and thrust pressure. Much of the drive was also done with a live subway tunnel 1.5 m (5 ft) overhead. ■

Construction on Port of Miami tunnel begins

Contstruction work has begun on the Port of Miami Tunnel project to prepare the area for tunneling.

A $45-million Herrenknecht tunnel boring machine (TBM) that will be constructed underground is expected to begin digging in September, *MiamiTodayNews.com* reported.

The tunnel is one of three transportation megaprojects under way in South Florida. The others are the $1.7 billion Miami Intermodal Center near Miami International Airport and the $1.8 billion reconstruction of Interstate 595 in Broward County.

The tunnel will link the port for the first time to area expressways in a bid to speed cargo traffic and ease traffic congestion in downtown Miami.

Currently, trucks headed to or from the port meander through surface streets just north of downtown Miami as they make their way between the seaport and Interstates 395 and 95.

The Herrenknecht TBM will be built during the next year and shipped in parts to Miami where it will be reassembled at Watson Island to begin boring the tunnel said Christopher Hodgkins, vice president of Miami Access Tunnel, the team in charge of designing, building, financing, operating and maintaining the port tunnels.

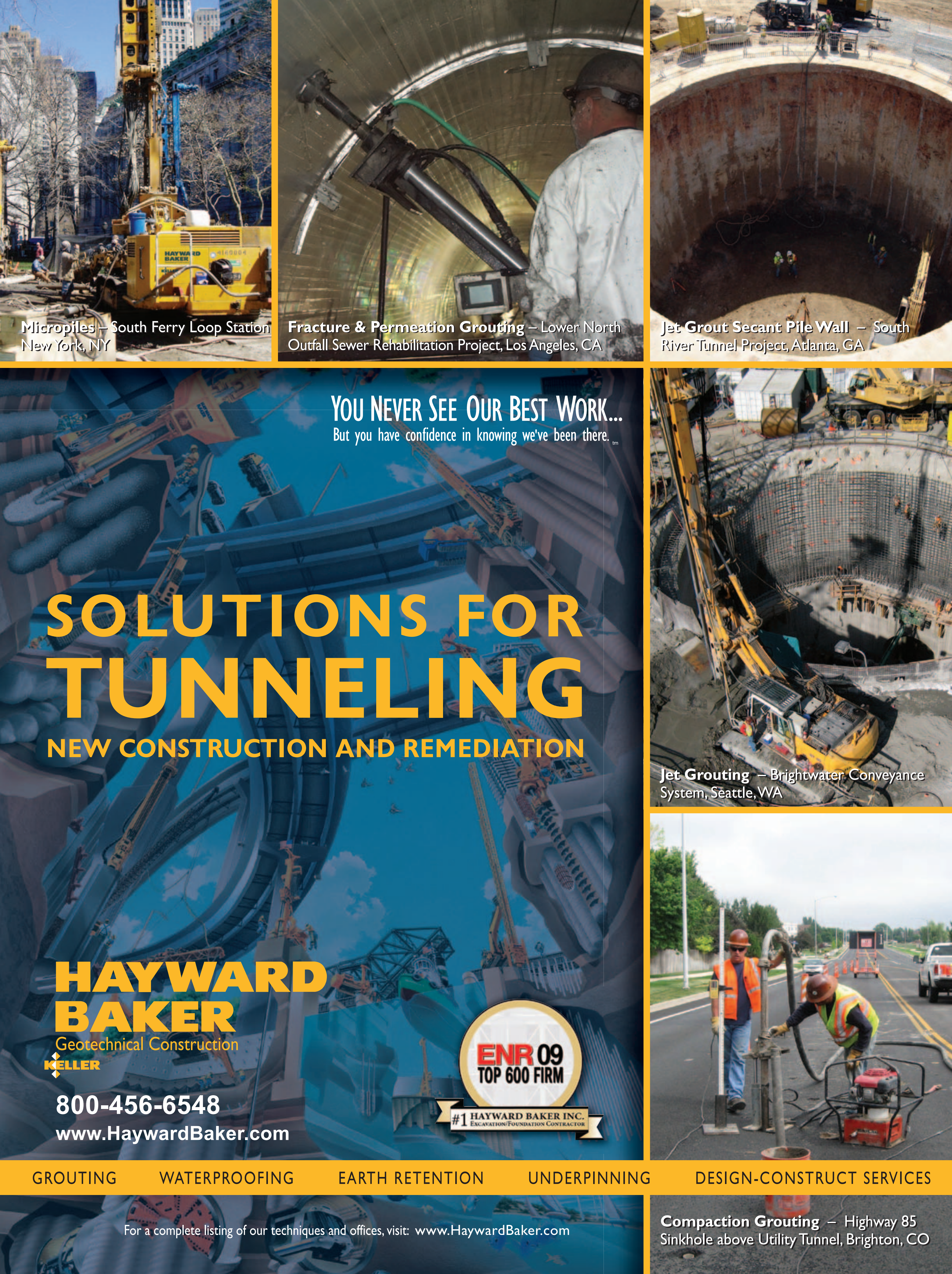
Dirt from the boring will be shipped elsewhere on barges.

The tunnel entrance will be at Watson Island on the median of the MacArthur Causeway, which connects to Interstate 395.

The project is a public-private partnership with the Florida Department of Transportation, covering $457 million; Miami-Dade County, contributing $402.5 million and Miami, set to put in $50 million.

Herrenknecht is custom designing the machine with Miami's geology in mind and aims to minimize noise and vibrations, Hodgkins said.

Once the port tunnels are dug — completion is expected May 15, 2014 — the machine is to be disassembled, barged out and shipped back to Germany for Herrenknecht to use as parts. ■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Politicians choose sides on Alaskan Way viaduct

Changing soil conditions, the reminder of what can go wrong at a project just 19 km (12 miles) away, fears of cost overruns and a clause in the contract has Seattle, WA Mayor Mike McGinn raising caution flags about the proposed tunnel project that would replace the Alaskan Way viaduct with a 2.7-km (1.7-mile) long tunnel.

A clause in state legislation states that cost overruns from the project will be paid by "Seattle property owners who benefit" from the tunnel. McGinn, who has spoken often about cost overruns, said he would sign off on agreements dealing with utility access, schedules and other planning issues that would get the work done by 2016 if the language is changed.

The Seattle Times reported that Washington Gov. Chris Gregoire, a tunnel supporter was adamant in saying, "we have no cost overruns on this project at all, zero."

The 2.7 km (1.7 miles) long tunnel will be bored with a Herrenknecht tunnel boring machine (TBM) with a 17-m (56-ft) diameter cutter face has been estimated to cost $2 billion.

Two international teams will bid in October for the six-year contract. A third team, led by Kiewit Pacific, dropped out of the bid process.

The budget includes a $415-million cushion for risk, contingencies and inflation. The project also includes $500 million in surety bonds, a department of transportation (DOT) study said.

However, there is still concern.

In King County, WA, 19 km (12 miles) northwest of Seattle, soil conditions similar to those of the Seattle area where the tunnel will be built caused a TBM to stall, delaying the project and creating massive overruns. Tunnel detractors have also talked about the problems at Boston's Big Dig Project.

Tunnel supporters say the tunnel is needed to replace the Alaskan Way viaduct that was built in 1953 and could cause catastrophic harm if it were to collapse in an earthquake.

Each side has recently brought in their own experts to evaluate the project.

John Newby, a consultant hired

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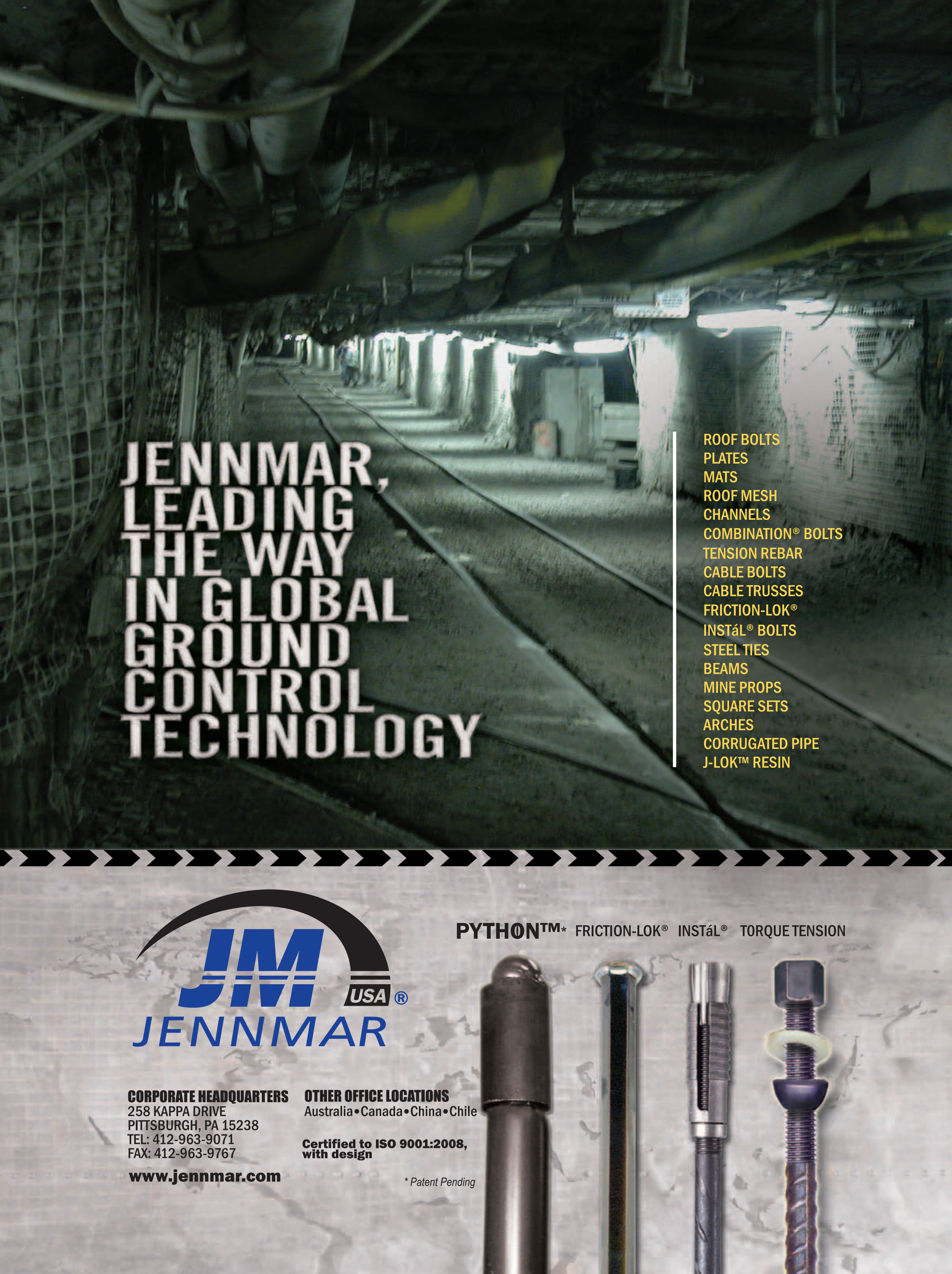
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Four Lovat machines ordered for Eglington Crosstown project

Lovat Inc. will build four custom tunnel boring machines (TBM) that will be put to work on Toronto's new Eglington Crosstown Light Rail Transit (LRT) project that will incorporate both above and below ground travel.

Metrolinx, Ontario's regional transportation agency for the Greater Toronto and Hamilton area, placed the $54 million contract with Lovat.

The Eglinton Crosstown LRT project aims to take more cars off the road, improve air quality, create approximately 46,000 jobs, reduce travel times and support a stronger regional transit system in the greater Toronto area. The project is estimated to cost $4.6 billion and will be completed by 2020.

About 12 km (7.4 miles) of the Eglinton LRT will run underground.

Lovat Inc. is also supplying the Toronto Transit City (TTC) projects with four other TBMs.

The TTC's $58 million order for machines last year will be used to extend the subway into York Region.

The same machines could not be used for both projects because the tunnel on Eglinton will be about 6 m (19-ft) wide, compared with the 5.4-m (18-ft) tunnel on Spadina.

Light rail vehicles require pantographs (overhead structures) for their power supply, unlike the subway, which uses a third rail, Metrolinx head Rob Prichard said.

The ridership on Eglinton will be adequately served by light rail rather than subway, Prichard told *The Toronto Star*.

The first of the tunneling machines, will take about 18 months to build,

Most of the tunneling will take place between 2012 and 2014, with the entire first phase of the line complete by 2020.

The current Metrolinx plan calls for all four Transit City projects and a $1.5-billion express bus lane system in York Region to be completed over 10 years. ■

Tunnel boring machine arrives at New York's 2nd Avenue Subway project

A tunnel boring machine (TBM) originally built by The Robbins Company to dig New York Metro Transit Authority's (MTA) 63rd Street tunnel in the late 1970s is back underground and ready to bore another tunnel in New York.

The 181-t (200-st) cutterhead was lowered into the launch box of the Second Avenue Subway tunnel. The majority of the parts for the machine are now in place to begin mining the western tunnel for the new two-track line that will reduce overcrowding and delays on the Lexington Avenue line and provide better access to mass transit for residents of the far east side of Manhattan. The line is being built in phases. Mining for the first phase was scheduled to begin in May.

Construction of Phase I of the Second Avenue Subway began in April 2007. When complete in December 2016, Phase I will serve 213,000 daily riders who are currently using other subways, buses, taxis or cars. It will decrease crowding on the adjacent Lexington Avenue Line by as much as 13 percent, or 23,500 fewer riders on an average weekday. It will also reduce travel times by up to 10 minutes or more (up to 27 percent) for those on the far east side or those traveling from the east side to west midtown.

The Second Avenue Subway TBM was originally manufactured about 30 years ago and has been used on at least four other projects. The machine has been reconditioned and was rebuilt in Newark, NJ at contractor Schiavone's yard where it was assembled, tested and then disassembled for shipment to the site. The TBM was most recently used on the Fall River CSO project in Fall River, MA.

The total length of the TBM plus the trailing gear that contains the

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mechanical and electrical equipment that powers the cutterhead is 137-m- (450-ft-) long. The cutterhead has 44 rotating discs and is the vital piece of the TBM that will drill and excavate the approximately 2,300-m- (7,700-ft-) long tunnels.

“The arrival of the TBM at Second Avenue is a clear indicator that the MTA is delivering on a major expansion project that will have a dramatic impact on Manhattan’s East Side easing overcrowding within our transit system and serving as an economic driver for the region as a whole.”

Michael Horodniceanu, MTA president

“The arrival of the TBM at Second Avenue is a clear indicator that the MTA is delivering on a major expansion project that will have a dramatic impact on Manhattan’s East Side, easing overcrowding within our transit system and serving as an economic driver for the region as a whole,” said MTA Capital Construction President Michael Horodniceanu.

The launch box, which extends from just south of 92nd Street to 96th Street along Second Avenue and is approximately 250-m- (815-ft-) long by an average of 20-m- (63-ft-) wide and 17-m- (56-ft-) deep, forms the shell of the new 96th Street Station. This is also where the machine will be assembled and launched from one of two starter tunnels in May. Excavation of the launch box began in June 2009 using a combination of controlled blasting and mechanical methods. In total, 89,000 m^3 (117,000 cu yd) of rock and soil were removed.

The Second Avenue Subway will reduce overcrowding and delays on the Lexington Avenue line and provide better access to mass transit for residents of the far east side of Manhattan. The line is being built in phases, with the Phase I of the Second Avenue Subway providing service from 96th Street to 63rd Street as an extension of the Q train, three new ADA-accessible stations along Second Avenue at 96th, 86th and 72nd Streets, and new entrances to the existing Lexington Avenue/63 Street Station at 63rd Street and Third Avenue. ■

Caltrans begins tunneling for the Caldecott fourth bore

Tunneling on the fourth bore of the Caldecott Tunnel began on Aug. 9 when one of the world's largest roadheaders, a 118 t (130 st), 16-m- (54-ft-) long, 4.2-m- (14-ft-) tall machine that was built in Germany and assembled on site, began boring on the tunnel to widen Highway 24 between Orinda, CA and Oakland, CA.

The $5.2 million project will ease traffic congestion at the choke point by adding two freeway lanes. The roadheader will dig a 1,032-m- (3,389-ft-) long bore in the mountain. The project is expected to be complete in 2013.

Contractor Tutor-Saliba will use the roadheader to excavate about two-thirds of the tunnel from the Orinda side. A subcontractor with a smaller roadheader will swing into action later to dig one-third of the tunnel from the Oakland side.

Excavated dirt and rock will be moved by a conveyor belt into trucks. The trucks will haul most of the dirt to San Francisco construction sites on Treasure Island and Hunters Point, although some may go to landfills at the Altamont Pass near Livermore.

Any dirt found to have hazardous levels of naturally occurring or man-made impurities will be shipped out of the area to hazardous waste landfills, *The San Jose Mercury News* reported.

A maximum of 50 truckloads a day of dirt and rock will be hauled out of the two sides of the tunnel, Caltrans said.

Federal economic stimulus dollars will cover $197.5 million of the construction cost, while Contra Costa County sales tax will pay for $122.8 million. The rest will come from bridge tolls, and other state, local and regional sources. The original Caldecott Tunnel opened with two bores in 1937. The third bore opened in 1967 nad has since become a major point of traffic congestion.

"The new tunnel will reduce congestion for those living in the East Bay and put people to

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work," said U.S. Transportation Secretary Ray LaHood. "This is what the Recovery Act is all about."

The $420 million project relies on $197.5 million from the Recovery Act, making it the nation's second-largest investment of Recovery Act highway funds. Of the more than 12,000 highway projects, it is the largest tunnel excavation funded by the Recovery Act. The fourth bore will be the first on the route since 1964.

SR 24's existing three tunnels, which give drivers a total of six lanes, are inadequate for the heavy volume of Bay Area traffic each day. The route serves an estimated 160,000 drivers daily. When completed in 2013, the new tunnel will have 3.6-m (12-ft) lanes, shoulders and emergency walkways.

Located less than a half mile from the Hayward fault, the tunnel will be built to withstand an earthquake - as are the existing tunnels - and will include numerous safety features, including seven emergency escape passages to the adjacent tunnel.

"The new tunnel will reduce congestion for those living in the East Bay and put people to work. This is what the Recovery Act is all about."

Ray LaHood, U.S. Transportation Secretary

Of the more than $26.6 billion in ARRA highway funds available nationwide, California received nearly $2.6 billion for highways – and more than $4 billion in ARRA funding for all transportation projects, which supplements billions more in local and state spending.

As of July 30, the state had funded 946 projects, with 455 projects under way and 122 completed. ■

World's largest earth pressure TBM will be ready to begin work in Italy in 2011

A 15.55-m (51-ft-) Herrenknecht earth pressure balance shield tunnel boring machine (TBM) will be ready to begin construction of the Sparvo Tunnel, a project that will extend the A1 highway between Bologna and Florence.

The machine will be the largest TBM ever built and will set a record in diameter in mechanized tunneling. The tunnel will consist of two parallel-running tubes with a length of 2.5 km (1.5 miles) each. The tubes will each accommodate a three-lane road. Because of the size and the geological conditions, the construction of the tunnel is considered to be the most challenging part of the overall project. The Italian contractor, Toto Costruzioni Generali S.p.A, decided to use mechanized tunneling technology to improve work safety and to accelerate the work. Toto will carry out the tunneling work in loose soils with local presence of gas using earth pressure balance (EPB) technology on a total length of 5 km (3.2 miles). The Sparvo Tunnel is part of the project awarded by Autostrade per l'Italia S.p.A.to a joint venture comprising Vianini Lavori S.p.A., Toto Costruzioni Generali S.p.A. and Profacta S.p.A.

In order to produce the two 2.5-km- (1.5-mile-) long tubes of the Sparvo Tunnel, Herrenknecht developed and built an EPB shield with an exterior diameter of 15.55 m (51 ft), a weight of 4.3 kt (4,700 st), a cutterhead power of 12,000 kW (16,100 hp) and an overall length of 120 m (393 ft). After completion at the Schwanau plant, the TBM will begin its work in Italy.

Preparations for the assembly of the record-breaking TBM have begun in Schwanau. A tight time schedule has been set for the construction of the Sparvo Tunnel. In line with the current planning, the machine is expected to begin tunneling near Florence toward the north as early as in the first half of 2011. The 6-7 lot is the last section of the Variante di Valico project that will considerably reduce the traveling time between Bologna and Florence for up to 90,000 vehicles per day after the alternate route is opened according to schedule at the end of 2013. ■

Milestone hit at No. 7 Subway Extension project

New York City's No. 7 Subway Extension project reached another milestone this summer when, on July 15, the second of two 907-t (1,000-st) tunnel boring machines (TBM) reached the chamber adjacent to the current terminus for the No. 7 train underneath 42nd Street. The breakthrough by the second TBM marked a major milestone in the $2.1-billion project that will extend the No. 7 line to 34th Street and will support the growth of an emerging community on the west side. The project is funded by the city of New York and managed by the Metropolitan Transportation Authority (MTA).

The TBM broke through into 61-m- x 15-m- x 12-m-(200-ft- x 50-ft- x 40-ft-) deep receiving chamber just below the Port Authority bus terminal in close proximity to the bus terminal foundation and utilities, as well as the 8th Avenue Subway Line. This is where the new tunnels will connect with the existing No. 7 Line terminus at Times Square.

"This marks the final leg of the second of two, 907-t (1,000-st) tunnel boring machines that have mined more than a combined 2,800 m (9,300 ft) to reach this point," MTA chairman and chief executive officer Jay H. Walder said. "It's a major milestone working toward the completion of a project that will increase capacity within our transit system and help redevelop a vital part of our city that will spur future growth."

The two TBMs will be partially disassembled and backed up to where they began tunneling at 26th Street and 11th Avenue where they will be lifted out of the shaft.

The receiving chamber under the bus terminal was excavated by controlled drill-and-blast in 2009. Through coordination and cooperation with the Port Authority, the 24-hour construction operation was completed in six months instead of two to three years as originally planned. There was not a single complaint from the public.

The TBMs were launched in the summer of 2009. As the machines mined, they placed precast concrete lining rings along the excavated tunnel, making up the permanent liner of the finished tunnel.

Tunneling north from 34th Street presented unique challenges, as the tunnels run under Amtrak/NJ Transit tunnels, tunnels to the former New York Central Line, the Lincoln Tunnel and the Port Authority Bus Terminal and ramps.

Work will now commence on station entrances and finishes, as well as support facilities such as ventilation and traction power substations. Customers will be able to take advantage of the new service in December 2013 as scheduled. ■

Kenny/Obayashi low bidder for OARS project

The joint venture team of Kenny/Obayashi presented the lowest of three bids for Phase 1 of the Olentangy-Scioto Intercepting Sewer Augmentation Relief Sewer (OARS) in Columbus, OH.

The project includes 7,100 m (23,300 ft) of 6.1-m (20-ft) internal diameter tunneled sewer as well as a 16-m (52-ft) internal diameter pump station shaft (Shaft 1), a 13-m (42-ft) internal diameter screen shaft (Shaft 2) and a 14-m (48-ft) internal diameter shaft (Shaft 6) with an internal surge chamber and hydraulic drop pipe. The depth to tunnel invert ranges from approximately 40 to 56 m (130 to 185 ft). Depth to bedrock varies from 9 to 37 m (30 to 120 ft). The tunnel will collect combined sewer overflows through the downtown area and will be constructed through limestone bedrock containing Karst features. Ground water pressure at the tunnel elevation is anticipated to vary and require a pressurized face tunnel boring machine.

Kenny/Obayashi was the lowest of three bidders at $264,506,000. Other bidders to the City of Columbus, Department of Public Utilities opened bids for Phase 1 of the OARS, were Jay Dee/Traylor Brothers/J.F. Shea with a bid of $290,499,392 and Kiewit/McNally at $306,956,100. Pending approval by the city council, notice to proceed was expected to be given in September.

Phase 2, which is expected to be advertised for bids in early 2011, will include off-line Shafts 3, 4 and 5. Both projects are being designed by DLZ Ohio and Jenny Engineering Corp. ■

Continued from page 6

by the pro-tunnel city council said "Clearly there is inherent risk in anything you do in the subsurface. You're dealing in ground you can't see."

However, Newby said that while risk can be particularly great beneath a dense urban area, most risks can be mitigated with close management and careful maintenance, and that the chance of a TBM completely breaking down is extremely rare.

"WSDOT is doing the right things to address and manage these risks. WSDOT has assembled a strong team, combining their experienced staff with external tunnel and risk experts, and the design-build process provides the opportunity for this team to work together with the selected...contractor team giving the project the best chance for success.

Thom Neff, a longtime project manager and soil expert in Boston, New York and Portland, OR, warned of tricky soils below downtown, which he called worse than in Boston's Big Dig. In particular, there is no place in the route where the soil is all of the same type, he said.

"They're definitely worse than Boston. We didn't have abrasive soil, we didn't have boulders eight feet in diameter, we're not in a seismic zone, and we didn't have water pressure," he said, referring to Boston's extensive, problem-plagued project. ■

New Irvington Tunnel contract awarded

The joint venture of Southland Contracting Inc. from Ft. Worth, TX and Tutor Perini Corp. of Sylmar, CA was awarded the contract for the New Irvington Tunnel Project by the San Francisco, CA Public Utilities Commission (SFPUC).

Southland/Tutor Perini JV submitted the lowest qualified bid at $226.6 million, which is $26.6 million below the commission's estimate.

The 5.6-km (3.5-mile) New Irvington Tunnel will have an internal diameter of approximately 2.6 to 3.2 m (8.5 to 10.5 ft). It will lay parallel to the existing tunnel between the Sunol Valley south of Highway I-680 and Fremont, CA.

Construction is expected to begin in September 2010 with final completion by April 2014.

Located between the Calaveras and Hayward fault zones, the mixed-face tunnel is made up of interbedded layers of sandstone and shale, with several smaller fault zones. Adding more complications, the tunnel offers 213 m (700 ft) of cover and high hydrostatic head with potential water inflows up to 63 L/s (1,000 gpm).

The new tunnel will provide a seismically designed connection between water supplies from the Sierra Nevada Mountains and the Alameda Watershed to Bay Area water distribution systems. Not only does it provide a seismically sound alternative to the existing tunnel, the new tunnel will allow the SFPUC to take the existing tunnel out of service for much needed maintenance and repair. ■

Chairman's column

Continued from page 2

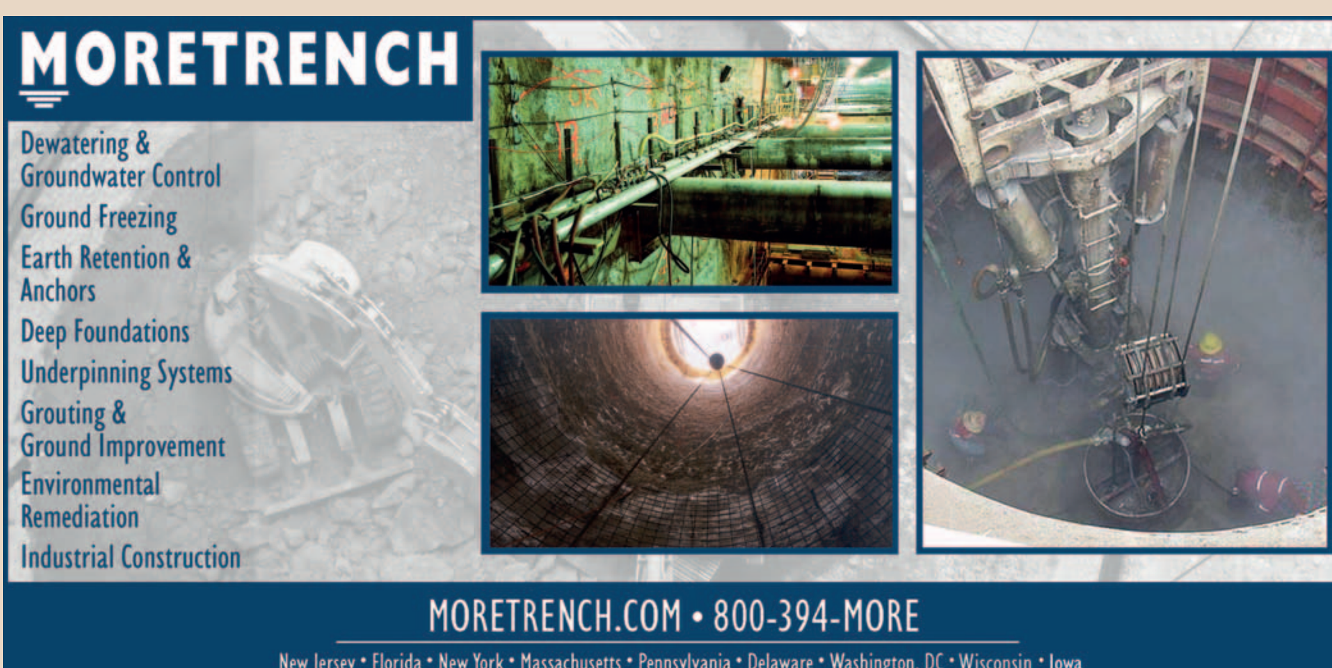
sectors. The gauge of the industry is driven by large projects and programs such as the ARC Program Hudson River Tunnels, Washington DOT Alaskan Way Tunnel project, the DC-WASA Blue Plains Tunnels, NEORSD Euclid Creek Tunnel project and the TTC Eglinton Subway Extension. All of these projects are advancing through the bidding stages. Other projects and programs are advancing in Austin, TX, San Francisco, CA, Atlanta, GA and Cincinnati, OH. These, and other upcoming projects, are detailed in the Tunnel Demand Forecast section of this magazine (page 40).

During the past month, I was underground on two interesting projects that are important to our industry that I am sure will be evaluated very closely in upcoming conferences. First, I was underground at the MTA No. 7 Subway Line Extension project in New York City. The construction of the station cavern is awe-inspiring due to its complexity and size. It was there that I observed a situation that will impact our industry — the successful tunnel boring machine (TBM) construction of hard rock tunnels with the use of one-pass precast segmental tunnel linings. Most people think that these are only applicable in soft ground applications. However the people at the project installed the linings with a high degree of precision and the quality appeared excellent. Congratulations to Jim Marquardt and the people of S3 II JV for demonstrating that complex projects can be constructed with quality in a major urban environment.

The second project was the Devil's Slide Tunnel project south of San Francisco, CA. The project is interesting as the contractor is casting the final lining while continuing to excavate the two north and southbound tunnels from the south portal. A section of the tunnel is completed, with the final lining in place and with architectural reliefs cast into the final lining concrete at eye level of the motorists that will be using the tunnel. Plus the arch is now painted. The project will hole through at the north portal in October of this year. I want to thank Paul Madsen for taking me on the "walkabout" and to Dan Griffin, project manager, as well as the people of Kiewit Pacific Co. for demonstrating that quality work can be performed in difficult conditions.

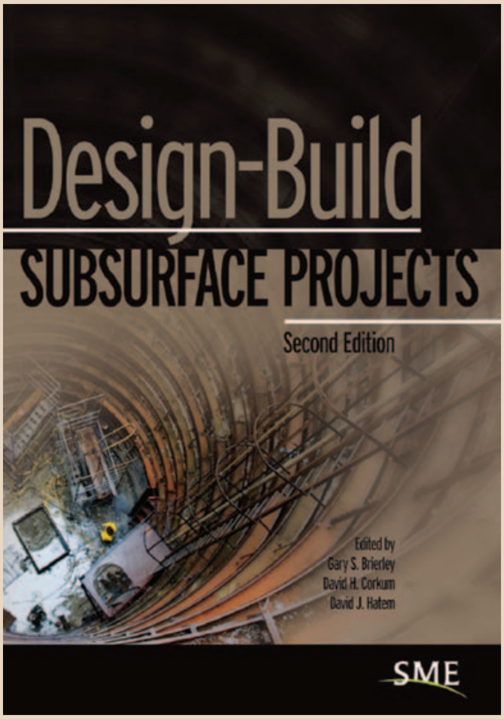
On a final note, I am advising that, in the June UCA Executive Committee meeting, changes were made in the structure of the UCA Education and Training Committee as outlined by committee chairman Bill Edgerton, and agreed to by the executive committee. The UCA and the committee members do not have the resources and/or time to develop, publish and implement education and training programs at this time. This is best left to academic institutions, organizations and companies that have the expertise and resources to perform such work. The new role of the committee will be one of an advisory capacity that will review and consult, providing industry comments and assistance were feasible. The current committee is non-active and at my request (e-mail: dklug@drklug.com) and Bill Edgerton (e-mail: edgerton@jacobssf.com) direct an expression of interest complete with your full contact information to Bill or I if you are interested in serving on this committee .

We are looking for "working committee members" and not "resume committee members" to assist Edgerton in this important industry endeavor. ■



NEW MEDIA

Design-Build Subsurface Projects, Second Editon



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Design-build construction has become so widely accepted that owners and their advisors must seriously consider this approach when making decisions about project delivery. With its opportunities for cost containment and substantial risk transfer, design-build is increasingly becoming the delivery method of choice for owners with challenging funding limitations.

But deciding to use the design-build system for underground projects is one thing; successfully implementing it is quite another.

Design-Build Subsurface Projects, Second Edition, can help bridge that gap. This cutting-edge book provides a straightforward, comprehensive look at how to make design-build work on complicated projects involving tunnels, highways, dams and deep foundations.

The authors are a "who's who" of subsurface construction experts, many of whom are key players in the most high-profile and challenging projects in the world. Drawing upon their wealth of practical experience, they spell out a list of common sense best practices that can be used by today's project owners and designers.

Be advised: these authors do not shy away from the many thorny issues of design-build. Nor are they unabashed cheerleaders. They dispassionately explore both the advantages and disadvantages of this system, which must be carefully weighed and evaluated so planners can decide what is best for their projects based on all of the important variables, including third-party impacts and environmental/community concerns.

The reader will find extensive information about procurement, as well as risk allocation issues, which are significantly different from the design-bid-build approach. Team structure, agreements, design development, subsurface exploration, geotechnical reports, construction phase issues and insurance are also examined in great detail.

Design-build Subsurface Projects is an indispensable resource for owners, engineers, construction managers, contractors and others involved in the design and construction of subsurface projects. You will gain a thorough understanding of how and why the system works and where the pitfalls can arise. The authors' years of experience will benefit even the most seasoned of practitioners. ■

FEATURE ARTICLE

Large diameter tunnel boring machine development

The 15.43 m (50.6 ft) mixshield TBM, built by Herrenknecht, is the largest in the world. It was built for the Changhai Changxing Under River Tunnel.

The world's growing population and rapidly proceeding urbanization are boosting an enormous demand for new and high-capacity infrastructures to secure the mobility of goods and people.

Densely populated areas face the challenge to provide efficient traffic infrastructure, such as a modern public transportation system. At the same time, the maintenance and modernization of supply and disposal structures for water, sewage, energy and communication are also essential. Additionally, supra-regional transportation routes such as long distance water diversion schemes are the challenges for the future. All these projects are as demanding as they are characterized by a tight time schedule.

In this context, the demand for efficient tunnels for traffic and utility lines is increasing as the way of new infrastructures leads, in most cases, underground because of limited space above ground. Also, tunnels are the obvious choice to cross natural barriers like mountain ranges.

Martin Herrenknecht and Karin Bäppler

Dr.-Ing. E.h. Martin Herrenknecht is chairman of the board of management and **Dr.-Ing. Karin Bäppler** is with the sales department, respectively, with Herrenknecht AG, Germany, e-mail bappler.karin@herrenknecht.de.

The tendency of the upcoming traffic tunnel projects shows the demand for large to very large profiles. The increasing need for high-performance infrastructure in the sector of transport and utility tunneling favors tunnel solutions and, thus mechanized tunneling. With the manufacturing of one of the first of the largest type of tunnel boring machine (TBM) (mixshield, 14.2 m or 47 ft in diameter) for the fourth tube of the Elbe road tunnel in Hamburg, Germany and the largest TBM to date for the inner-city tunneling (earth pressure balance (EPB)-shield, 15.2 m or 50 ft) for the M30 highway project in Madrid, Spain, as well as the two (15.43-m- or 51-ft- mixshields), TBMs for the Changjiang Under River Tunnel Project in Shanghai, China, the feasibility of large diameter tunnels, and the outstanding examples for applied technical engineering, are given (Fig. 1).

The SMART tunnel project in Kuala Lumpur, where two mixshields with a diameter of 13.21 m (43 ft) have been used, is one of the first pioneering examples to show that the tunnels can take over more complex service functions. With its dual-usage, such as preventing flooding and alleviating traffic congestion, the project presents the tendency of extending the utilization ratio of the future tunnels.

Trend of very large diameter tunnel profiles

More than 70 machines with diameters larger than 10 m (33 ft) had been delivered by the end of 2009. However, tunnel projects are often planned with diameters exceeding the 10 m (33 ft) diameter limit. The large diameter TBMs are not restricted to special ground types as they are applied for both soft and hard rock or mixed face conditions. Mechanized tunneling with diameters larger than 15 m (49 ft) are now state-of-the-art and can be operated safely. Compared to conventional construction methods, the mechanized shield tunneling with larger diameters is considerably faster and its limits are set by logistical issues such as removal of excavated material, rather than by construction safety or financial questions. Large tunnel profiles allow contractors and planners the possible installation of additional service and safety facilities for the operation of the tunnel. Herrenknecht's large diameter TBMs operating worldwide show that extremely large tunnel diameters can be safely and efficiently produced with the chosen tunneling technology. Examples include the machines used for the Fourth Elbe tunnel in Hamburg, the Lefortovo and Silberwald tunnels in Russia, the SMART tunnel in Kuala Lumpur, the M30 highway project in Spain and the two 15.43-m- (51-ft-) diameter machines that excavated parallel tunnels near Shanghai.

Challenge in Spain

At the M30 Highway North tunnel in Madrid, an EPB-shield 15.2 m (50-ft) excavated and lined the three-lane, 3.65-km- (2.3-mile-) long highway tunnel in the center of Madrid with an extremely tight time schedule. The target construction time of 12 months could be reduced, and the eight-month tunnel construction time equalled an excellent TBM performance of more than 450 m/month (1,476 ft/month). The unique TBM with two concentrically arranged cutting wheels and three screw conveyors for material discharge out of the working chamber achieved top performances of up to 36 m/d (118 ft/day) of excavated and lined tunnel.

The tunnel profile was not a challenge on this project, but the logistics were. During the construction of the 3.65-km- (2.3-mile-) long highway tunnel, an average of 60 trucks a day went to the inner-city construction site for the delivery of the segments used to line the tunnel. At peak times, 720 trucks passed the construction site on one day to remove the excavated material.

World's largest TBMs to date applied in Shanghai

The largest current machines, two mixshields 15.43 m (51 ft) for the Changjiang Under River Tunnel Project in Shanghai, excavated parallel 7.47-km (4.6-mile) long, three-lane highway tunnels. They excavated at a depth of up to 65 m (213 ft). The tunnels connect the Changxing River Island with the mainland of Pudong/Shanghai.

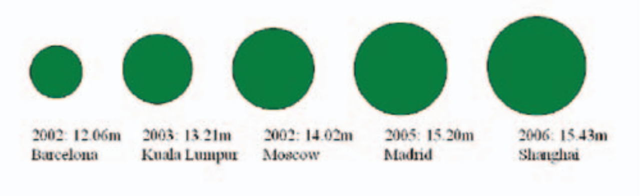
The innovative features of the shields are the cutting wheels that are accessible in free air for the replacement of the cutting tools.

Two other large diameter mixshields with diameters of 14.93 m (49 ft) excavated and lined 2.9 km (1.8 miles) of road tunnel each. Both machines crossed parallel beneath the Yangtze River in Nanjing (Jiangsu Province, eastern China). The machines were also equipped with the feature of cutting wheel arms that are accessible under atmospheric conditions.

In November 2006 and January 2007, respectively,

FIG. 1

Largest TBM by year (Herrenknecht AG).



the TBMs began the construction of the Shanghai Changxing Under River Tunnel" in China.

Parallel 7,170-m- (23,525-ft-) long motorway tunnels were built between the mainland of Pudong and the island of Changxing. The waterway in between is a busy main shipping route. The connection between Changxing and the island of Chongming was achieved by a bridge construction.

The parallel motorway tunnels have two levels. The upper level contains three lanes for road traffic and the lower level is planned to integrate a rescue lane in the center and a safety passage.

The main challenges of this project were the large shield diameter of 15.43 m (51 ft) and the predicted geological and hydrological conditions with high ground water pressures of up to 6.5 bar.

The tunnels were built in clayey formations below the ground water table. At the deepest point, the tunnels run about 65 m (213 ft) below the surface.

Therefore, both mixshields were designed for a maximum working pressure of 6.5 bar. To avoid adhesion of sticky clay at the cutting wheel, its center area was equipped with its own slurry circuit. Large openings in the cutting wheel optimize the material flow and reduce the risk of blockage of material in the center.

A special feature of the soft ground cutting wheel is six accessible main spokes, sealed against the water pressure. The design of the cutting wheel was conceived in order to allow man access to its interior space in free air, sealed from the ground water pressure outside.

To handle the clayey soil conditions the cutting wheel was equipped with soft ground tools and buckets. Tool change devices integrated in the cutting wheel allow workers to replace tools under atmospheric conditions from the interior of the cutting wheel.

The tunnel is lined with reinforced concrete segments. The heavy segments that weigh up to 16.7 t (18.4 st) each were delivered by two special trucks from the segment fabrication yard, about 1.5 km (1 mile) away from the jobsite. The tunnel lining has an inside diameter of 13.7 m (45 ft). Each tunnel ring consists of 9+1 segments and has a length of 2 m (6.5 ft).

The breakthrough of each 7,170 m (23,525 ft) tunnel was in May 2008 and September 2008, 12 and 10 months earlier than scheduled, respectively. The commissioning of the BOT tunnels was planned for 2010. The structural

Workers at the Gottahard Base Tunnel project celebrate the breakthrough of the 9.58-m- (31-ft-) Herrenknecht tunnel boring machine, which had been given the name Gabi 1. The breakthrough came six months ahead of schedule. In the meantime, Gabi II reached its target in Amsteg. On the southern side of the Gotthard, there are still two Herrenknecht Gripper-TBMs on their way. The first breakthrough on the south is expected in October 2010.

steelwork for the two new 15.43-m- (51-ft-) diameter mixshields was manufactured in China. The assembly time of only four months displayed a high technical standard in the field of tunneling technology. And this was for projects with huge demands, like the excavation of the parallel motorway tunnels below the Yangtze River with high ground water pressures.

Two mixshields for the rail tunnel access route to the Brenner Base tunnel

Two mixshields with diameters of 13 m (42.6 ft) were used for the construction of the northern rail access to the future Brenner base tunnel in Austria. The tunnel will form a key link between Germany, Austria and Italy. This project is also characteristic of the demanding conditions of tunneling with large diameter TBMs in extremely heterogeneous geological formations.

The sections concerned are situated in the Lower Inn Valley where the existing 40-km (25-mile) doubletrack railway had to handle north-south traffic as well as the east-west traffic between Vienna and western Austria. It is an important junction, especially taking an increase in traffic both for freight and passenger capacity into consideration, which cannot be handled with the existing infrastructure.

One mixshield excavated a section of 5,835 m (19,144 ft) for a double-track railway tunnel on Lot 3 – 4 (Münster-Wiesing). The second mixshield, which was used before in the SMART tunnel project in Kuala Lumpur, was used for the 3,470-m- (11,385-ft-) long Lot 8 (Jenbach). Along this section, the 13-m- (42.6-ft-) diameter shield passed under the Jenbach Station, a power station channel and the motorway.

The machine had to be adapted from 13.21 m (43.3 ft) to a shield diameter of 13 m (42.6 ft) to fit the demands for the railway tunnel project Lot 8. The shield was equipped with a 4,400-kW (5,900-hp) hydraulic cutterhead drive system.

The mixshield used for the lot H3-4 excavated the 5.8-km- (3.6-mile-) long main tunnel, the longest tunnel section of the new Lower Inn Valley rail. This shield was equipped with 20 electric motors generating a power of 3,200 kW (4,300 hp). The shield started from a 30-m- (98-ft-) deep shaft. Over a length of approximately 250 m (820 ft) it passed beneath the River Inn with minimal distance between the tunnel crown and the river bottom. Also, the motorway, A 12, and the existing railway line was undercut. The shield drive ended in a cavern. The shield skin remained in the tunnel and the rest of the TBM was dismantled through the already built tunnel.

The extremely heterogeneous geological formations in the bottom of the valley of the Lower Inn, comprising alluvial sands, clays, gravels and boulders with the ground water level just below the surface, was a particular structural challenge. The 13-m (42.6-ft) mixshields are among the largest TBMs ever used in Europe.

Concerning the design of the tunnel profile, a system with two independent sealing levels was demanded for reasons of operational-technical requirements, whereby one seal level must maintain the pressure. As a standard profile, a double shell lining in the form of a circular cross-section with segmental lining and an additional fire protection shell of in situ concrete was preferred.

The TBM was designed and manufactured according to the predicted geological conditions. The mixshield technology presented the best solution for the handling of the prevailing changing geological conditions with permeability of 10–5 m/s in the gravel formations.

The tunnel face was stabilized with a bentonite suspension, which functions, not only as a support medium but also as a transport medium. In a conventional mixshield, as used for Lot H3-4 (Münster-Wiesing), a submerged wall separates the working chamber from the bulkhead, enabling the regulation of the quantity and pressure of the supporting medium separately from each other. The substantial advantage of the divided working chamber with air cushion in the rear chamber for the regulation of the support pressure at the tunnel face is the decoupling of the support pressure regulation from the total circulating quantity of the suspension in the slurry circuit.

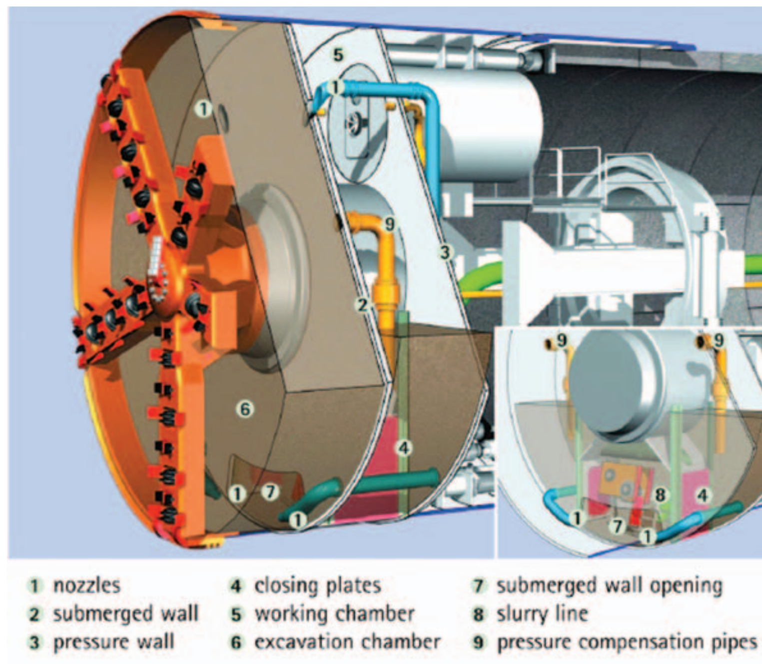
The mixshield for Lot 8 (Jenbach) was designed with an isolated invert segment. This innovative patent protected version of the mixshield is predominantly used in cohesive soils. This technology was used for the first time in the mixshield 11.67 m (38.3-ft) for the Weser Road Tunnel Project near Bremen, Germany.

With an isolated invert segment, the function of support pressure control is separated from the soil conveying. Due to the isolation of the invert area, the prepared bentonite suspension is injected directly into the working chamber. The slurry circulates towards the suction nozzle by the isolated invert through the working chamber. The pressure control at the tunnel face is no longer exercised by the submerged wall opening as is usual, but through two pressure compensation pipes (see 9 in Fig. 2) situated between the working chamber and the excavation chamber. The connecting pipes ensure that the support pressure control is still guaranteed by the air cushion and secondary compressed air equipment.

The isolation of the invert area of a TBM ensures the safe and controlled transportation of the excavated material even in cohesive and sticky ground. This makes a continuously high excavation speed possible, no matter the quality of the ground.

FIG. 2

Isolated invert. Increasing tunneling performance through controlled flow.



The excavated soil that is mixed with the suspension is pumped by slurry line to a separation plant outside the tunnel. There, the excavated soil is separated from the transport medium. It is planned to recycle the material as far as possible and to dump the unusable material.

Except for the planned downtime for maintenance, the mixshield for the double-track railway tunnel advanced 24 hours, including the weekends and holidays. The 13-m (42.6-ft) mixshield for the Lot 3-4 (Münster-Wiesing) of the Lower Inn Valley finished its 5,835-m-(19,143-ft-) long drive after approximately 19 months of excavation, six months faster than schedule.

Double-shielded, hard rock TBMs for the Brisbane North South Bypass tunnel (NSBT)

The NSBT project is a public private partnership (PPP) project. The main benefit of the PPP is that the RiverCity Motorway Co. is responsible for delivering the project on time and on budget, reducing the overall cost and construction risk to the city council. The RiverCity Motorway has contracted the design and construction of the NSBT to the Leighton Contractors and Baulderstone Hornibrook Bilfinger Berger Joint Venture (LBB JV).

The project includes parallel bored twin-lane tunnels that were excavated and lined in rock below the city of Brisbane and under the Brisbane River.

The tunnel provides a link between the Inner City Bypass and Lutwyche Road in the north with Ipswich Road and the South-East Freeway in the south. And it provides an additional Brisbane River crossing. The northbound and southbound tunnels bypass 18 existing sets of traffic lights. Moreover, they take a significant number of vehicles underneath the city each day, reducing surface congestion and, thus, enabling a series of urban enhancements to be completed in adjacent suburbs.

The geological conditions at tunnel level comprise Brisbane Tuff and Neranleigh Fervale (NF) beds. The NF beds are characterized by arenites and phyllites with quartz veins. Both the tuff and the rocks of the NF beds are generally of high to very high strength.

Due to the predicted local geological conditions along the excavation of the tunnels, a combination of tunnel excavation methods were used. They included cut-and-cover sections and sections driven by two TBM's and six roadheaders.

The overall excavated tunnel length by the TBMs is 8.4 km (5.3 miles). Two 12.34-m (40.5-ft) double-shielded, hard rock TBMs of identical design were used for the parallel bored tunnel sections of 4,067 m and 4,348 m (13,343 ft and 14,265 ft), respectively. They excavated about 70 percent of the tunnel sections.

Double-shielded TBMs are among the most sophisticated TBM types in tunneling because two applications — shield TBM and gripper TBM — are combined in the same machine. Changing ground conditions can be handled with this type of machine because the shield can be adapted to the geological conditions relatively easily and without any major setbacks affecting its progress, even if poorer rock zones are encountered. This excavation method is characterized by safe working conditions.

Moreover high and continuous production rates can be achieved in good rock conditions because the tunnel support can be placed while excavating.

The two double shields were ordered in July 2006. The cutterhead with a diameter of 12.4 m (41 ft) was fitted with 74, 482 mm (19-in.) back-loading disc cutters and 12 buckets. The double shields were fitted with an electrical 6-m- (20-ft-) diameter main drive and installed with a power of 4,200 kW (5,632 hp).

The geological condition, the inner-city location of the tunnel and the undercut of the Brisbane River required the TBMs to be equipped with drillings for probing ahead and taking core samples from the TBM. A full preexcavation grouting pattern as well as two probing ports were arranged in an angle of 8° through the gripper shield skin between approximately 11 and 1 o'clock in the crown. The machine was equipped with a percussive drill rig mounted on top of the first trailer. This drilling unit was installed on a moveable (180°) ring carrier to drill on a length of 22 m (72 ft) ahead of the TBM.

Mucking out of the tunnel was done by a conveyor belt that was equipped with a weight-measuring system and a volume-measuring system (scanner device). The excavated material was taken to a purpose-built, loadout facility and transported primarily by the arterial road network.

The tunnel is lined with a sealed segmental lining that consists of 8+1 reinforced concrete elements, each having a length of 2 m (6.5 ft). Each segment is provided with an all-round seal that prevents ground water from entering the tunnel. The tunnel lining has an outer diameter of 12 m (39 ft) and an inner diameter of 11.2 m (36.7 ft).

The machine was equipped with a segment storage magazine that holds one complete tunnel ring (8+1) to avoid downtimes due to a delay in segment delivery. The segments were manufactured in a segment factory installed 10 km (6.2 miles) from the jobsite. The equipment was supplied by Herrenknecht Formwork Technology GmbH, a 100-percent subsidiary of Herrenknecht AG, which delivered a turnkey lining segment production facility for the NSBT project. In addition, Herrenknecht Formwork provided and installed all of the associated facilities and equipment. This included handling equipment to turn, orientate, remove, deliver and store the segments, as well as equipment to install seals and produce the surface finish of the segments.

The segment factory included a carousel system capable of carrying five sets of molds (45 molds), a curing tunnel, a concreting station, a reinforcement assembly area and a mold preparation line. The segment plant produced 10 complete rings in two, 10-hour shifts using the five sets of molds in production.

The design of the Herrenknecht Tunneling Systems for the NSBT in Brisbane was based on the contract specifications of the client that defined the technical basis and requirements for the double-shielded, hard rock TBM, the backup systems and peripheral equipment such as tunnel belt conveyor and segment plant.

Hard rock tunneling for Switzerland's - the Gotthard Base tunnel

The Gotthard base rail tunnel is currently under construction. The project is a future-oriented flat railway through the Alps and will be the longest rail tunnel in the world with its two tunnels of 57 km (35 miles) each. The tunnel will be put into service at the end of 2017. This pioneer work of the 21st century will lead to a prominent improvement of travel and transport possibilities in the heart of Europe.

The concept for the Gotthard Base tunnel provides a simultaneous advance in five parts of different lengths comprised of TBMs and drill-and-blast.

The mechanized tunnel sections excavated by means of gripper TBMs comprise in total following four subsections:

- Erstfeld (two at 7,178 m or 23,550 ft).
- Amsteg (two at 11,350 m or 37,240 ft).
- Faido (one at 12.4 km or 7.7 miles, one at 11.9 km or 7.4 miles).
- Bodio (two at 14 km or 8.7 miles).

The first mechanized tunnel of the subsection Amsteg was completed in June 2006. The parallel section was excavated by the beginning of October 2006 about half a year ahead of schedule.

The approximately 14-km- (8.7-mile-) long parallel tunnels of the subsection Bodio were completed at the beginning of September 2006 and the end of October 2006, respectively.

The four gripper TBMs excavated the often demanding rock massif and fault zones finished the total of about 50 km (31 miles) on time.

For the subsection Faido to Sedrun, the two gripper TBMs used in Bodio were completely refurbished.

The geology along this section comprises two tectonic units, the Penninic Gneiss zone (approximately 5 km or 3.1 miles) and the Gotthard Massif (approximately 10 km or 6.2 miles). The Piora zone was predicted to comprise solid, compact and partially metamorphic dolomite anhydrite rocks at tunnel level. The TBMs applied for the subsection Faido have been modified. To be prepared for the greater overburden of 2,470 m (8,100 ft), up from1,200 m (3,940 ft) and rock pressure, in addition to an increase in excavation diameter along this section, 12 buckets were applied instead of eight and the 431 mm (17-in.) disc cutters were replaced by 457 mm (18-in.) cutters. To support the 9.5-m- (31-ft-)

diameter, the gripper and the walking legs were adapted. Modifications were also done on the cutterhead dust control system with an increase from 600 m^3/min (21,200 cu ft/min) to 1,100 m^3/min (38,850 cu ft/min).

For the subsection Erstfeld the geology is characterized by mainly solid and geotechnically favorable, highly metamorphic gneisses (Erstfelder gneiss). The AlpTransit Gotthard AG administrative council awarded the subsection Erstfeld to the Gotthard Base Tunnel North Joint Venture (JV). The JV consists of Murer-Strabag AG, of Erstfeld, Switzerland and Strabag AG of Spittal/Drau, Austria. The TBM section comprises the excavation of two, single-track tunnels of 7.2 km (4.5 miles) from Erstfeld to Amsteg. The tunnels are excavated and secured by the two TBMs that have driven the two 11.35-km- (7-mile-) long subsection Amsteg. This section includes an underground junction to permit a future extension of the tunnel toward the north without interrupting the operation.

In connection with the TBM drives of a long tunnel with a large overburden (>2,500 m or 8,200 ft) and in a tectonically active rock mass (folding of the Alps), one can draw the conclusions that despite extensive clarifications in the run-up to the project, there can be a great difference between geological prediction and geological finding. The rock behavior and the hazard scenarios can prove to be less favorable than expected. This could make impossible an optimal use of the drive systems designed according to the hazard scenarios dominating the service contract.

The constructional relevance can change very quickly on site. Correspondingly, the mountain only forgives faults in exceptional cases and sometimes requires quick decisions of all persons involved in the project and the prompt realization of immediate measures.

The applied TBM technology proved, however, that it is in a position to master technically essentially more critical situations than were provided in the service contract. The construction of these TBMs and trailers were subject to extensive adjustments

(among others due to the extraordinary conditions) and optimizations during the drive for more than altogether eight years and nearly 30 km (18.6 miles) each.

Extraordinary conditions can additionally aggravate the already very demanding technical and logistical challenges. A close and constructive cooperation between client, author of the project, supervisor of works and enterprise is essential for the success of the project of the structure of the century.

Outlook

The cited projects show the multitude of pioneering references in large diameter mechanized tunneling development such as Shanghai (mixshield 15.43 m of 51 ft) and M30 Madrid (EPB-Shield 15.20 m or 50 ft). They support the feasibility of the construction of very large tunnels. The performances that have been achieved by the current largest TBMs also include an excellent logistical concept, which presents a good basis for administrative authorities, project owners and contractors regarding the feasibility, reliability, safety and speed of upcoming large diameter projects.

The tendency of future large diameter tunnel projects are in direct relation to the progressing urbanization and the possible impending total gridlock especially in metropolitan areas or larger cities and also at junctions such as the access to the Brenner Base tunnel.

To summarize the current state of the art in TBM technology, the TBMs range from 100 mm (3.9 in.) to 16 m (53.5 ft). They are today reliably used for the realization of complex projects. In the future, tunnels with diameters of more than 16 m (53.5 ft) are envisaged, not only in densely populated areas, but also through natural barriers like mountain ranges or under rivers and estuaries. The market requires practical engineering skills under the toughest conditions.

Innovations, such as seismic probing ahead, cutting wheels accessible under free air, muck control, drill units for ground stabilization measures from the TBM and cutter wear detection systems, were designed and further developed. Information technology and sophisticated measuring techniques in tunneling are increasing safety as well as economic profitability. ■

Herrenknecht mixshield S-352 at Schwanau, Germany. It was used to construct the 5,768-m- (19,000-ft-) long New Tunnel for the Lower Inn Valley Railway, Austria.

FEATURE ARTICLE

Single bore solution for transit tunnels

The use of a single tunnel boring machine (TBM) tunnel of approximately 12 to 13 m (40 ft to 43 ft) diameter for transit systems to house both light rail or subway tracks in a stacked configuration is an advanced concept that allows significant savings in construction cost and time while reducing, to a large extent, the negative effects on the environment.

This solution, similar to the recently completed Barcelona Metro Line 9, integrates station platforms, train storages, crossovers, bypass tracks, ancillary areas and utility corridors inside a single tunnel. Each of the underground stations consist of a cut-and-cover entrance structure and ventilation shafts, that also serve as emergency exits. The excavations for the station structures and shafts can be done on one side of the street with nominal impact on traffic and utilities.

The North American transit agencies are familiar with the application of the twin tube tunneling approach, as most of their recent subway extensions have used this method of construction. At the same time, large bore tunneling has been used as the preferred method on multiple projects during the last two decades all over the world.

The primary feature of the single tube tunnel configuration for a transit line is that station platforms, crossovers and tail tracks are all accommodated within the tunnel cross section. As such, the location of each of these major elements can be adjusted along the entire corridor to maximize design efficiency and minimize construction impacts. Another key feature is that station structures can be located on either side of the street. This allows for structures that are constructed using cut-and-cover method, to be built with minimal impact on traffic along the street. This is critical to residents, businesses and the general public.

The new transit lines are often introduced as a means of alleviating traffic congestion and the associated noise and air pollution. However, the traffic impacts, noise, dust and business disruption that would be generated by cut-and-cover construction along a highly dense corridor may be counterproductive to the objectives of these projects. Part of this disruption would also affect existing public transportation services during several years construction phase of the underground structures.

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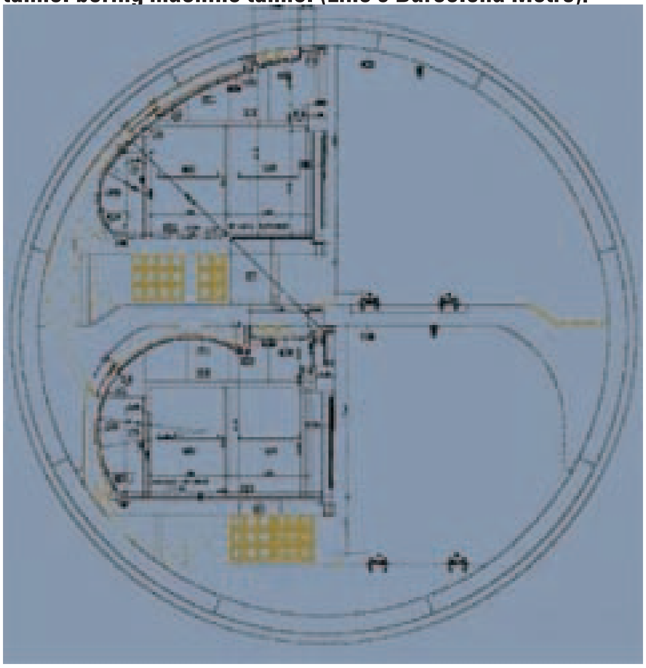
Placing the stations inside the running tunnel

Since the early 1990s, in many parts of the world, the design of new transit lines has generally followed a typical configuration: excavation of cut-and-cover stations as rectangular boxes using slurry walls as support of excavation is followed by connecting these boxes by a single tube tunnel boring machine tunnel

FIG. 1

Stacked platform station within a single large diameter tunnel boring machine tunnel (Line 9 Barcelona Metro).



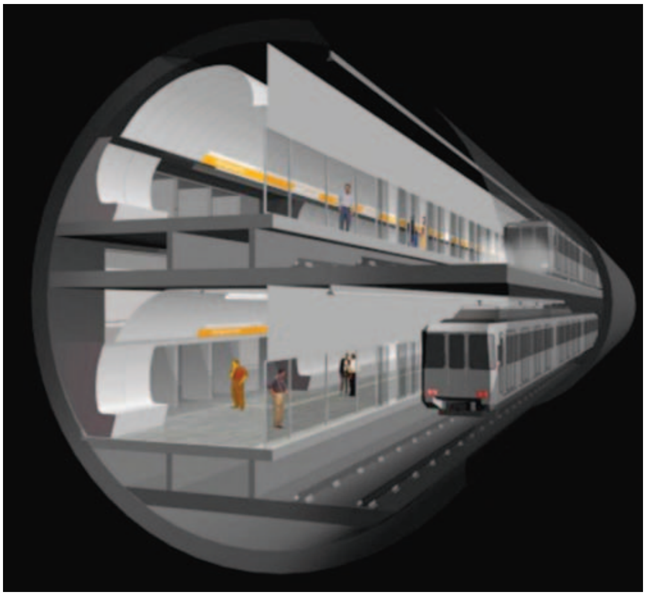
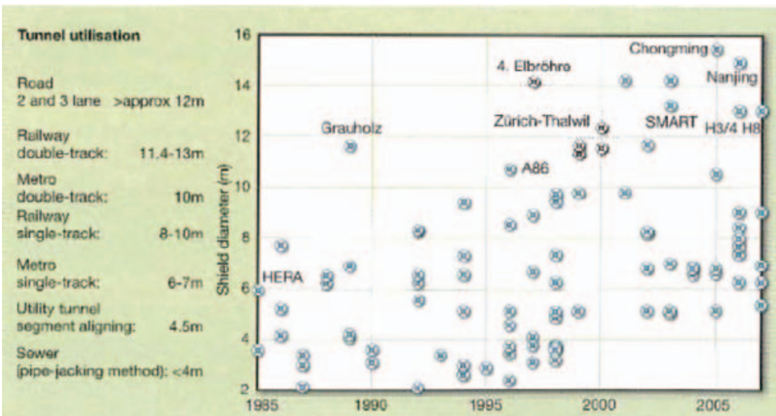


FIG. 2

Increase in Mixshield diameter manufactured by Herrenknecht in the past two decades.



housing two side-by-side tracks.

The twin tube system was preferred during the 1980s. It was considered to be easier to build and to generate less settlement, but has since been abandoned. Aside from major geometrical constraints, the experience shows that the twin tube is clearly more expensive than the single tube. It should be noted that a TBM with a diameter large enough to place two, side-by-side subway tracks within it (external diameter of about 9.5 m or 31 ft) can be well controlled. The conventional mining method for subway tunnel construction is now almost abandoned because of the risks involved with the construction crews and adjacent structures that are not totally controllable.

After multiple use of large diameter TBM for building double track side-by-side transit tunnels, Spanish engineers working on the Line 9 of the Barcelona Metro decided to go farther and put the stations inside the tunnel by slightly increasing the TBM diameter. This revolutionary concept was applied to 28 km (17 miles) of tunnel using a 12-m- (40-ft-) diameter TBM housing two stacked tracks (Fig. 1) (Della Valle 2003).

The conventional twin tube tunnels with cut-and-cover stations construction is disruptive to vehicular and pedestrian traffic and requires significant construction costs to provide for temporary decking, special staging and phasing of the project and usually extends the construction duration due to the restrictiveness of the worksite below the surface.

Since the platform is integrated within the tunnel of the single tube option, the remaining underground work at the stations is limited to access shafts and short connector tunnels. Station configuration can be developed to satisfy the transit agencies' design criteria and requirements for vertical circulation, ventilation and fire/life safety. Each of the underground stations consists of a cut-and-cover entrance structure and ventilation shafts. These also serve as emergency exits. These excavations are performed on one side of the street with no impact on the traffic and utilities.

The single tube solution promotes operation safety. In fact, the internal slab seals off the two platforms that behave like two separate tubes with the possibility of closely spaced emergency stairs equipped with fireproof doors between the two tracks. Each platform acts as a refuge area for the other, with a connection possibility at a much higher frequency than the actual standard safety requirement.

The platform edge doors solution can be adopted, similar to those found in major cities like Paris, Singapore, London, Bangkok, Hong Kong and Barcelona. The doors physically separate the tracks from the platform enhancing safety in case of fire and reducing the psychological effect of the incoming train.

The access shafts can be equipped with high-capacity elevators and emergency stairs. The elevators may be synchronized with train arrival to minimize waiting time at the shaft bottom. The number of elevators per each shaft varies in function of the expected number of passengers.

Based on the studies performed by the author on several North American projects, the duration of construction

FIG. 3

Change in track configuration from side-by-side to stacked.

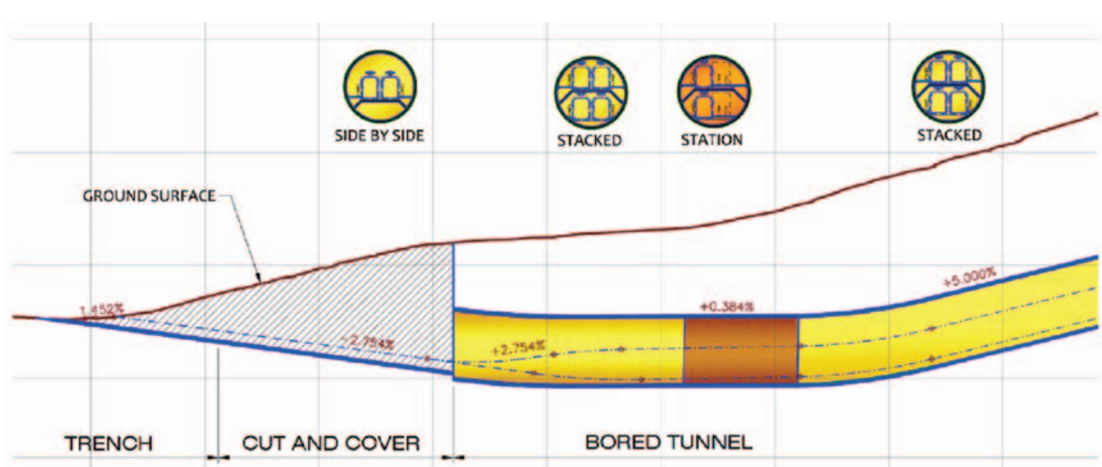
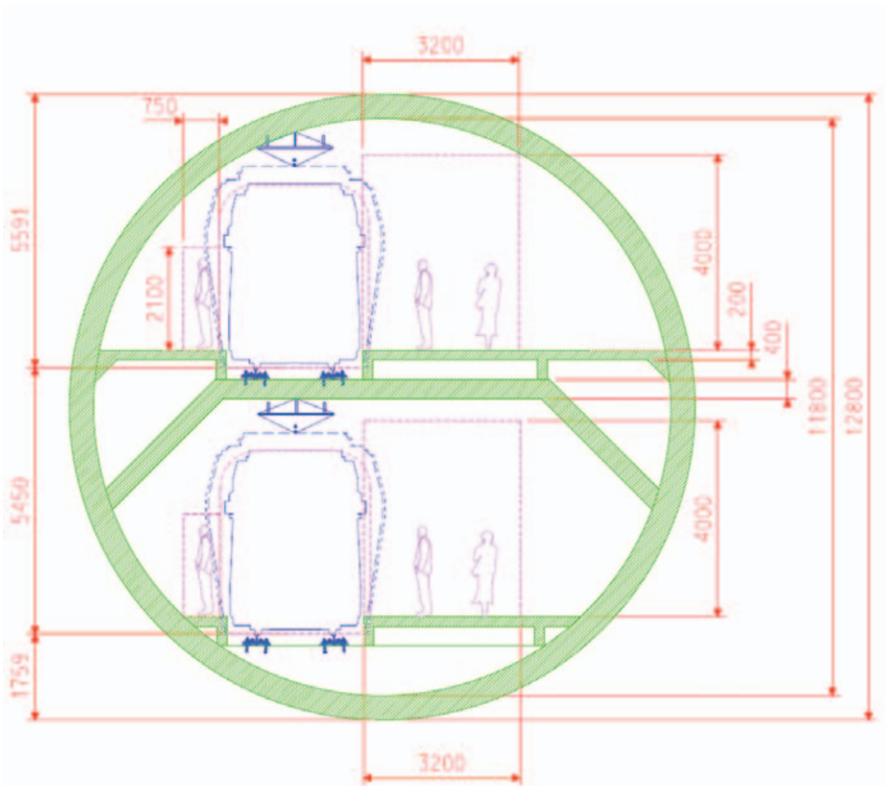


FIG. 4

Example of cross section of the single tube tunnel for a LRT project (lengths shown in mm).



is clearly shorter for the single tube option. The advance rates for both single and twin alternatives are comparable based on reported cases. In the case of single tube alternative, the platform structure can be completed just after the passage of the TBM. These studies also show that the estimated construction cost for the single tube alternative is clearly lower.

Some of the advantages of the single tube option compared to twin tube include:

- Construction disruptions are minimal on the street, as building the stations, entrances and other structures would be done outside the street right-of-way. This is true, especially considering the large construction areas and muck disposal activity that would occur at each station location, associated with the cut-and-cover that would be required for the twin tube.
- Cost of disruption to businesses as a result of construction, including muck disposal, traffic and pedestrian reductions/restrictions as well as the additional costs that would be associated with the hoarding, piling, decking, detouring, dewatering, utilities relocation and others at the stations.

TBM selection

The growing need worldwide for efficient infrastructure systems encourages tunneling solutions, particularly by mechanized methods. The mechanized tunneling process offers a safe, settlement controlled alternative to other tunnel excavation methods. Innovative solutions, such as the multipurpose use of the tunnel profiles, are increasingly demanded. This requires large diameter tunneling technology. Mechanized tunneling with diameters of up to 16 m (52 ft) is reliably controlled and, compared with conventional tunnel construction, is substantially faster.

The TBM method requires a more comprehensive and thorough geological investigation, mapping and testing during the planning stage in order to evaluate the overall TBM viability and possible machine types that could be applicable. Considerations to use the TBM method have to take place during the early planning stage to establish tunnel alignment and profile. Possibilities to reduce adits and job sites while still maintaining the overall construction deadline should also be considered in early planning stages.

Planning the tunnel projects with diameters exceeding 10 m (33 ft) is now a common practice. The large diameter TBMs can be designed for soft soil, hard rock or mixed face conditions. Mechanized tunneling with diameters even larger than 15 m (49 ft) is now the state-of-the-art and can be dealt with safely. Compared to conventional construction methods, the mechanized shield tunneling, even with larger diameters, is considerably faster and its limits are set by logistical issues, such as mucking, rather than by construction safety or financial concerns (Herrenknecht and Bäppler 2008).

It is now possible to use the TBM method for just about any purpose and ground condition including open hard rock TBMs and shielded TBM designs like single shields, double shields, mix shields, earth pressure balance (EPB) machines, and slurry shields in diameters from about 2 to 3 m (6.5 to 10 ft) and up to approximately 16 m (52.5 ft). Figure 2 shows the increase in TBM diameter in recent years of one particular machine type (Mixshield) produced by one of the main TBM manufacturers.

Typically, a TBM consists of a rotating head that excavates the material. From there, the spoil enters into a chamber from which the material is transported to the surface. The complete operation requires a crew driving and running the cutting head, an excavation handling crew, and a segmental liner installation and storage crew.

The diameter of the cutting head is selected based on the required tunnel geometry and total thickness of the assembled segmental liner ring and annular grout ring behind it.

Three types of TBM technology are predominantly used in current practice. They are referred to as open face, EPB and slurry shield.

The open face shield method cannot effectively control the inflow of water or support the face of the poorly graded sand and gravel, and water pressure anticipated at most soft ground sites.

The EPB has been traditionally used in finer grade materials such as silts and clays. But, with the development of foams and polymers, EPB can now be used in a wider range of soils and is even being used in rock tunneling. Advantages for the EPB over the slurry TBM include more flexibility in the chosen mode of operation, easier access to the face for cutter changes; potentially cheaper machine costs and a faster rate of advancement for tunnels in mixed ground conditions. Disadvantages include the difficulties associated with maintaining a good quality spoil in highly permeable, coarse-grained soils.

Advantages for the slurry TBM include operating well in sands and gravel soils and tunnel spoil is pumped to the surface, avoiding the use of mucking cars or conveyor belt system on steep grades. Disadvantages for the slurry TBM include higher operating and slurry handling equipment costs, and the potential for slurry blowout causing environmental pollution.

Recent developments in TBM technology have brought about effective methods of building tunnels in various types of soil, rock and mixed face conditions. A dedicated TBM is usually designed for the specific subsurface materials and conditions expected to be encountered on each project. The alignment is selected to provide at least one tunnel diameter of cover to the extent possible.

The development of underground technology using TBMs in recent years has reduced the potential differences between the EPB and slurry TBM systems. A pressurized face machine is often recommended for use on the project. The contractor will have the option to choose either an EPB or a slurry TBM. Figure 3 shows the change in tracks configuration from side-by-side at the portal to stacked at the station.

For transit projects, a large diameter, single tube tunnel (12 to 13 m or 40 to 42 ft TBM diameter with about 15 cm or 6 in. annular grouting) can be considered to house both light rail or subway tracks in a stacked configuration. This solution, which is similar to the recently completed Barcelona Metro Line 9, integrates station platforms, train storages, crossovers, bypass tracks and ancillary rooms inside the single tube tunnel (Fig. 4). Based on the existing experience, the construction cost and time and environmental impact of this concept is lower than the twin tube option.

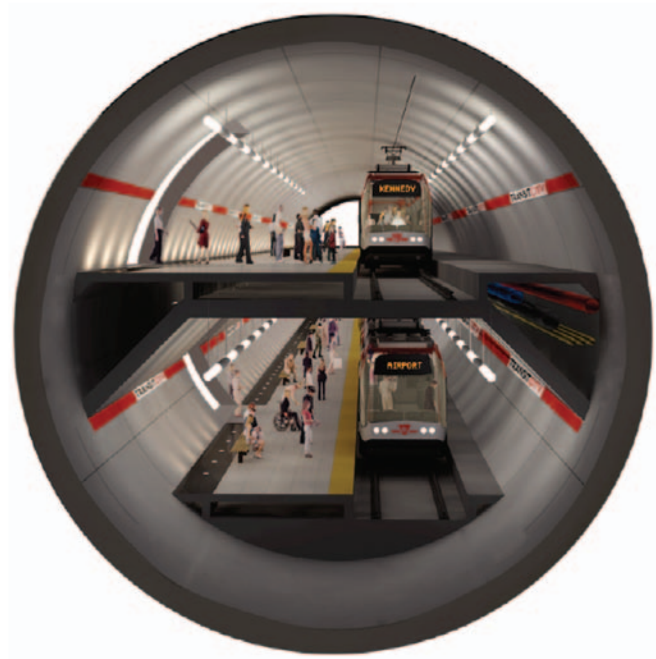
Station configuration

Stations for single tube tunnel consist of three separate functional elements:

- Stacked side platforms.
- Vertical circulation (entrances and emergency exit buildings).
- Fire ventilation units (FVU).

FIG. 5

Single tube station platform.



The platforms are located within the single tube tunnel itself, one at each level, to one side of the running tunnel. Essentially, the station consists of side platforms stacked one atop each other within the tunnel structure to provide consistent access to the vertical circulation elements (Fig. 5). As such, a single point of entry or egress to and from both platforms can be located anywhere along the length of the station. In addition, the stacked side platforms can be located to the either side of the running tunnel within the tunnel depending on the preferred location of the main entrance building.

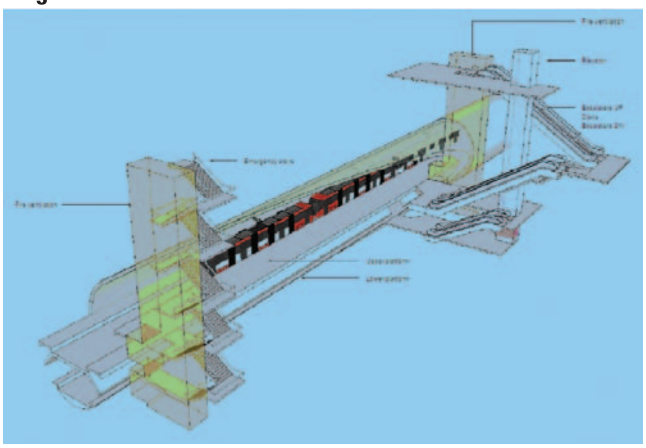
Vertical circulation structures include a main entrance building and, at minimum, one emergency exit building, each located at either end of the station. These structures are separate entities connected to the single tube tunnel and platforms by individual pedestrian adits.

The main vertical circulation can include two sets of escalators (one up, one down, 1.6 m or 5.2 ft each), stairs (2.4 m or 8 ft) and an elevator (2.5 m or 8.2 ft). Due to the depth of the station platforms, an additional escalator can be included to accommodate faster passenger access between the platforms and the street (Fig. 6).

The emergency exit building provides egress from

FIG. 6

Single tube station 3D view.



each of the platforms and would include fire doors at each platform level to secure a safe access route to the surface.

FVUs are required, one at each end of the station beyond the platforms. For the purpose of this study, standard FVUs applied in the transit systems have been used, stacked atop one another beyond either end of the platform. This allows for all vertical circulation and fire ventilation elements to be consolidated into single or adjoining structures, reducing the number of footprints required (Fig. 7). As such, ventilation shafts can be raised higher, beyond street level to avoid impacts during smoke discharge.

Station design initiatives from other single tube tunnel studies had investigated options for staggering the side platforms within the tunnel, each to opposing sides of the subway or LRT running tunnel. The staggered platform layout was intended to provide direct access from each platform to both sides of the street above. The design investigations revealed that staggered side platforms within the single tube tunnel would require a complex combination of mezzanines and pedestrian tunnels outside of the main tunnel to connect the platforms with one another and any vertical circulation to the street. This complexity would not only necessitate far more elevators and escalators but also lead to disorientation among passengers attempting to connect between the platforms and the street.

The ability to combine FVUs with vertical circulation into a single or adjoining structures reduces the number of structural components required. Albeit larger in size, ideally the station requires only two vertical structures:

- Main entrance building with adjoining FVU.
- Emergency exit building with adjoining FVU.

These structures exist independently of the single tube tunnel (horizontal structure) and can be located anywhere along the length of the station platform but must always be located on the same side of the tunnel as the platforms. The platforms also exist independent of any site constraints since they are within the single tube tunnel and can be located anywhere along the horizontal alignment, limited only by natural topography (slopes) and associated track work. Additionally, due to the larger diameter size, the stacked platforms can be located on either side of the single tube tunnel. This versatility in sitting individual elements allows the main entrance building to be located at a preferred location, typically at an intersection, allowing direct connection to surface transit routes. The location of the entrance building will determine the location of the platforms. Opportunities exist for satellite entrances to be located in the immediate vicinity (either side of the street) and connect by pedestrian tunnels to the main vertical circulation building.

Construction of the platforms occur within the tunnel structure that has no impact on adjacent properties or surface activities. In addition, the continuity and independence of the tunnel from the vertical structures allows for increased capacity with the ability to lengthen the platforms without additional impacts. As an example, the platforms could be constructed at a length of 64 m (210 ft) for a two-car train and, in the future, extended to 96 m (315 ft) for a three-car train. Should demand warrant, these platforms can be extended even farther, limited only by the vertical alignment constraints and special track work.

The combined structures of vertical circulation and fire ventilation can be constructed independently from the single tube tunnel. These structures can be constructed prior, during or after tunnel boring operations without impact on street level activities. The impacts will be similar to that of any surface building structure affecting only the immediate sidewalk or curbside lane depending on the size of setback. Once both the tunnel and vertical circulation structures have been completed, connections between the two elements can be mined.

In all situations, construction of the entrance and emergency exit buildings, along with tunneling operations, can occur with no impact on day-to-day surface activities. As such, vehicular and pedestrian traffic can flow unimpeded, especially at intersections, making it ideal for high-density areas.

The vertical circulation structure is based on local building code standards to determine minimum spatial requirements. The depth of a single tube tunnel and associated platforms may not be conducive for passengers' perception of comfort and safety when implementing engineering minimums. Passenger safety and comfort is directly associated with visibility. Visibility from the entrance building, down the vertical circulation structure and through to the platforms can be highly constrained when using engineering minimums typically applied for shallow or deep stations.

The design and functional layout of a single tube station are different from the typical center platform arrangement found at many of the subway stations. The emphasis on connectivity and accessibility in twin tube stations is on horizontality versus verticality in single tube stations.

Passenger accessibility for single tube stations should not be perceived as a drastic departure from that for twin tube, since the vertical circulation structure is more similar to that found in buildings, especially office towers or shopping centers, with multilevel atria.

The perception of depth is a social and psychological factor that is premised upon the volumetric confines within which a person either feels forced or choosing to enter. The ability to see where one is traveling is an important criterion affecting people's perception of depth and safety. Designing the vertical circulation shaft in a single tunnel station to be spacious and open is equally as important as managing direct and well lit access from individual entrances to a mezzanine or concourse level in twin tube stations.

The introduction of an atrium-type space within the vertical structure would greatly increase visibility between levels and allow passengers to not only see where they are going, and want to go, but also assists in reducing the perception of depth and distance. Atria have been highly successful in higher density developments of all types, worldwide. The application of an atrium-type volume would allow the vertical circulation structure to function as the backbone for ancillary underground passages to adjacent properties, especially in high density downtown areas.

The single tube tunnel concept can be made compliant with all of the requirements of the latest version of NFPA 130 and other local codes. Stations are designed to be evacuated within four minutes with all passengers reaching full safety within six minutes. This is an easily achievable goal given the excellent location potential of fire separations in the structures immediately beside the platforms of the single tube tunnel. It is reasonable to consider the single tube tunnel performs more safe in this regard as fire separations can be placed anywhere along the platforms in the connections to the vertical transportation elements.

Summary

Two TBM tunneling methods for transit projects are compared. The alternatives considered in this evaluation are:

- Twin tube alternative — two conventional size TBMs for excavating two running tunnels and cut-and-cover tunneling method for the construction of under ground stations and crossovers.
- Single tube alternative — one large diameter TBM for excavating one running tunnel that includes all of the stations and crossovers.

These alternative tunneling methods were studied as part of the environmental impact studies for several North American transit projects to determine the most cost-effective method of construction.

Construction staging and maintenance of traffic is determined to be more favorable for the single tube alternative. Major cut-and-cover operations for the twin tube option will result in difficult construction conditions in congested areas along the street. Environmental impact in general is more favorable toward the single tube alternative.

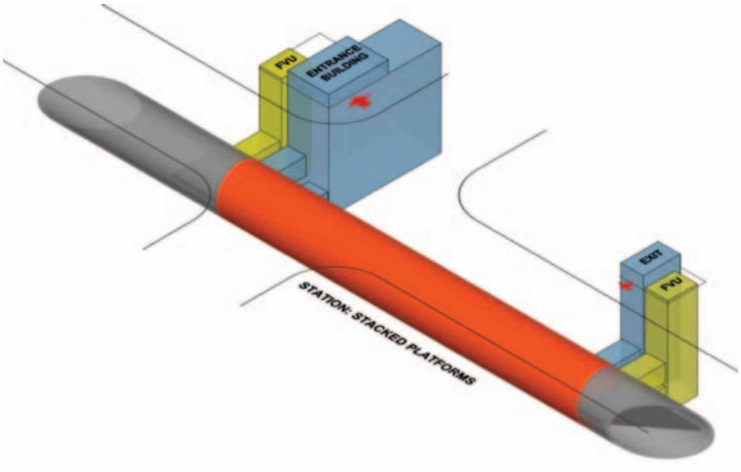
Over the past 20 years, the TBM technology has evolved around the world to the point that TBMs with diameters greater than 12 m (40 ft) have become common. Conceptually, the primary feature that would make single tube the preferred configuration is that the running tracks, station platforms and ancillary spaces are all contained within a large diameter tunnel. As such, provisions for station entrances, ventilation shafts, etc. can be taken "off alignment" of the tunnels and greatly reduce the need for roadway and intersection disruptions at the surface as would be required with cut-and-cover construction.

The time savings in construction of the single tube are realized mainly from the construction of the stations. Both the time savings and minimization of roadway right-of-way disruptions, due to cut-and-cover construction, translate into significant construction cost savings and a more manageable public relations effort.

Given the significant cost savings, overall shorter project construction time, simpler station design and construction with significant less surface disruption and reduced need for complicated cut-and-cover and maintenance and protection of vehicular and pedestrian traffic, the single tube tunnel solution can be considered as a serious alternative in the study of transit projects. ■

FIG. 7

Single tube station entrance and FVU configuration.



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FEATURE ARTICLE

Waterproofing: Key to SCL tunnel lining design

The global tunneling industry has many challenges, both technically and financially, with the latter likely to be a significant feature over the next few years. Many industries have adopted standard practices in order to overcome specific technical challenges, from which standard outcomes are anticipated. In tunneling, however, every project is unique so standardized practice is not easy. This requires original thinking and being open to adopting new techniques and technologies as they emerge. Sprayed waterproofing is a hot industry topic and a paper recently presented at the North American Tunneling conference not only discussed this methodology for achieving a dry tunnel but also how it can reduce build costs and construction time.

Workers inspect a tunnel sprayed with a waterproofing membrane.

Despite their being relatively few "universal truths" throughout the tunneling industry, there is one opinion that appears to be shared by most in the sector, "all tunnels leak."

"Coming from the angle of a specialist waterproofing manufacturer with 25 years of experience in waterproofing all types of civil engineering structure throughout the world, the concept that leaking tunnels are acceptable seems quite odd," said Stirling Lloyd's development director, Mike Harper. "However, tunnel engineers across the world relate to their experience of what they have known up to now; that is, to a greater or lesser extent, tunnels let water, regardless of what you do. Tunnel engineers are, therefore, having to compromise on what they feel is an acceptable level of leakage rather than creating a dry tunnel. Over the last eight years, we have been asking ourselves whether it is possible to achieve a watertight tunnel and have developed a method for achieving this."

In other industries, accepting something that is nearly watertight is just not acceptable. For example in the aviation industry having an aircraft that allowed water to penetrate the outer shell would not be tolerated, neither would a submarine which had a few leaks, damp patches or running water. In an environment such as tunneling, where water penetrating into the structure can cause many problems it is not acceptable for tunnels to let in water. If an aircraft or a submarine can be made watertight, so can a tunnel. It is true that the tunnel environment presents different challenges for waterproofing than some other engineering environments, such as bridge decks or chemical tank linings. But if the requirements are clearly understood, effective waterproofing can be achieved.

Waterproofing is an exact science. A structure is either waterproof or it is not. This is a case of black and white — gray is leaking. The risks presented by water ingress include short-term maintenance issues that, in the long term, can degrade the fabric of the tunnel itself, shortening the overall life of the asset. Poorly waterproofed tunnels have serious economic and environmental impacts, which is why addressing this issue is so fundamental.

Waterproofing that works

The decision on how to waterproof a structure is much more important than the lowest initial cost per square meter of material. It is how the waterproofing will perform over the 120-year design life of the tunnel, and what the risks, costs and environmental considerations associated with failure of the waterproofing are.

There are some well established criteria for successful waterproofing systems to meet to waterproof a concrete structure, which have been implemented in the external lining of tunnels, such as cut-and-cover and immersed tube tunnels, for the last 20 years. These five key requirements can, and should, also be applied to the internal lining of a tunnel of SCL/SEM/NATM design to create a dry tunnel.

Crack bridging capability

This is fundamental to a successful long-term waterproofing membrane when the membrane is intimately and continuously bonded to the concrete substrate. Cracks in new concrete are inevitable at some level, whether from shrinkage during curing or from ground movements. A sprayed membrane needs to be able to bridge cracks that open up or the waterproofing will also crack with the concrete and leaks will appear. Consequently, the product must not only be flexible but also have a very high tensile strength.

Seamless

Where sheet systems are concerned, the problems of leaking tunnels emanates not from the middle of preformed sheets but from the seams where the sheets have been welded together on site. The more seams that are present, the more likely leaks are. Complex geometry provides the opportunity for even more seams, which gives the potential for more leaks. Therefore, the goal is minimizing, or preferably, eliminating seams.

Where sprayed membranes are concerned, seams can still be an issue. The chemistry of the system should be such that a completely seam-free installation is achieved. Much as been done to minimize the impact of seams, including double seaming, trying to test seams and installing grout pipes to try and stop leaks through seams. But these fail to address the root cause, which is the presence of vulnerable seams in the first place.

Suitability

There are many types of waterproofing membranes in the world made from a variety of base chemistry. These include well known systems such as polyurethane, epoxy and methyl methacrylate (MMA), and lesser known systems, such as polyureas, rubber emulsions, polysulfides and polymer modified cements. All have various characteristics that are better suited to some applications rather than others.

The confined space environment of a tunnel and the high cost in terms of time of tunnel construction present some challenging requirements for a successful tunnel waterproofing membrane. In addition to it being watertight, the system must have low toxicity and a low explosion risk. The membrane must also be tolerant to moisture, as there is a negative water pressure environment and some ingress prior to application of the waterproofing is inevitable. The membrane should also cure quickly to ensure there is no costly, unproductive time during the construction process.

Rapid application and cure.

These requirements have necessitated a specific chemistry design for the product to deal with this particularly challenging environment.

Control

As with any trade, control of the activity is key. Although some perceive that forming a membrane in situ is more difficult than forming it in a factory, the material only becomes a waterproof membrane once it is installed. Therefore, controlling the installation of sheet systems can often be more difficult than a sprayed system.

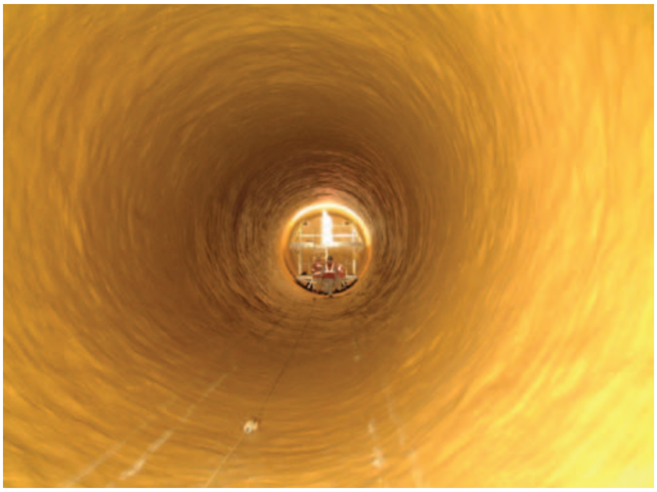
Application of sprayed membrane should be accurate. Wet film thickness tests throughout the application will ensure that the membrane is being applied to the correct thickness. The material should be installed by a spray operative as robots will not be able to see if a section has been missed. A system that is applied in two thinner coats is more effective than a single coat membrane; not only is thickness more controllable, but the second coat will rectify any potential small defects in the first coat, thus reducing the possibility of any problems.

The material should also be simple to use. To avoid on-site variance, the product should be prebatched and pumped together in fixed ratios. All of this needs to be covered by an on site quality assurance regime and comprehensive training should be given to operatives.

Proof

A membrane must be 100 percent effective, whether sheet or sprayed, in order to be watertight. Being able to prove this is of the utmost importance. Where the ground has been dewatered, the effectiveness of the membrane may not be evident until the ground water table is re-established. Therefore, using a quantitative, reliable test method to ensure that the membrane will not leak is essential and should always be undertaken. For sheet membranes, this cannot be done. It may be possible to test for defects in the preformed sheet itself in the factory, but they cannot be

Seamless spray and waterproofing.



re-tested for the effects of site damage during installation or by following trades once in situ. Also, not all seam types can be adequately checked on site. Therefore, potential for leaks go undetected.

For some sprayed membranes, testing is simple. Spark testing is a nondestructive test method that has been used to great effect in other industries. It tests every inch of the membrane and finds any defects, even one the size of a pinhole in 100,000 m^2 (1.1 million sq ft) of applied waterproofing, ensuring that the waterproofing membrane is completely continuous. If any defects are identified, these can be rectified prior to the application of the final lining, before it becomes expensive and nearly impossible to fix. This is the only method of ensuring that the waterproofing integrity has been achieved.

A dry tunnel is possible

A dry tunnel can be achieved by using products that are controllable, suitable, seamless and can be reliably tested. Other areas of the tunnel industry, such as cut-and-cover and immersed tube tunnels, as well as other sectors of the construction industry, have used this "best practice" methodology for many years throughout the world and it has been proven to work.

For contractors, there is also the benefit of reducing uncertainty. The time, expense and disruption from chasing leaks around a tunnel that should be dry, requiring expensive repair, should no longer be a concern when the waterproofing can be done correctly first time.

Consequently, there is now no reason for clients to accept a leaking tunnel. Poor quality environments for tunnel users, long-term running costs issues, such as pumping and disposal of water and early degradation by the action of water ingress and its associated damage, should be a thing of the past.

Design opportunities

At present, the tunnel industry around the world is looking at the issue of effective waterproofing carefully, not only because of increasing requirements for water tightness , but also because of a realization that a fully bonded sprayed waterproofing in tunnels of an SCL/SEM/NATM design offers some poignant design opportunities. This has much greater implications for tunneling projects, in terms of reducing cost and time.

Sheet systems

In traditional SCL tunnel construction, regardless of how much sprayed concrete is applied as the primary lining, from a structural perspective, this concrete is ignored. The full structural load is supported by the final or secondary lining. The traditional build would, therefore, be sprayed concrete onto the excavated surface, followed by installation of a sheet membrane. The sheet membrane is tacked to various points and is not fully bonded to the primary concrete. The choice for final lining construction is then limited by the nature of the waterproofing membrane because it is exceptionally difficult to get sprayed concrete to bond to a sheet membrane system. This is because the membrane does not have a continuous bond to the primary lining. Thus, the sprayed concrete therefore tends to rebound off the membrane surface. This effect can be reduced by the use of lattice girders and reinforcing steel mesh to help support the sprayed concrete during application. However, this tends to reduce the quality of the final lining, as achieving adequate compaction of sprayed concrete through a network of steel reinforcement is difficult. This results in voids and failure to passivate the steel against corrosion from ground water when it is not adequately encapsulated.

The construction method currently favored for final linings tends to be traditionally reinforced cast in situ concrete. This is much slower than spraying concrete, and therefore, potentially more expensive. In long tunnels of consistent cross-section casting. the use of shutters can be cost effective. However, in complex geometry situations, such as metro stations, where interconnecting tunnels and passages have widely varying cross-sections, shuttering becomes increasingly complex and expensive. At the same time, waterproofing requirements are usually most onerous in these areas, where both LUL and Crossrail are currently asking for completely dry tunnels in their specifications.

Sprayed systems

The great design benefit of a spray applied waterproofing membrane is that the final lining can be installed using permanent sprayed concrete instead of cast in situ. With fiber reinforcement, traditional lattice girders and rebar are no longer required, increasing build speed and reducing cost.

Colin Eddie, from Morgan Sindall Underground Professional Services, takes the view that "depending on the design of the tunnel, cost savings of up to 50 percent are achievable with a sprayed solution, when considering the waterproofing and final lining taken together."

Reduced cost, faster build speed and higher quality waterproofing performance are a powerful argument in favor of sprayed waterproofing membranes for tunneling. However, the most significant advance that a fully bonded sprayed membrane enables is use of the "composite effect" between the primary and secondary sprayed concrete layers.

The composite effect

Construction that includes sprayed waterproofing, the primary and secondary concrete layers are both fully and intimately bonded to the membrane. Consequently, both of the concrete layers are acting together. Therefore the primary and secondary linings contribute to the load bearing capability of the tunnel, unlike when using sheet systems

Research carried out by Morgan Sindall, both in its Underground Professional Services division at Rugby and supported by further work at Warwick University to test this theory, have shown that two concentric rings of sprayed concrete, bonded together by Stirling Lloyd's Integritank HF tunnel waterproofing membrane, behave in the same way as a monolithic ring of the same dimensions.

While earlier work has suggested that a mechanical key between the concentric rings is required by way of an uneven interface, the Warwick University work actually shows that this is not the case and, even with a smooth interface the full effect is achieved.

This is where the major benefit for future tunnel design lies and one that will have a profound effect on the industry. If part of the primary lining can be considered to contribute in structural calculations then the ultimate application could mean that tunnels can be built with a lower overall lining thickness. This means reduced excavation, reduced volume of concrete required and a reduction in the associated transport and installation costs. There is also a significant environmental benefit in reduced waste and reduced carbon generation, in addition to the commercial benefits of building lower cost tunnels in a shorter timeframe.

So the move to sprayed waterproofing that is occurring around the world in tunneling has far wider implications than "only" achieving the previously seemingly impossible dream of dry tunnels. It also produces significant environmental and commercial benefits. Better performance, greater longevity, reduced environmental impact and lower cost. In a world reeling under financial constraints, this could not have come at a better time. ■

Contributed by Sterling Lloyd Polychem, Ltd., Cheshire, United Kingdom. e-mail info@sterlinglloyd.com.

Giving credit where credit is due: Tunnel education in the US

I knew it was inevitable when I was writing the article about tunnel education in the United States that I would forget some names of prominent individuals. Although the emphasis of the article was on institutions of higher learning, I did try to identify various individuals that had contributed to tunneling over the past few decades. During the NAT convention in Portland, OR (June 20-23), it became obvious that some names had been overlooked.

Foremost among those names was Mike Vitale from Hatch Mott McDonald in Cleveland, OH. Vitale is a University of Illinois graduate who has been actively involved in tunnel design for more than 25 years. Other names that popped up during discussions in Portland included Larry Eckhart, Refik Elibay, Ed Plotkin, Charlie Daugherty, Ray Henn, Bob Stier, Jerry Shaw, Ted Budd, Paul Zick, Toby Wightman, Jon Kaneshiro, Tom Clemens and Lok Home.

Two other aspects of the tunneling industry became obvious in Portland. The first is that the tunneling industry truly operates like a gigantic fraternity. Many organizations associated with tunneling have been around forever and specialize in the successful pursuit of tunneling projects. Those organizations include tunnel designers, tunnel contractors, owners, equipment suppliers, specialty contractors and major law firms.

The second aspect of tunneling that is quite interesting is how many family names are associated with the industry, such as Kiewit, Shea, Traylor, Kenny, Diponio, Coluccio, Akkerman, Lovat, Robbins, Shank, Bradshaw, Affholder, Atkinson, Kassouf and many others, I am sure.

Finally, I would like to highlight a few more names of some of the "old-timers" that were not listed in the original article such as Gail Knight, Vint Garbesi, Al Provost, Gene Waggoner, Jim Irish and Terry McCusker.

Having written the original article I now know what my wife endured trying to decide who to invite to my daughter's wedding. I know there are still more names that should be mentioned, but I guess we have to call it quits for now.

Gary S. Brierley
Andre Hawks

FEATURE ARTICLE

North American Tunneling 2010 Conference highlights

Even though the economy of the United States remains in recession — or not, depending on which economist you listen to — municipalities still need improved transportation, water and wastewater transit systems. And they are willing to spend the necessary funds on those systems, provided they are affordable, environmentally friendly and sustainable.

From June 20-23, professionals in the tunneling and underground construction industry from around the world gathered in Portland, OR to learn new ways of providing those systems using the latest technology available. The North American Tunneling (NAT) conference attracted 803 attendees and 108 exhibiting suppliers of equipment and services.

The exhibit at the NAT Conference attracted 108 exhibitors.

In addition to the technical programming, provided by the world's leading professionals in the underground construction industry, the NAT program included two short courses, Grouting in Underground Construction, and Soft Ground Tunneling. Two workshops were also held — Better Specifications for Underground Projects: Perspectives of Owners, Engineers, Contractors and Suppliers; and Professional Liability Issues for Consulting Engineers on Tunneling Projects: Perspectives of Owners, Constructors and Consulting Engineers.

Technical programming

The technical program at NAT included more than 100 papers presented in four tracks — technology, design, planning and case histories. Among the topics covered by authors from around the world were project planning and implementation, risk, project sustainability, project delivery, budgeting, innovation, applied technologies, and conventional and pressurized face tunneling.

The papers are available as a proceedings volume, available from SME, US$139 for members and student members, and US$189 for nonmembers. Online www.smenet.org/store; phone 303-948-4225 or 800-763-3132; e-mail books@smenet.org; mail SME, Book Coordinator, 8307 Shaffer Parkway, Littleton, CO 80127.

The following is a sampling of a few of the presentations.

Steve Kral, Editor

Projects in Portland. Tunneling in Portland mirrors the industrialization and urbanization of America, according to Susan L. Bednarz, Paul T. Gribbon and Joseph P. Gildner. In the Applied Technologies session, the three presented a history of tunneling in the Portland area, including rail and highways. Beginning with rail tunnels in the early 1900s, tunneling has evolved as a tool to protect the environment by reducing combined sewer overflows into the Willamette River that runs through Portland.

At least 14 tunnel projects exist in the Portland area, the authors said, ranging from a 1909 rail tunnel to the East Side CSO Tunnel, currently under construction. The variety of tunneling methods used to construct these tunnels reflects the diverse local geology, ranging from basalt bedrock to open gravel and boulders to soft silt. Challenging ground conditions have led to tunneling innovation, including the first use of a slurry mixshield tunnel boring machine (TBM) in North America and the longest microtunneling drive in the United States.

Shaft lining. In their paper "Large diameter segmentally lined shafts," Darin R. Kruse and Rodney Meadth, of Cobalt Construction, examined some of the unique engineering challenges in building shallow, large diameter (up to 90 m or 300 ft) segmentally lined shafts for nontraditional heavy civil or commercial uses, such as parking, storage, transportation or housing facilities.

The proposed design and construction approach the authors discussed addressed several inefficiencies that are currently present in commercial practice. The studied design considers excavation depths up to 15 m (50 ft), and includes internal structural bracing (floors and ring beams) and post-tensioning elements in its final form. The results of economic modeling, field testing, prototype grouting methods and two-dimensional and three-dimensional finite element models were discussed.

TBM hybrids. The Lake Mead No. 3 Intake Tunnel will be constructed using a hybrid TBM — both slurry shield and open mode operation are possible — mostly through tertiary sedimentary rocks. Georg Anagnostou, Linard Cantieni and Marco Ramoni, of ETH Zurich, and Antonio Nicola, of ImpregiloSpA, discussed the geotechnical aspects of operating a TBM at the Lake Mead project.

Due to the poor quality of the ground and the high pore pressures prevailing in the 4-km- (2.5-mile-) long subaqueous section of the tunnel (up to 14 bar, the highest pressures seen to date in closed shield tunneling worldwide), the authors said that particular attention must be given to the risk of shield jamming or face collapse during boring or during the performance of maintenance activities in the working chamber. They examined the expected geological-geotechnical conditions and discussed their potential impact on the operation of the hybrid TBM (mode of operation and face support pressures), as well as proposed auxiliary measures, including advance drainage, grouting and decision-making during construction.

Equipment suppliers showed the latest in tunneling technology.

Underground structure design. Sustainable design is an integrated design process that complies with the principles of economic, social and ecological sustainability. In his paper, "Sustainable underground structure designs," Lei Fu, of URS Corp., said the philosophy of sustainability should be applied at various phases of an infrastructure system — the planning, design, construction and operation. The author reviewed current practices in sustainable infrastructure design, especially underground structure design. And he discussed the issues related to the application of the philosophy of sustainability to the design and construction of underground projects.

Sustainable tunnels. The concrete industry is one of the planet's largest consumers of natural resources. In their paper "Design for sustainable and economical tunnels," Derek J. Penrice and Bradford F. Townsend, of Hatch Mott MacDonald, said that cement production results in approximately 7 percent of the annual global emission of carbon dioxide (CO2). With the continued threat of global warming, and increased costs for commodities, they said that it is critical that owners, designers and contractors promote the development of sustainable underground structures that make economical use of natural resources.

This process starts with design, the authors said. The selection of a particular design standard and design concept, as well as materials specification can significantly influence a project's resource requirements, and cost. They identified ways the underground construction industry can develop and promote more sustainable and, consequently, more economical practices within the industry.

Corrosion protection. Wastewater tunnels are continually exposed to highly corrosive environments. Owners are requiring 100-year design lives for their tunnels. So these tunnels, traditionally lined with concrete, will require protection from the corrosive environments they are deployed in. URS Corp.'s James B. Carroll and Heather M. Ivory discussed the available corrosion protection products on the market today for rehabilitation and new constructions. They examined the risks involved with the application of corrosion protection products in underground structures and the cost associated with these products.

Geotechnical variability. Geotechnical analyses for long tunnels should account for both variability and uncertainty, according to Jack Raymer, of Jordan, Jones and Goulding. Variability is a natural condition of the ground, he said. Uncertainty involves limits in knowledge about the ground. Variability can be described geologically and statistically using models based on the bell curve.

Ground problems typically involve the extreme conditions at the tails of the bell curve. Uncertainty comes from having a limited amount of data, models that are imperfect and the change in scale between boreholes and the tunnel. Raymer provided several examples to show how baselines can be developed to account for both variability and uncertainty.

Washington D.C. river projects. The Anacostia River Projects (ARP) is the major component of the long term control plan for the District of Columbia Water and Sewer Authority. Amanda Morgan, of Jacobs Associates; Kevin Fu, of URS Corp.; and Ronald E. Bizzarri and Carl M. May, of the District of Columbia Water and Sewer Authority, said the ARP consists of an approximately 20.4-km- (12.7-mile-) long tunnel system. The project includes 18 large-diameter deep shafts and supporting structures.

The authors reviewed the ongoing geotechnical investigations used to characterize the subsurface for the ARP. Drilling methods include sonic and conventional, they said, and boring spacing is about 190 m (600 ft). Field testing includes pressuremeter, vane shear and crosshole seismic. Laboratory testing includes index, triaxial, consolidation, soil abrasion testing (SAT), soil chemistry and water quality. The estimated cost for the investigations is $6.5 million.

Setting the owner's budget. Many major underground public works programs have had problems with original published budgets compared with actual final costs. The cause of this, in most cases, is a poorly considered initial budget, according to Paul T. Gribbon and Julius Strid, of Portland's Bureau of Environmental Services and EPC Consultants, respecitively. The problem, they said, is that the public expects an accurate project budget to be published before there is any site investigation, engineering or design or a bid from a contractor, in addition to the inevitable changes that occur during all phases of an underground public works program.

The responsibility for establishing the budget falls squarely on the owner, the authors said. This usually occurs when the owner has no avenue for assistance from contrac¬tors or designers familiar with the type of work since they cannot hire someone to help them until program has begun. Some owners are lucky enough to have experienced personnel on staff familiar with major underground projects. But most do not, since these projects are not a regular occurrence for owners.

Additionally, the benefits of a project are not necessarily fully explored prior to the go-ahead to offer a contrast between the anticipated public investment in the project versus what the economic-environmental-community benefits are estimated to be throughout its life.

Gribbon and Strid presented an approach to setting a realistic owner's budget and preparing a benefits analysis for an underground public works program. Their presentation attempted to define the problem and give some answers. Included was a program budget guideline checklist, a benefits checklist and a few rules of thumb for predicting budgetary items.

Urban Ring Project. Three authors described the key planning phase issues and tradeoffs associated with a potential tunneled portion of the proposed Urban Ring Project in Boston, MA. D.M. Watson and J.P. Davies, both of Hatch Mott MacDonald; and J.A. Doyle, of AECOM, said the project is intended to provide new and improved transit service along an orbital corridor in Boston and several surrounding municipalities. It would link up the existing radial transportation system outside of the downtown core with a bus rapid transit system.

The tunnel portion of the corridor would be approximately 2.4-km- (1.5-miles-) long and would be constructed under the densely developed Longwood Medical and Academic area (LMA) and Fenway neighborhood of Boston. The dense urban environment, coupled with highly sensitive surface and subsurface conditions, imposed many constraints on the planning and conceptual design. Consequently, a range of alignments and profiles were considered, along with different tunnel construction techniques. These included single bore or twin bore pressurized face TBMs up to 12.8 m (42 ft) in diameter, sequential excavation methods and cut-and-cover techniques.

UCA awards, UCA Executive Committee members

The UCA of SME presented its individual and project of year awards during NAT. Refik Elibay received the 2010 Outstanding Individual Award. Elibay is a tunneling practice leader with Jacobs Engineering Group. His career spans more than 40 years in tunneling and underground construction. He has also served on the UCA of SME Executive Committee.

Edward S. Plotkin was the recipient of the Lifetime Achievement Award. Throughout his career, he has worked as a tunnel constructor and as project manager for numerous tunneling and construction projects, mostly in the East. He was also commissioner of public works for Westchester County in New York, where he was responsible for maintaining county facilities and a $200-million annual budget for new and ongoing capital expenditures.

The UCA of SME presented Levent Ozdemir its Outstanding Educator Award. He retired from the Colorado School of Mines (CSM) after 32 years of teaching and conducting research into tunneling and underground construction. Throughout his career at CSM, Ozdemir taught undergraduate and graduate courses in design and construction of underground structures, tunneling, site investigations, excavation project management and underground mining.

The Metro Gold Line Eastside Extension Tunnels project received the UCA of SME Project of the Year Award. The project extended the Los Angeles County Metropolitan Transportation Authority's light rail system to the East Los Angeles communities. The project included a 2.7-km (1.7-mile) underground segment in cut-and-cover and twin-bored tunnel structures. Work was performed by Eastside LRT Constructors, a joint venture between Washington Group International, Obayashi and Shimmick. The tunnels were contracted to Traylor Brothers and Frontier Kemper.

Four new members of the UCA of SME Executive Committee were elected during NAT (see page 43). A fifth, Marcus R. Jensen, was re-elected to serve another term.

The four new members include Douglas Harding, vice president of international sales with The Robbins Co.; Colin A. Lawrence, senior vice president with Hatch Mott MacDonald; Michael Rispin, managing director of Normet's North American region; and David Rogstad, vice president and chief operating officer of Frontier Kemper Constructors. ■

Professional liability workshop generates interesting discussions

The Professional Liability Issues for Consulting Engineers on Tunneling Projects workshop held during the North American Tunneling conference was well attended and produced several interesting discussions about designer risk.

The workshop began with a presentation by David Hatem and topical discussions by David Corkum, Jack Lemley, Doug MacDonald, Gary Brierley and Mike Silchuck. David Hatem's presentation was comprehensive and covered many topics associated with "disappointed expectations and risk allocations" for tunnel designers including design/build procurement, subsurface investigations, construction means and methods, differing site conditions, standard of care, performance specifications, insurance considerations and third party exposures. Four of the above issues were discussed in greater detail by the panel and the audience.

Serving as the owner's consultant for a design/build project. The owner's consultant for a design/build tunnel must set the stage for every issue associated with project success including project layout, subsurface conditions, third party impacts, design requirements and construction conditions/limitations. The owner's consultant will also be heavily involved with qualifying and selecting the design/build team. It is fair to say that it is more difficult to prepare the contract package for a design/build procurement than it is for design/bid/build.

Serving as the contractor's designer for a design/build project. The contractor's designer for a design/build tunnel is also inundated by a variety of project responsibilities. In general, designers should only work with contractors with whom they have a longstanding relationship and who are dedicated to the highest standards of quality and safety. Even so, the contractor's designer becomes involved with many issues associated with construction means and methods that may not be well defined in the contractual relationship. Ground control procedures associated with adjacent third parties are particularly difficult to define since there are no contractual relationships with those entities.

Gary Brierley

Gary Brierley, member UCA of SME, is president Brierley Associates LLC, Littleton, CO, email ataylor@brierleyassociates.com.

Preparation of a geotechnical baseline report. Geotechnical baseline (GBR) reports for a design/build tunnel are difficult to write and require extensive coordination between the wwner's and the contractor's geotechnical consultants. Multiple phases of subsurface investigation and GBRs for bidding and construction must be prepared. In addition, subsurface exploration results by the contractor must be incorporated into the contract and could result in claims of differing site conditions at the beginning of a project. In general, only the best and most experienced geotechnical consultants should become involved with this process and a great deal of thought must be invested in how the subsurface risks are distributed among the parties.

Indemnification and duty to defend. Indemnification and duty to defend clauses in contract documents for engineering services are becoming increasingly onerous. This is especially true for subconsultants who are being asked to accept "flow down" requirements from the prime agreement. In general, those clauses may not be insurable and are sometimes not legally enforceable. As a minimum, a design professional should not accept responsibility to indemnify or defend a client except for actions resulting directly from negligence and/or willful misconduct. Owners must also consider the fact that the best, most experienced designers will not agree to onerous indemnification provisions that actually increase the possibility of major design errors for those projects.

This workshop was generally worthwhile but I believe additional emphasis on this topic and a much more focused and hard-hitting workshop would be appropriate. Tunnel designers need all the help they can muster when it comes to minimizing risk and avoiding liability for underground construction projects. ■

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Hudson River Crossing	NJ Transit ARC Program	Newark	NJ	Subway	8,000 x 2	24.5	2010	Bid date 10/05/10
Palisades Tunnel	NJ Transit ARC Program	Newark	NJ	Subway	5,400 x 2	24.5	2009	Awarded to S3 JV
Manhattan Tunnel	NJ Transit ARC Program	New York	NY	Subway	6,000 x 2	24.5	2009	Awarded Barnard/ Judlau JV
THE 34th St. Cavern & Station	NJ Transit ARC Program	New York	NY	Subway	2,200	100 x 100	2011	Under design
Second Ave. 72nd Street Station	NYC-MTA	New York	NY	Subway	1,000	70	2010	Awarded SSK JV
Water Tunnel #3	NYC-DEP	New York	NY	Water	24,000	20	2012	Under design
Harbor Siphons Tunnel	NYC-DEP	New York	NY	Water	10,000	10	2010	Awarded OHL/Tully JV
Cross Harbor Freight Tunnel	NYC Regional Development Auth.	New York	NY	Highway	25,000	30	2013	Under design
Clinton CSO Tunnel	City of Syracuse	Syracuse	NY	CSO	2,000	17	2011	Under design
Silver Line Extension	Boston Transit Authority	Boston	MA	Subway	8,400	22	2013	Under design
East-West Subway Extension	Baltimore MTA	Baltimore	MD	Subway	32,000	18	2012	Under design
WASA CSO Program Blue Plains Tunnel Anacosita River Tunnel Northeast Branch Tunnel Northeast Boundry Tunnel	DC Water and Sewer Authority	Washington	DC	CSO CSO CSO CSO	23,400 12,500 11,300 17,500	23 23 15 23	2011 2013 2018 2021	RFQ 3Q 2010 Under design Under design Under design
North/South Tunnel	Georgia DOT	Atlanta	GA	Highway	77,000	41	2015	Under design
Snapfinger Interplant CSO Tunnel	Dekalb County	Decatur	GA	CSO	26,400	28	2010	Under design
Port of Miami Tunnel	Florida DOT	Miami	FL	Highway	7,400	39	2011	Awarded Bouyges Civil Work Florida
Lockbourne Interceptor Sys. Tunnel	City of Columbus	Columbus	OH	Sewer	10,000	12	2012	Under design
OSIS Aug. & Relief Sewer Tunnel	City of Columbus	Columbus	OH	Sewer	25,300	18	2010	Kenny/ Obayashi JV low bidder
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

The editors of Tunneling & Underground Construction encourage UCA of SME members to submit projects to the Tunnel Demand Forecast online at www.smenet.org. The items will be posted on the online TDF once they are verified.

FORECAST T&UC

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Euclid Creek Tunnel	NEORSD	Cleveland	OH	CSO	18,000	24	2010	Bid date 09/30/10
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	9,600	30	2015	Under design
Water Treatment Plant #4	City of Austin	Austin	TX	Water intake	45,000	7 to 9	2010	Bid date 1st Q 2011
Waller Creek Tunnel	City of Austin	Austin	TX	CSO	5,300	22	2011	Under design
Deep Rock Connector Tunnel	City of Indianapolis	Indianapolis	IN	CSO	34,000	18.5	2011	Under design
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
Drumanard Tunnel - Pilot Tunnel	Kentucky DOT	Louisville	KY	Highway	2,200	12 x 12	2011	Under funding review
Alaskan Way Highway Tunnel	Washington DOT	Seattle	WA	Highway	10,500	54	2011	Bid date 10/28/10
Central Subway Tunnel	S.F. Municipal Trans. Authority	San Francisco	CA	Subway	16,600	20	2011	Under design
Bay Tunnel	S.F. Public Utility Commission	San Francisco	CA	Water	26,200	10	2010	Awarded Michels/ Jay Dee/Coluccio
New Irvington Tunnel	S.F. Public Utility Commission	San Francisco	CA	Water	18,200	10	2010	Awarded Southland/Tutor Perini JV
Sunnydale Aux. Sewer Tunnel	S.F. Public Utility Commission	San Francisco	CA	Sewer	4,000	11	2010	Awarded Super Excavators
San Francisco DTX	Transbay Joint Powers Authority	San Francisco	CA	Transit	6,000	35 to 50	2012	Under design
LA Metro Wilshire Extension	Los Angeles MTA	Los Angeles	CA	Subway	24,000	18	2012	Under design
SVRT BART	Santa Clara Valley Trans. Authority	San Jose	CA	Subway	22,700	20	2011	Under design/ delayed
Spadina Line Extension	Toronto Transit Commission	Toronto	ON	Subway	22,000	18	2010	Awarded 4th Q 2010
Eglinton West Tunnel	Toronto Transit Commission	Toronto	ON	Subway	10 km	20	2011	Under design
Yonge Street Extension	Toronto Transit Commission	Toronto	ON	Subway	15,000	18	2013	Under design
Port Mann	Greater Vancouver Regional District	Vancouver	BC	Water	3,300	10.5	2010	Bid date 10/01/10
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 Transportation	Golden	BC	Highway	4,800 x 2	45 x 32	2012	Under design

2011 UCA of SME Calendar Call for Photos and Sponsors

Do you have great tunnel project photos? UCA is asking for photos for the 2011 calendar that will be sent to UCA members. The best 18 photographs will be selected. One for each calendar month....along with photo credits. Please send your high resolution photos (tif or jpg format) to Mary O'Shea at oshea@smenet.org by October 1, 2010. Selection of photos will be made by October 30th, 2010.

OR

You can be a sponsor for the 2011 UCA Calendar! The benefits include:

- Guaranteed photo of your choice in the calendar
- Photo credit
- Company logo on the same page as the photo

• Sponsorship ($1,000) •
• Sponsorship for the Front or Back Cover of the calendar ($3,000) •

Complimentary calendars will be sent to 700+ UCA members.

If you would like to be a sponsor, please contact Liz Jones:
jones@smenet.org or 303.948.4216

EXECUTIVE COMMITTEE

UCA announces new Executive Committee members

Four new members joined the Executive Commttee of the Underground Construction Association (UCA) Division at the North American Tunneling Conference in June 2010. Marcus Jensen was re-elected to serve another term. They began their terms on July 1, 2010.

Douglas Harding — Committee Member

Douglas Harding is the vice president of the International Sales Division of The Robbins Co. Robbins is a global tunnel boring machine company based in Solon, OH. Robbins has four primary manufacturing facilities and seven international sales and service locations.

Harding has served in several capacities with Robbins since 1979. These include managing the engineering, project management and manufacturing departments of Robbins. Harding's current responsibilities include international sales, as well as responsibility for overseeing the Robbins Customer Service Division. This division incorporates the field service and spares departments for North America and other divisions in China, Europe and India.


HARDING

Harding received a B.S. degree in mechanical engineering from Cleveland State University in 1982.

Marcus R. Jensen — Committee Member

Marcus R. Jensen spent the year before he entered college as a welder and structural steel fabricator. He then toured throughout Southeast Asia and India in 1976. This convinced him that he would like to make his contributions to the world as a civil engineer.

Jensen earned his B.S. degree in civil engineering from San Diego State University in 1982 and began a 28-year career focused on engineering public water systems. During the past 15 years, he has been associated with the planning, design and construction of more than $2 billion of regional water system improvements for southern Nevada, including submerged water intakes, tunnels, pumping stations, pipelines and water treatment facilities.

Jensen is a professional engineer and became director of the Southern Nevada Water Authority's engineering department in 1999. The Southern Nevada Water Authority is currently engaged in more than $500 million of construction for Intake No. 3 at Lake Mead.


JENSEN

Colin A. Lawrence — Committee Member

Colin A. Lawrence is senior vice president with Hatch Mott MacDonald and serves as the firm's deputy practice leader for tunnels in the eastern United States. He has more than 30 years of specialized experience in all types of tunneling for transportation, water and wastewater projects in a variety of ground conditions in soil and rock. He has been involved in all aspects of underground project implementation from planning, design, project management to construction management and project completion.

Lawrence has gained a reputation for successfully undertaking some of the more technically challenging and high-risk tunnel projects around the world, including the Channel Tunnel, the Storebaelt Rail Tunnel Project in Denmark and the Strategic Sewerage Disposal Scheme in Hong Kong.


LAWRENCE

Michael Rispin — Committee Member

Michael Rispin earned a bachelor's degree in mining engineering, with a minor in management, from McGill University in 1985. After graduation, he joined DuPont Canada's Explosives Division and served in positions of increasing responsibility. His 12-year career with explosives concluded at Austin Powder Canada. Throughout this period, he was primarily involved with underground applications in mining and tunneling construction.

In 1996, Rispin accepted the position of mining manager with

Master Builders in Cleveland, OH and became involved with sprayed concrete. He was responsible for the Allentown Equipment Division and served as manager of underground construction for North America. This culminated with an assignment in Switzerland with BASF, a company acquisition. His 13-year focus was on tunneling and underground mining. Since 2009, Rispin has served as managing director for Normet's North America Region, and he also serves as president of Normet Americas and Normet Canada, a manufacturer and supplier of equipment for tunneling and underground mining. It is also involved in the processes of sprayed concrete and explosives charging.

In addition to the UCA of SME, Rispin is a member of the Professional Engineers of Ontario, the Canadian Institute of Mining, Metallurgy and Petroleum, the American Society of Civil Engineers, the International Society of Explosives Engineers, the American Concrete Institute and the American Shotcrete Association.


RISPIN

David Rogstad — Committee Member

David Rogstad received a B.S. degree in building construction in 1979 and an M.B.A. in 2001, both from the University of Washington. From 1979 through 1981, Rogstad worked for Genstar Construction in Bellevue, WA. In 1981, he joined S.J. Groves & Sons and worked as an engineer on lock, dam and bridge projects on the Mississippi and Saginaw rivers.

He worked in Alaska from 1985 through 1991. He first served as project engineer for Christenson, Raber Kief & Associates of Seattle, WA, and later as project engineer and project manager for Enserch Constructors on the Bradley Lake hydro project. Rogstad was project manager for S.A. Healy Co. on the Dallas Area rapid transit's NC-1B project, which involved 10,668 m (35,000 ft) of rail tunnel and related structures. He joined Frontier Kemper Constructors (FKCI) in 1995 as an estimator in its headquarters office. In 1997, he was promoted to regional manager of FKCI's Northwest Division office. In 2004, he was elected vice president and chief operating officer.


ROGSTAD

Rogstad became president and chief executive officer of the company in 2008. ■

New topics to be discussed at Breakthroughs in Tunneling course

Emerging technologies in tunnel boring machine (TBM) construction increasingly allow large-diameter tunnels to be bored across North America and around the world. Projects in Niagara Falls and Seattle are among others in Europe and Asia using TBMs with diameters up to and exceeding 15.2 m (50 ft). The current plan for the Alaskan Way project in Seattle is to use a soft-ground TBM with a diameter of approximately 16.8 m (55 ft), which would be a world record.

Breakthroughs in Tunneling, an annual tunneling short course at the Colorado School of Mines (CSM), will explore the issue of TBM technology for large-diameter tunnels and more. The course will be held Sept. 22-24, 2010 on the CSM campus in Golden, CO.

Also new to the agenda is a focus on conditioning for pressurized face tunneling. This timely subject includes a discussion of earth pressure balance and slurry TBM projects that are coming up in the United States and for which proper face conditioning is a critical aspect of success.

CSM professor emeritus Levent Ozdemir, a recognized expert on mechanized tunneling, and Tim Coss, president of Microtunneling, are the course directors. This one-of-a-kind course is designed for contractors, owners and design engineers who are building or planning to build a tunnel. The course is organized by CSM in conjunction with *Tunnel Business Magazine* and Microtunneling. Attendees will receive continuing education units for attending the course. For more information or to register for the course, visit www.tunneling.com. ■

UCA Division seeks nominations for the 2011 Executive Committee

The Underground Construction Association (UCA) Division seeks recommendations and nominations from all UCA members for interested individuals to serve on the 2011 UCA Executive Committee. The executive committee consists of three officers — chair, vice chair and past chair — and four directors from each of the following areas: engineers, contractors, owners and suppliers. Ideally, the UCA Executive Committee has balanced representation from the four categories, but the committee has the option to have more members serving in one or more categories with fewer representatives in others.

If you would like to nominate someone for consideration, please e-mail your recommendation to Mary O'Shea, oshea@smenet.org, at SME headquarters by Nov. 1, 2010. SME staff will compile all nominations for the UCA Nominating Committee's consideration. Please identify in which of the four areas the individual should be considered for service — engineer, contractor, owner or supplier. Also include a brief biography or résumé outlining the person's industry experience and service to UCA and other professional organizations.

Please remember that the individual must be a member of the UCA of SME. ■

UCA calls for award nominations

The Underground Construction Association (UCA) Division of SME will present the UCA awards at the 2011 Rapid Excavation and Tunneling Conference in San Francisco, CA. The awards to be presented are: Outstanding Individual, Project of the Year, Outstanding Educator and the Lifetime Achievement Award. The nominations for the awards will be reviewed and the winners selected by the UCA Executive Committee at its January meeting. The recipients' photos and biographies will appear in the June issue of *T&UC*. Guidelines and nomination forms are available on the UCA of SME website, uca.smenet.org. Submit nominations by Jan. 3, 2011 to Mary O'Shea at oshea@smenet.org. ■

Submit your photos for the UCA calendar — or become a calendar sponsor

Do you have great tunnel project photos? The UCA Division is asking for photos for its 2011 18-month calendar, which will be available to all UCA members. The best photographs will be selected, one for each month, and credit will be given to each photographer. Please e-mail your high resolution photos (tif or jpg format) to Mary O'Shea at oshea@smenet.org by Oct. 1, 2010. The final photos will be selected by Oct. 30, 2010. We want to see your work.

Or be a sponsor

Sponsor's benefits include a guaranteed photo of your choice in the calendar, photo credit and a company logo on the same page as the photo. Inside sponsorships of $1,000 and front or back cover sponsorships of $3,000 are available. Complimentary calendars will be sent to the more than 700 UCA Division members. Potential sponsors should contact Liz Jones at jones@smenet.org or phone 303-948-4216. ■

Croton Aqueduct Tunnel, Croton, NY. TBM Breakthrough with Crew and Staff. Photo courtesy of Lovat.

PERSONAL NEWS

Akkerman Inc. has appointed **RICK ZAVITZ** (SME) to the position of area sales manager for the North American and Canadian markets. He has more than 17 years of expertise in lubrication products, slurry separation, mud mixing and directional drill manufacturing in the trenchless market. Zavitz previously worked for Wyo-Ben in Billings, MT, Surface to Surface Inc. and Trenchless Utility Equipment. ■

Tsurumi to represent Primax Pumps in Europe

Tsurumi Europe has announced an agreement with Australian pump manufacturer, Primax Pumps, to sell its automatic self-priming diesel pumps to Germany, France, Austria and Switzerland. The new pumps are highly versatile and will complement Tsurumi's current product range. Tsurumi Europe will introduce the new pumps at the bauma 2010 trade fair in Munich, Germany (April 19-25).

Tsurumi will sell Primax's Yakka pumps in Europe.

Tsurumi Europe continues to expand its range of specialist pumping solutions with the addition of a new product line.

The new pump line joins Tsurumi's current offerings and allows the company to provide a compact, mobile and fuel efficient pumping solution for almost any application.

The Yakka are compact and maneuverable pumps that can be mounted on a single axle trailer. The versatile range has a maximum head of 67 m (220 ft)and maximum flow of 132 L/s (2,090 gpm). The pumps can be used for general dewatering and wellpoint applications.

The Yakka have market leading fuel efficiency, with a full tank providing up to 30 hours of use. The pumps are also very quiet thanks to a special acoustic casing. Running at 1,500 rpm, the Yakka emits just 65.5 dBA at 7 m. Gull wing doors allow for easy maintenance.

www.tsurumi-europe.com

Bobcat introduces new line of compact excavators

Bobcat has introduced a new series of compact excavators known as the M-series. The new compact excavators are reengineered to deliver greater strength in a lighter machine.

Backed by industry-leading cycle times, M-series compact excavators provide improved digging performance in a lighter machine. The advanced hydraulic system provides more usable power, consistent and smooth operation and predictable results every time. Some new features include auto shift travel, auto idle and fingertip controls.

With reduced noise levels, improved climate control and convenient storage, M-series models are built for all-day operation. The new easy-to-use rotary knob allows for precise throttle adjustments.

M-series compact excavators feature a redesigned work group for improved lifting performance and durability. The new X-frame undercarriage offers better ground clearance and less cleanup time. Integrated slew brakes hold the load steady when working on a slope.

The machines include simple checkpoints for easy maintenance. The swing-open tailgate and side access hood allows for eas access to key maintenance points. Side panels are easily removed for additional engine access.

www.bobcat.com

Bobcat M series excavator.

• Denotes new listing.

Industry Events

September 2010

• **21-24, InnoTrans 2010,** Messe Berlin, Berlin, Germany, Italy. Contact: Messe Berlin GmbH, phone 49-030-3038-2036, fax 49-030-3038-2190, e-mail innotrans@messe-berlin.de, website www.innotrans.com.

• **22-24, Breakthroughs in Tunneling Short Course,** Colorado School of Mines, Golden, CO. Contact: Levent Ozdemir, 780 Kachina Circle, Golden, CO 80401, phone 303-526-1905, e-mail lozdemir1977@aol.com, website www.tunneling.com.

October 2011

26-27, Underground Infractructure of Urban Areas 2011, Wroclaw, Poland. Contact: Institute of Civil Engineering, Wroclaw Universty of Technology, website www.uiua2011.pwr.wroc.pl.

November 2011

• **8-10, 28th International No-Dig 2010,** Suntec Singapore International Convention & Exhibition Center, Singapore, China, website www.istt.com.

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

March 2011

• **27-31, NASTT's 20th No-Dig Show,** Gaylord National Resort & Convention Center, Washington, D.C. Contact: Michelle Hill, Benjamin Media, Inc. 1770 Main St., P.O. Box 190, Peninsula,OH 44264-0190, phone 330-467-7588, fax 330-468-2289, e-mail mmagyar@benjaminmedia.com, website www.benjaminmedia.com.

May 2011

• **21-26, ITA-AITES World Tunnel Congress,** Helsinki, Finland. Contact: Congrex/Blue & White Conferences Oy, P.O.Box 81, FI-00371 Helsinki, Finland, phone 358-9-5607500, fax 358-9-56075020, e-mail wtc11@congrex.fi, website www.wtc11.org.

June 2011

• **19-22, NAT,** San Francisco, CA. Contact: Meetings Department, SME, 8307 Shaffer Parkway, Littleton, CO 80127, phone 800-763-3132 or 303-979-3461, e-mail sme@smenet.org, website www.smenet.org. ■

UCA of SME

George A. Fox Conference
Jan. 26, 2011
Graduate Center City University of New York, New York, NY

FOR ADDITIONAL INFORMATION CONTACT: Meetings Dept., SME 800-763-3132, 303-948-4200 fax 303-979-4361, e-mail sme@smenet.org

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