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TBM tunneling in Pakistan
The Superconducting Maglev project
2019 Cutting Edge Conference

Special Editorial Supplement from the publisher of Mining engineering

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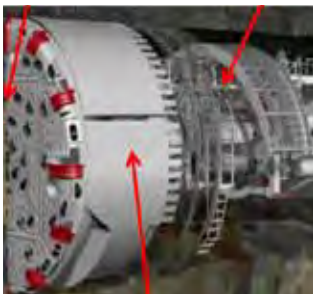
The Superconducting Maglev project is a proposed high-speed train system that would connect the city of Baltimore to Washington, DC. It would use the same technology that has been in operation in Japan since 1964. On page 18, Vojtech Gall and his co-authors provide an update on the proposed project. Cover photo: Shutterstock.

Feature Articles



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Want to get involved in UCA? Let us know and we can help

Engagement with the activities of UCA is the best way to make sure that what comes out of the Association is what you want. To get engaged, all you need to do is raise your hand. Also, it should be recognized that the people who should be capturing your interest (and especially me) may not get back to you immediately. This is a fault of the UCA but we are trying to do better. It really helps us, and helps you too, if you could raise your hands multiple times to make sure you get noticed.

Please do not think you are being ignored. We are all volunteers with day jobs and it is sometimes difficult to make every connection in a timely manner. So, I hope all of you potential volunteers will keep prompting us and keep the good ideas and the good energy coming.

One surefire way of accelerating your involvement in UCA is to volunteer to author an industry guideline document. Bringing the idea, as well as your energy, to such a project immediately benefits both you as an individual and the industry. Bring your idea to the attention of any executive committee member that you know — or email me — and let's get the ball rolling on whatever you think the industry needs. UCA can help with identifying a committee and industry reviewers to get such a guideline published through SME.

One item that many members are apparently not aware of is the amazing reference library contained within the OneTunnel.org database. OneTunnel.org contains every paper published in the North American Tunneling conference and *Rapid Excavation Tunneling Conference Proceedings* volumes, plus many others, for a total of nearly 140,000 technical papers and documents on every possible underground subject. It is a perfect way to check on the latest industry developments; the standard of the practice in many and various fields; as well as providing the author, whom you can call for additional information if needed.

OneTunnel.org provides every UCA member with the ultimate resource of technical information. It is freely available on the UCA web site. To get there, simply go to https://www.smenet.org/uca; log in using your credentials; look under the "publications and resources" section and click on OneTunnel. You can also type https://www.onetunnel.org/ directly into your browser.

OneTunnel is a keyword-searchable database to which UCA and SME continue to add references. It is a fabulous benefit to you as a member of UCA.

In closing, I am constantly seeking to improve the connection between the UCA and you as a member of the tunnel industry. Let me know how you think the UCA of SME can better serve your needs and the needs of the industry. I look forward to hearing from you.

Robert JF Goodfellow,
UCA of SME Chair

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ARGENTINA'S AGUA SUR

In recent years, TERRATEC's order book has demonstrated significant growth around the world. In Argentina, two 4.66m diameter TERRATEC Earth Pressure Balance Machines (EPBM) are currently being deployed by Italian contractor CMC di Ravenna on a 13.5km-long tunnel that will carry drinking water from the newly expanded General Belgrano Water Treatment Plant to the city of Lomas de Zamora.

The tunnel is a key component of the multi-billion-dollar Agua Sur system that is being built by Argentina's national water company AySA. It is the country's largest water infrastructure project in 40 years and will provide fresh water to 2.5 million inhabitants in the southern region of Buenos Aires.

TUNNELLING SOLUTIONS | WATER

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Delta Conveyance Project moves forward

California Governor Gavin Newsom's administration issued in January a Notice of Preparation for a water project that would include an underground tunnel that would pump billions of gallons of water from the San Joaquin Delta in the northern part of California to the southern part of the state.

The Notice of Preparation is the first step in the state's lengthy environmental review process.

In 2019, Newsom halted the California WaterFix Twin Tunnel project, a similar project that would have built two tunnels for the same purpose. The new project will have only one tunnel, and it will carry less water.

The current version is called the Delta Conveyance Project. It is a single-tunnel, dual-water conveyance plan that aims to modernize infrastructure and restore and protect water supply in the Sacramento-San Joaquin Delta.

The project is a part of California's Draft Water Resilience Portfolio, released Jan. 3 by Newsom and is a derivative of California WaterFix, which is a $17 billion project that is opposed by some water agencies and environmental groups, including the Natural Resources Defense Council, because of its cost and its potential impact on threatened and endangered species. The new tunnel faces similar opposition.

With expectations that the environmental review and permitting process will take three years, construction on the new project cannot begin until at least 2023, and the Department of Water Resources (DWR) expects the overall conveyance project, if approved, will take 13 years to construct and commission, said Erin Mellon, assistant director of DWR's public affairs office.

The tunnel would be a major addition to the State Water Project, the complex system of reservoirs, aqueducts and pumping plants that deliver water to more than 27 million Californians and 3 million acres of farmland. The water comes from rain and snow in the Sierra Nevada mountains.

State officials say they need the tunnel because intake for the current system is only 1 m (3 ft) above the average sea level, making it vulnerable to climate change.

The proposal calls for a single main tunnel and pumping capacity that would accommodate a total of 6,000 cu ft per second through two intake facilities. In addition, the plan includes construction of tunnel reaches and shafts, forebays and pumping plants, which would likely require building access roads, barge unloading facilities, concrete batch plants, fuel stations, mitigation areas and power transmission and distribution lines.

Cost estimates, as well as a cost-benefit analysis and a financial analysis, will be developed during project planning, Mellon said.

The project would be funded by the State Water Contractors (SWC), a nonprofit association of 27 public water agencies, which purchases water from the California State Water Project, a DWR-operated, 1,126-km (700-mile) water storage and delivery system of reservoirs, aqueducts, power plants and pumping plants that supply water to 27 million people in California.

California's current conveyance system — which moves large portions of California's surface water supply — faces major vulnerabilities including floods, subsidence, earthquakes and climate change, said Mellon. "This project is crucial to ensuring the long-term reliability of this major water supply."

Meanwhile, Jeffrey Kightlinger, general manager of the Metropolitan Water District of Southern California, a state-established cooperative that supplies water to 19 million people in six counties, calls the plan welcome progress on a long-overdue upgrade to the state's water-delivery system.

According to the Water Resilience Portfolio, even a gradual rise in sea level will force more ocean saltwater into the San Francisco Bay/Sacramento-San Joaquin Delta and affect brackish and freshwater habitats. ■

Jury in Washington awards WSDOT $57.2 million

A jury in Thurston County, WA awarded the Washington State Department of Transportation (WSDOT) $57.2 million on Dec. 13, 2019 and said the contractor, not WSDOT, was responsible for the breakdown of the giant tunnel-boring machine (TBM) Bertha that stalled the SR 99 tunnel construction for more than two years.

Tutor Perini Corp., one of the two prime contractors that made up the Seattle Tunnel Partners (STP), said that it would appeal the verdict that also rejected STP's $330 million in claims against Washington state over the breakdown of TBM Bertha six years ago.

STP has argued that a 30 m (110 ft)-long steel pipe that Bertha hit on Dec. 3, 2013 caused the breakdown. The *Seattle Times* reported that the pipe had been installed for ground water testing by the WSDOT in 2002, during preliminary engineering for the Alaskan Way Viaduct replacement project.

In a statement, Tutor Perini emphasized a 2015 finding by the project's dispute-review board, composed of three tunneling experts,

(Continued on page 9)

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Project in Sydney, Australia faces cost overruns

The massive metro rail project in Sydney, Australia could cost as much $16.8 billion to complete, more than $4 billion above what has been budgeted for the project under Sydney Harbour.

The *Sydney Morning Herald* reported that the government originally budgeted the rail line to cost A$11.5 to $12.5 billion for the project but due to blowouts across many parts of the City & Southwest project, costs have skyrocketed.

An internal review by Sydney Metro, the state's operating agency delivering the railway, has forecast it will cost $16.8 billion to finish by 2024. The confidential budget review, completed about 18 months ago, shows the biggest projected cost overruns are for new trains and systems and excavating tunnels and sites for underground stations, such as at Martin Place and Barangaroo, and extensive work at Central and Sydenham stations.

While blaming market pressures for much of the cost blowout, the review found significant under-estimates in the much-vaunted project's final business case, which was completed about five years ago.

The cost of buying new trains and systems, and then integrating them into the rail network, is projected to nearly double to $2.3 billion.

The budget review reveals that nearly $220 million for temporary transport, which includes putting on replacement buses while the existing Bankstown rail line is closed, was not anticipated in the project's final business case five years ago.

The revelations raise questions about how the government will find the money to cover a blowout in the City & Southwest metro line, while committing the state to other rail projects whose cost will run into the tens of billions of dollars this decade.

They include the opening of a rail link to Western Sydney Airport at Badgerys Creek by 2026 — dubbed Metro Greater West — and an underground train line from central Sydney to Parramatta, known as Metro West, by the end of the decade.

The budget review shows the government is forecast to collect an extra $500 million — above what was originally anticipated for City & Southwest — from companies building offices, shops and apartments on top of new underground stations such as Victoria Cross in North Sydney.

But it reveals the large cost blowouts in other parts of the project will far outweigh the higher returns from those over-station developments.

Sydney Metro officials have requested extra funding from the New South Wales (NSW) Treasury to help cover the forecast shortfall, according to transport sources.

The government has yet to release an estimate for its planned Metro West line, from central Sydney to Parramatta, although it has said it will cost "upwards of $20 billion."

Sydney Metro said in a statement that the NSW government was "fully committed" to delivering the City & Southwest, Metro West and Greater West rail projects.

"The final cost of each project won't be known until services commence," it said.

A spokesman said Metro Northwest from Rouse Hill to Chatswood, which opened in May last year, was on time and $1 billion under budget. ■

Boring of first tunnel at Las Vegas Convention Center complete

Las Vegas Convention and Visitors Authority (LVCVA) officials announced that boring of the first of two-people mover tunnels, being dug as part of the Las Vegas Convention Center's expansion project, is nearly complete.

Brian Yost, LVCVA's chief operating officer, said the tunnel-boring machine used to bore the first, nearly mile-long tunnel would be lifted out of the ground at the far west end of the convention center campus and trucked back to the original starting point outside South Hall.

The machine will then begin to dig a second parallel tunnel.

Digging for the $52.5 million underground people-mover transit system started in November 2019.

The people-mover, which will take meetings attendees from one side of the convention center's 200-acre campus to the other, is part of a $1.5 billion renovation and expansion project. The underground transport system is expected to be finished in time for the CES 2021 gadget show in January.

Steve Hill, the authority's chief executive officer said the Boring Company is tunneling 26 to 31 m/day (85 to 100 ftpd).

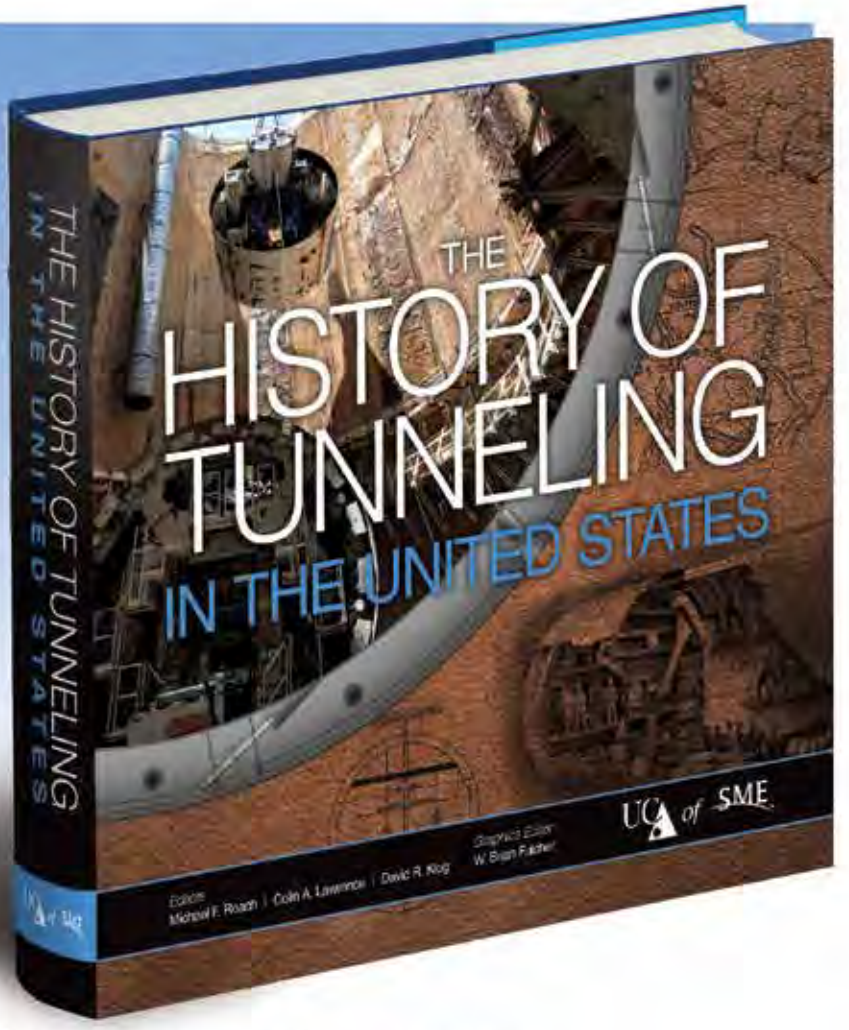
"The Boring Company has picked up speed from the first month of operation, as well as smoothed out that operation," Hill said. "They'll use the same boring machine for the second tunnel and that will probably be the last time that machine is used. They are working on a machine that is significantly faster than the one they have now."

Hill said the most difficult part left for the tunneling project will likely be completing of the only station out of three that will be underground.

That station will need to be built during a period between two conventions that will be using the parking lot above it. "That will be the most time-constrained part of the process," Hill said.

Work is expected to begin on the station following the RECon real estate show — one of the best-attended conferences in Las Vegas — in May. ■

New Book Chronicles 200 Years of Tunneling in the United States



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Largest hard-rock TBM unveiled at Mill Creek drainage relief project in Dallas, TX

In December 2019, the largest hard-rock TBM ever to bore in the United States was unveiled in Dallas, TX. The 11.6 m (38.1 ft)-diameter Robbins Main Beam TBM will excavate the 8-km (5-mile) Mill Creek Drainage Relief tunnel, and its size is not its only distinction. The adaptable machine will change size partway through the bore, to a more compact 9.9 m (32.5 ft).

The unique Robbins TBM will be used to dig a tunnel designed to provide 100-year flood protection for east and southeast Dallas, areas affected in recent years by severe storms. The tunnel will protect 2,200 commercial and residential properties, including Baylor Medical Center. The current drainage system in these areas was constructed 50 to 70 years ago, and only provides two to five years of flood protection. "The completion of the TBM assembly marks a major milestone in the Mill Creek Tunnel Project," said Council Member Lee Kleinman, chair of the Transportation and Infrastructure Committee for the City of Dallas. "I'm thrilled to see this type of engineering marvel happening right here in Dallas."

The dual-diameter aspect of the Robbins TBM will be a first-of-its-kind conversion process. The contractor, Southland/Mole Joint Venture (SMJV), will make the conversion underground about 2.8 km (1.8 mile) into the bore. The two diameters are needed as the upstream section of the tunnel is designed with a circular cross section and peak flow rate of 42 m^3/sec (15,000 cu ft/sec), while the downstream 2.8 km (1.8 mile) portion has a higher peak flow of 565 m^3/sec (20,000 cu ft/sec) and was initially designed as a horseshoe cross section. Using the TBM for the entire tunnel is less time-consuming and costly. "Robbins and SMJV are working closely to create the safest and most efficient sequence for completing this conversion within the limits of the bore. The city of Dallas (owner) and our project team are very excited to embark on this unique challenge," said Nick Jencopale, project manager for Southland Holdings.

The Robbins TBM, named "Big Tex" with permission from the State Fair of Texas, has been designed with a specialized cutterhead including removable spacers and adjustable bucket lips to convert to a smaller diameter. The TBM will first complete its 11.6 m (38.1 ft)-diameter section of the alignment, then back up about 21 m (75 ft) to a transition area for the conversion, which is expected to take six to eight weeks.

As the TBM bores, it will pass through Austin Chalk between 12 to 30 MPa at depths from 31 to 46 m (100 to 150 ft) below the city. The route is potentially gassy, so probe drilling is mandatory throughout the project. Crews will utilize ground support including eight 3.9 m (13 ft)-long rock bolts every 1.5m (5 ft) with wire mesh and channel straps as needed. The finished tunnel will be lined with a 380 mm (15 in.)-thick cast-in-place concrete lining.

"Big Tex will work 24 hours a day to excavate the tunnel with crews ranging in size depending on activities," said Rachel Sackett, marketing and communications director for Southland Holdings. Based on previous work through similar geology, the project team expects TBM excavation to progress rapidly to an average of 25m (80 ft) per day, allowing the project to be completed on schedule in 2023. ■

The 11.6-m (38.1-ft) Robbins main beam TBM is the largest hard-rock TBM ever to be used in the United States.

Brenner Base Tunnel excavation hits halfway mark

Almost half of the excavation works on the Brenner Base Tunnel have been completed.

Excavation works at the Brenner Base Tunnel (BBT) reached the halfway mark as 115 km (71 miles) of the total 230 km (143 miles) of the tunnel system have already been excavated for the longest railway link in the world.

BBT SE, the company planning and building the tunnel, announced that the project is moving forward with 11 excavation fronts and about 1,900 people are working on the project in Austria and Italy.

The works are proceeding on the four construction lots, Tulfes-Pfons, Pfons-Brenner, Mules and the Isarco River Underpass. The weekly excavation advancement of the BBT project, both mechanical and using explosives, is about 500 m (1,640 ft). The 115 km (71 miles) of tunnels excavated so far include 34 km (21 miles) of railway tunnels, 43 km (27 miles) of exploratory tunnels and 38 km (24 miles) of other types of tunnel works such as emergency stops and logistics or access tunnels.

"At the moment, there are 11 ongoing excavation fronts. Three tunnel boring machines (TBM) are underway. The number of excavation fronts will increase, as soon as the works on the Sill gorge lot near Innsbruck begin next year," Martin Gradnitzer and Gilberto Cardola, chief executive officers, said in a joint statement.

The BBT, the heart of the longest core network corridor established by the European Union with the TransEuropean Transport Network, will link northern and southern Europe. This project receives 40 to 50 percent co-financing from the European Union, since it is considered the most important measure in managing the continuously increasing volume of traffic over Brenner Pass. In 2019, more than 2.4 million heavy vehicles crossed the Alps there. That is a higher volume of traffic than the four Swiss and two French Alpine passes, combined, had over the same time period.

In 2028, the Brenner Base Tunnel will be open for freight and passenger traffic and, by cutting travel time almost 70 percent, it will usher in a new era of mobility along the Brenner Corridor. The BBT is also one of the most important environmental protection projects in Europe, because it will not be possible to achieve climate protection goals without railways. A ton of freight travelling by rail produces 21 times less CO_2 than the same amount of freight hauled by road. The construction of the BBT will have paid for itself, in terms of emissions, in about 18 years of operations — the service life is about 200 years. There are also numerous environmental compensation measures being carried out alongside the construction work that bring significant added value for both people and their natural habitat.

A particular characteristic of the BBT is its third tunnel tube, the exploratory tunnel, meant primarily for geological prospection. This allows better estimates of the rock mass types and excavation work to proceed with far less disruption. The excavation work is being carried out by blasting (50 percent) and TBMs (50 percent). The exploratory tunnel also saves time and money as a service and logistics tunnel during the construction phase and as a maintenance and drainage tunnel during the operational phase. ■

SR-99 Project: Court decision expected to be appealed

(Continued from page 4)

that the pipe constituted a "differing site condition" for which the state was responsible to solve or alert contractors. The board, whose views are nonbinding, didn't speak about how much damage the pipe caused.

STP had requested a reimbursement for the repair costs, in which WSDOT declined to pay saying it was the contractor's responsibility to repair the machine and complete the tunnel.

WSDOT said it believes the damage to Bertha was a result of "inadequate design and faulty operation." WSDOT then sued STP for failing to meet the contract requirements in 2016, seeking $57.2 million in damages.

STP then countersued for damages, blaming WSDOT for a steel pipe in the tunnel's path, according to WSDOT.

At the trial, in Thurston County Superior Court, WSDOT's attorney called the pipe "nothing more than a toothpick" for Bertha's massive cutter head, while STP argued the machine made steady progress except three days immediately after hitting the pipe.

In the buildup to the two-month trial, WSDOT attorneys uncovered documents showing that tunnel workers encountered and logged the pipe before digging began.

The four-lane tunnel opened for traffic this Feb. 4, 2020 to replace the old Alaskan Way Viaduct.

Not only did jurors reject STP's claim, but they awarded the state $57.2 million from the contractors based on 867 days of delay, while Bertha was exhumed from soggy waterfront soils and repaired.

State Transportation Secretary Roger Millar said he anticipates an appeal, so he hasn't earmarked the $57.2 million yet toward other projects. ■

Meeting the challenge in Pakistan's Lower Himalayas with the use of TBMs

The Neelum Jhelum Hydro Electric project is located in the Muzaffarabad district of Azad Jammu and Kashmir (AJK), in northeastern Pakistan within the Himalayan foothill zone known as the Sub-Himalayan Range. The terrain is rugged with ground elevations that range from 600 to 3,200 m (2,000 to 15,000 ft) above sea level. The project is a run-of-river scheme, employing 28.6 km (17.7 miles) of headrace and 3.6 km (2.2 miles) of tailrace tunnels that bypass a major loop in the river system, for a total static head gain of 420 m (1,400 ft). The headrace tunnels' twin bores (69 percent) contain the tunnel boring machine (TBM) excavation (Fig. 1).

Geological settings

The entire project was excavated in the sedimentary rocks of the Murree Formation, which is of Eocene to Miocene age. The TBM tunnels are being driven through a zone bounded by two major Himalayan faults that trend subperpendicular to the tunnels: the Main Boundary Thrust, and the subsidiary Muzaffarabad reverse/thrust fault. The lithologies are detailed as follows:

- Siltstones and silty sandstones: Uniaxial compressive strengths (UCS) are 50 to 70 MPa.
- Mudstones: With UCSs in the 30 to 40 MPa range,
- Sandstones: With UCS in the range of 130 to 230 MPa.
- In situ stresses: Overcoring tests in sandstone beds in the TBM tunnels found a tectonically altered zone of high stresses (k up to 2.9) with the major principal stress oriented sub-horizontally and sub-perpendicular to the tunnel azimuth.

Geological structures and conditions

In addition to the expected rock types, there are certain ground conditions that are expected to be encountered. The TBM was designed to manage these conditions and included facilities to detect these conditions in advance in order to take appropriate measures to successfully negotiate them. These structures and conditions included:

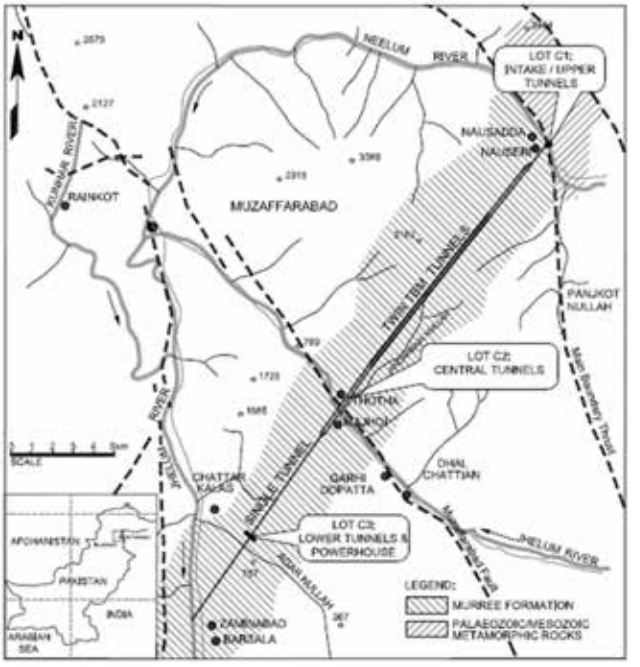
- Unstable rock zones.
- Squeezing and swelling ground.
- Soft ground.
- High water inflows.

Gary Peach

Gary Peach is resident engineer — TBM, Multiconsult AS, email garypeach@heraldix.com.

FIG. 1

Project layout showing TBM twin tunnels (in bold), major faults (dashed) and simplified alignment geology.



- Extensive fault zones.
- Rock bursts.
- High overburden depths (1,870 m or 6,135 ft).

TBM selection

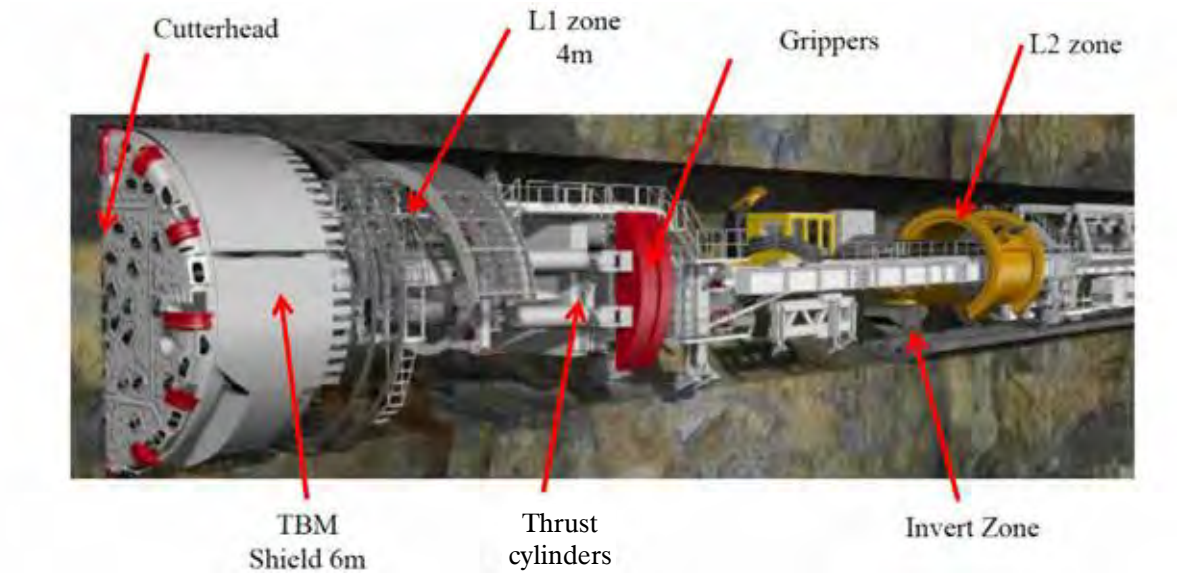
Two open (gripper) TBMs were used to excavate 20 km (12.4 miles) of the headrace tunnel system in two parallel tunnels.

A significant consideration for the TBM selection was the possibility of encountering squeezing ground, with deformations of up to 500 mm (19 in.) on the tunnel diameter. This would exclude many types of TBM designs due to the possibility of becoming trapped within the tunnel. The open (gripper) TBM was determined to be best suited to deal with this potential condition because of the short length of the front shield and its ability to collapse inward at various sections of the front shield, depending upon ground conditions, and still maintain the ability to excavate forward.

The second ground condition that was indicated to be present in the higher overburdens and more brittle rock was rock bursting. Again, the open (gripper) TBM configuration allows for equipment to be installed to detect and mitigate

FIG.2

General arrangement of open gripper TBM (Courtesy of Herrenknecht).



potential rock bursts.

The two TBMs were referred to by their model manufacturing model number, TBM 696 and 697. TBM 697 was launched first and for the majority of the tunnel excavation and was the lead TBM.

Rock support design. The initial design for the rock support consisted of four categories of support designated as Q2, Q3, Q4 and Q5. These support designs were to be installed according to the observed geology or Q class, which was revealed at the rear of the TBM shield as the TBM advanced. The most favorable rock class was Q2 and the least favorable was Q5. The support requirements in terms of quantity of shotcrete and rockbolts, wire mesh mining straps and full steel rings increased with the increase of Q class. The main component — shotcrete — started at 125 mm (5 in.) thickness and increased with class until in Q5 class, where the thickness was 350 mm (13.7 in.).The balance of support installation and rock class is an area that still relies heavily on human intervention, skill and experience to balance support installation with safety and production.

Challenge one — delivery of the two TBMs

With the two TBMs procured and manufactured, the first major challenge was the delivery of the TBMs and all associated parts to the construction site. The two TBMs were manufactured in Germany and China, respectively, and delivered to the port of Karachi in Pakistan. The manufacturer number was used for individual identification as 696 and 697. The TBMs were then loaded onto road transport and traveled 1,777 km (1,104 miles) to the construction site located in northwest Pakistan. The route used major road systems in the south and toward the end of the journey, the route climbed into the lower Himalayas following cliff edge roads and passing through towns and villages, (Fig. 3).

Challenge two — TBM power supply

The consequence of having two capable TBMs was the need for a dedicated power supply. The TBM construction site was located in a remote part of Azad Kashmir and did not have the power supply to meet the TBM requirements, and regularly experienced up to 16 hours a day of load shedding. Therefore, a complete 19.6-MW power station had to be constructed on a hillside near the TBM access adit. The power station consisted of four, 4 MW generators and one 3.6-MW standby generator, powered by heavy fuel oil (HFO). The full power station is shown in Fig. 5.

FIG.3

1,777 km (1,104 miles) in land transportation route for TBM delivery to Neelum Jhelum project.

FIG.4

Transportation route for TBM delivery to Neelum Jhelum project.

Challenge three — Fault zone

Commencement of tunnel excavation. Both TBMs commenced the planned 11.2 km (7 miles) of twin headrace tunnel excavation in early 2013. Both TBM launches were in stages to allow the continuous conveyors to be installed after excavation of 100 m (330 ft). The first TBM to be fully installed and operational was TBM 697 and, from early 2013, it steadily excavated and increased monthly production. The second TBM, number 696, followed suit and progressed approximately 500 m (1,640 ft) behind TBM 697. The alignment of the twin tunnels encountered an existing access tunnel some 1,700 m (5,580 ft) from the TBM launch location. This tunnel known as Adit 2 had been completed prior to the planned arrival of both TBMs.

Fault zone. About 90 m (300 ft) before this adit, the lead TBM 697 encountered an extensive fault zone of sheared mudstone more than 80 m (260 ft) in length. The first indication of this poor ground came when the thrust pressures dropped rapidly and large quantities of soft material came through the cutterhead and onto the TBM conveyor system. A cavity rapidly developed in front of the TBM that was stopped to assess the situation. The TBM was then started and advance was attempted; however, the soft ground flowed into the cutterhead that tripped electrically and stopped. A crew of tunnel workers was sent into the cutterhead to manually remove the buildup material; this operation took eight hours to complete. In an attempt to reduce the flow of soft material into the TBM, all six of the buckets had metal components welded into them to reduce the opening and restrict the free flow of material (Fig. 6a). A further three attempts were made to advance the TBM in the poor ground conditions, with limited success. It was then decided to stop any further attempts and to install a 15-m (50-ft) pipe roof canopy (Fig. 6b) over the TBM shield and in front of the TBM, allowing stabilization by way of ground treatment with grout and chemicals. Once the canopy was completed, a top heading (Fig. 6c) was constructed to access the collapsed area and install further support in advance of the TBM.

After nine weeks, the TBM was started again and slowly advanced through the faulted ground, installing full circular steel rings and 350 mm (14 in.) of shotcrete and breaking through into the adit in early 2014. The trailing TBM 696, having the benefit of the knowledge of the fault zone installed a systematic 15-m (50-ft) pipe canopy every 5 m (16 ft), was able to progress the fault zone relatively smoothly but at a reduced advance rate.

FIG.5

TBM power station.

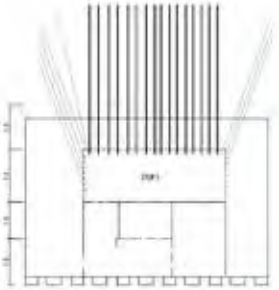
Challenge four — Rockbursts

Good progress. Both TBMs broke through and traversed Adit 2 in January 2014 and entered into a period of good progress, reaching 460 m/month (1,500 ft/month) in installing the full range of rock support for the ground encountered. This period of good progress lasted up until the beginning of November 2014. During this period, the TBM excavation was performed with tunnel overburdens in the range of 1,150 to 1,350 m (3,770 to 4,430 ft) and the only negative experience was the occurrence of a few rockbursts that resulted in

FIG.6

TBM 697 top heading and pipe roof canopy at fault zone.

a) Welding restrictions in the TBM buckets



b) Pipe roof canopy over the TBM

c) Top head over the TBM

damage to some of the TBM equipment.

Rockbursts. Rockbursts had been expected and mentioned in the geological baseline report and the expectation was that this would occur at the higher overburdens. By November 2014, with 4.7 km and 4.3 km (2.9 miles and 2.7 miles) of the tunnels excavated in the left and right tunnels, respectively, regular rockbursts warranted systematic recording. Rockburst events were categorized by magnitude, from "noise only" to "major rockburst." The system aimed to correlate timing and distribution of rockbursts and facilitate selection of mitigation measures at the TBM. The total number of rockburts encountered for the two TBMs during tunnel exavation was 1,695. Figure 7a shows the breakdown of rockburts by category.

The description of the rockbursts categories is as follows:

Category 1: Noise only — a slight popping sound is heard and there is no damage to the support or ejection of rock.

Category 2: Noise and weak rockburst — a popping sound is heard and there may be slight damage to the support and surrounding rock.

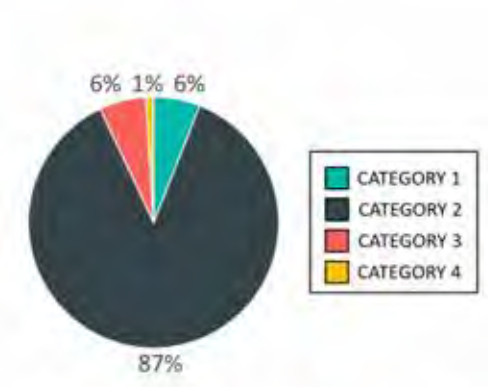
Category 3: Noise and medium rockburst — loud popping sounds are heard and there may be splitting, spalling or shallow slabbing to the support and surrounding rock.

Category 4: Noise and major rockburst — loud sound similar to an explosion, violent ejection of rock into the tunnel and severe damage to the installed support and TBM.

Figure 7a shows that the majority of rockbursts are classified as Category 2, but even this category of rockburst was responsible for delays while repairs were undertaken. Figure 7b shows the typical aftermath of a

FIG.7

Example of rockbursts at the front of the TBM.



a) 1700 Rockbursts by category

b) Category 3 Rockburst at the L1 section

FIG.8

(a) L2 zone during normal operations (b) L2 zone after the 5/31 rockburst.

Category 3 rockburst at the front of the TBM.

Rockbursts counter measures

Longitudinal relief holes. Drilling of longitudinal stress relief holes ahead of the tunnel face will fracture the rock mass, thereby releasing stress and reducing rockburst potential. Holes are drilled with the probe drill and should be closely spaced enough so the rock between the cracks or fractures to relieve the stress. The holes can be concentrated in highly stressed parts of the rock mass.

Radial relief holes. Radial stress-relief holes reduce the likelihood of rockbursts by shifting the tangential stress peaks away from the excavated perimeter. The holes must be large enough and closely spaced enough so the rock between the holes cracks and breaks. This creates a stress-relieved zone around the excavation perimeter. Fewer holes are required in fractured rock.

Horizontal side-wall probe. A significant contributor to the May 31, 2015 severe rockburst was a local change in the strike of the rock strata from perpendicular to the tunnel alignment to parallel. This hid the rockburst-prone sandstone beds behind siltstone beds. To detect future hidden sandstone beds, side probe holes were drilled at 5-m (16-ft) intervals on both sides of the excavated tunnel at tunnel axis height. This activity began on all TBM tunnels in siltstone after the severe rockburst of May 31, 2015.

Installation of shotcrete at the L1 zone. Reinforcement of the rock mass begins with installation of rock bolts and wire mesh, used routinely on the TBM. Steel fiber-reinforced shotcrete can contribute significantly to the energy-absorbing capability where rock conditions require less support. It is preferable to apply most of the shotcrete at the L2 zone to allow quicker installation of initial rock support and faster resumption of excavation. However, 94 percent of rockbursts were detected at the front 10 m (33 ft) of the TBM.

Full ring steel supports. The original purpose of full ring steel supports was to support the tunnel at faults, large overbreak areas, and soft and squeezing ground. These supports are time-consuming to install and can be installed at spacings ranging from 0.9 to 1.6 m (3 ft to 5.2 ft). The spacing directly influenced the daily advance rate. Initially these supports had been installed in large overbreak areas adjacent to sandstone beds. As the tunnel advanced, rockbursts commenced, and Category 4 events caused major equipment damage to rockbolts, mesh and mining straps. The full ring steel supports, however, remained mostly intact even when dislodged. These elements remained rigid but certainly prevented more extensive damage to rock supports and equipment and, most importantly, provided a degree of protection to TBM personnel.

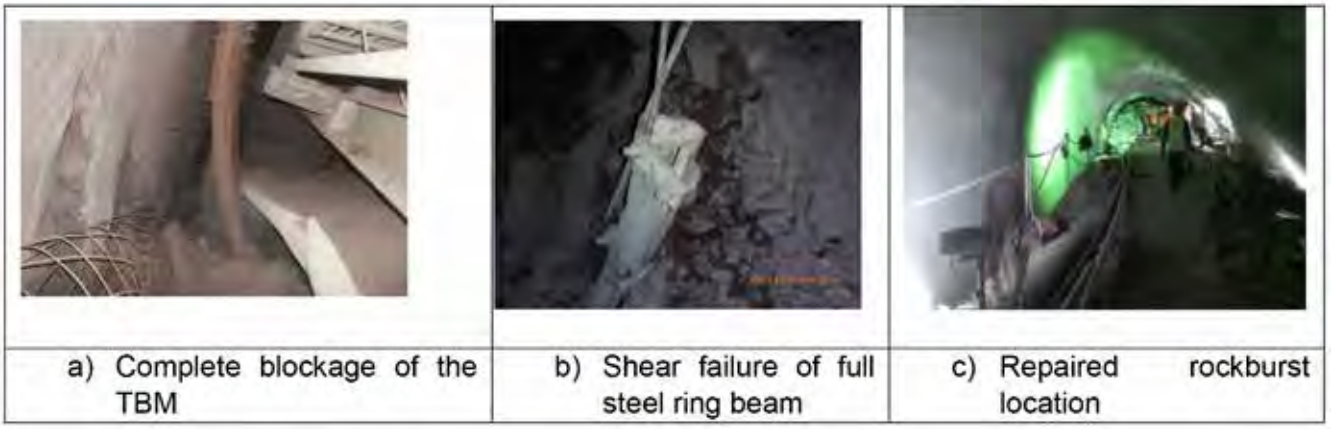
Challenge five — Severe rock bursts of May 31, 2015

The severe rockburst, referred to as the 5/31 event, occurred on TBM 696 (trailing TBM) at approximately 11:35 pm on May 31, 2015. The magnitude of the event was equivalent to a magnitude 2.4 earthquake on the Richter scale and consequent damages to the TBM, ancillary equipment and rock support were without precedent on the project. Figures 8a and 8b show the same location at the L2 zone of the TBM during normal operation and then after the 5/31 event.

The physical damage and losses were sudden and unforeseen and extensive. The rockburst occurred when the trailing TBM 696 was in mid-stroke. Visible damage was observed along the tunnel for 63 m (207 ft), with the most severe damage to the TBM, excavation profile and permanent rock support in a 22-m (72-ft) section some 28 to 50 m (92 to 164 ft) behind the shield. The maximum impact of the 5/31 event occurred at a tunnel location

FIG.9

Severe rockburst effects.



a) Complete blockage of the TBM

b) Shear failure of full steel ring beam

c) Repaired rockburst location

that was excavated 10 days earlier. The time lag between excavation and occurrence of the rockburst was highly unusual since rockbursts normally occurred in the region of the TBM cutterhead while excavating. The TBM was completely blocked by ejected material in two locations (Fig. 9a) and at these locations the whole TBM buckled and twisted 800 mm (31 in.) counterclockwise by the rockburst. Invert heave was evident throughout the 22 m (72 ft)-long most affected zone, with many of the steel ring beams sheared (Fig. 9b), displaced into the tunnel and lifted above the invert, along with the track and sleepers.

In some areas, the ring beams were also heaved out of position, causing massive secondary damage to the adjacent shotcrete.The severe rockbursts caused millions of dollars worth of equipment damage to a 60-m (197-ft) section of tunnel, as well as significant damage to the tunnel lining in the neighboring TBM 697 tunnel.

Once the area was deemed safe to enter and the recovery plan had been developed, work commenced on June 16, 2015. The most urgent activity was to start the debris removal from the top of the TBM to allow the replacement of tunnel rock support and also uncover the full extent of the rockburst zone. The exposed ground was then heavily supported with full ring steel supports, rockbolts and shotcrete. The whole recovery program took 7.5 months. Figure 9c shows the same location as Fig. 9a after the removal of ejected rock and the installation of heavy rock support, to a height of 8 m (26 ft) above the original excavated tunnel, prior to the May 31 event.

Challenge six — Height overburden and tunnel completion

The 5/31 event had occurred at an overburden of approximately 1,325 m (4,350 ft) and the maximum

FIG.10

a) TBM support post-5/31 event b) TBM 696 progress after 5/31 event.

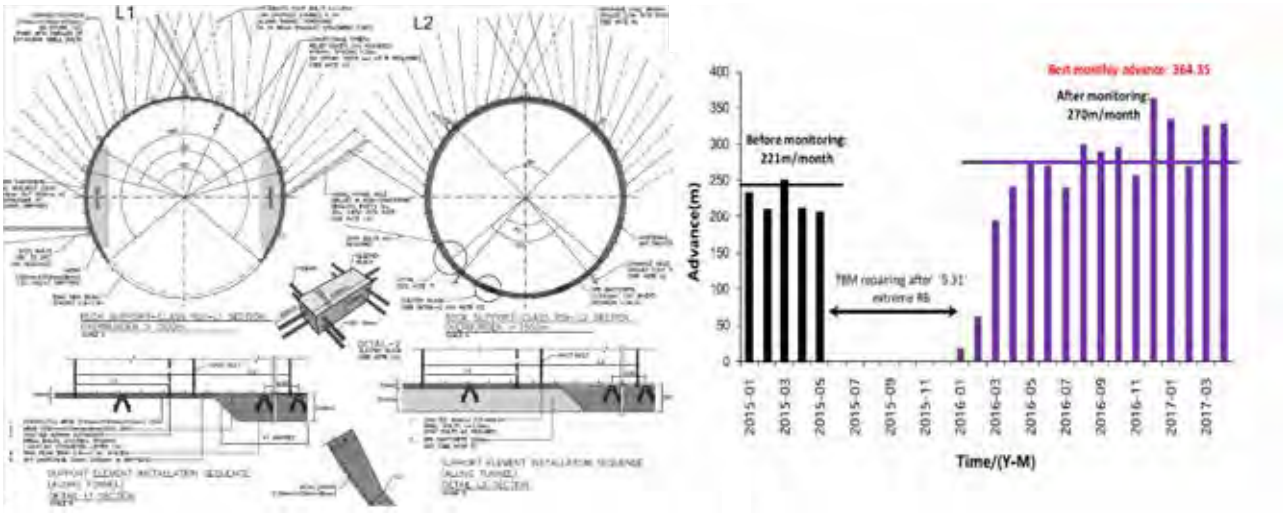
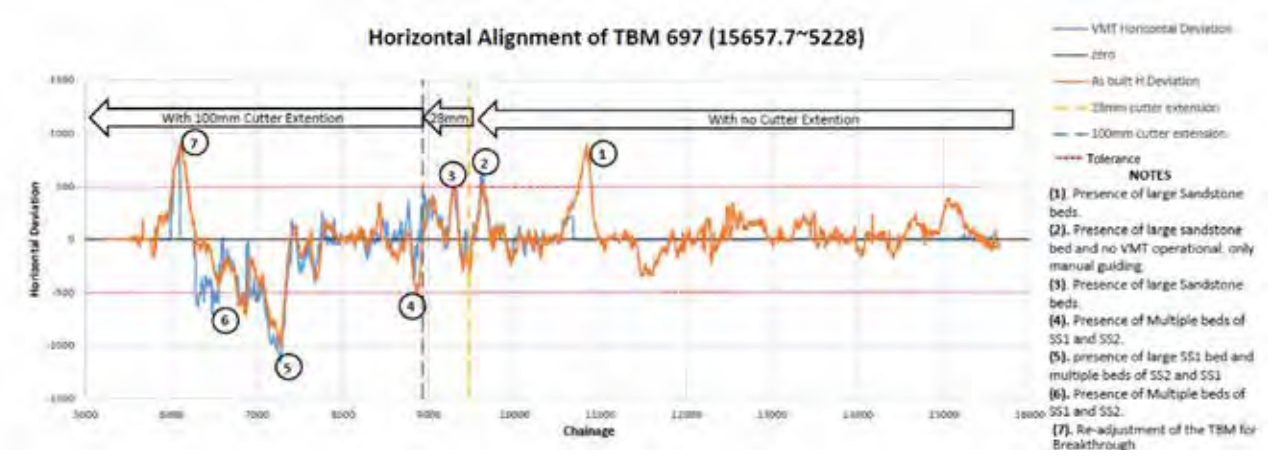


FIG.11

TBM horizontal alignment before and after overcutter installation.



overburden of 1,870 m (6,135 ft) was still about 2 km (1.25 miles) ahead.The recommencement of the lead TBM 697 eight days after the 5/31 event was undertaken with systematic counter measures. The tunnel rock support had been reevaluated and a special rockburst support lining designed and implemented on a permanent basis. The general design is shown in Fig. 10a.

The design incorporated continuous full circular steel rings, rockbolts, heavy-duty wire mesh and systematic shotcrete installed at L1 with a final lining thickness of 350 mm (13.7 in.) being installed at L2. Both forward longitudinal and radial stress-relief holes were drilled in and around the sandstone beds encountered during excavation. All these precautionary measures and heavy tunnel support directly impacted monthly progress specific to TBM 696, which experienced the severe rockburst event. The event and the subsequent detailed investigation resulted in new TBM operational procedures aimed at predicting and investigating future similar geological situations. The most important of these measures was the adoption of probing through the side wall of the tunnel to detect parallel, hidden sandstone beds.

The use of the microseismic monitoring data and other site information enabled the TBM project team to optimize all aspects of precautionary measures and excavation operations and quickly start to increase monthly production up to 364 m/month (1,200 ft/m) (Fig. 10b).

The daily trend analysis and operations recording revealed that the microseismic activity and rockbursts did not continue to increase as the tunnels headed for the highest overburdens. In contrast, the overall microseismic activity started to decrease. Further investigations were undertaken to record the actual in situ stresses and within the actual rocks that first experienced the Category 4 rockburst and then, secondly, at varying overburdens to ascertain if the ground stresses were related to overburden. The details of these findings indicated an area of elevated horizontal stresses that were not related to overburden.

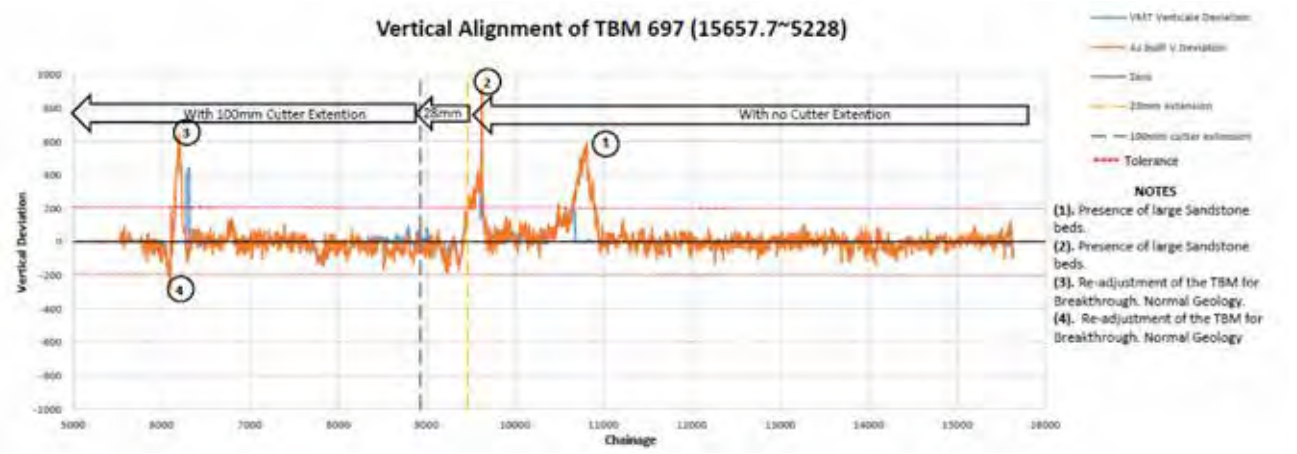
In the last 1 km (0.6 mile) of each TBM tunnel the occurrence of rockbursts reduced to virtually zero and progress increased accordingly. The lead TBM 697 broke through and connected with the dam site in October 2016 and the trailing TBM followed suit and broke through in May 2017.

Challenge seven — TBM overcutters

The excavation diameter of a TBM is the cutterhead width plus the protrusion of the gauge cutters. As the cutterhead turns and excavates the tunnel, the gauge cutters wear faster, leading to a reduction in the tunnel diameter. With a requirement for full circular steel rings and thicker shotcrete more space was required for these elements. Overcutting was achieved by extending the cutters located on the cutterhead periphery using shims to increase the effective width of the cut and by replacing the gauge cutters with large-diameter cutter wheels (from 431 mm to 457 mm of (17 to 18 in.). Both methods were employed to increase the tunnel diameter by 100 mm (4 in.). However, overcutters are normally deployed as a short-term measure to address a local problem. On this project they would need to be installed for a much longer period, close to 5 km (3.1 miles) or half of the proposed TBM alignment. The perceived problem with using the overcutters for a long period includes alignment control, both horizontal and vertical, and rapid and excess wear of the TBM shield components. Figure 11 shows the horizontal alignment for the lead TBM before and after overcutter installation. The graph shows the difficulty of maintaining the horizontal alignment within the expected tolerances after the overcutters were installed. The main points of deviation are numbered and the explanation is shown on the righthand side of the graph. Control of the vertical alignment (Fig. 12) experienced no such control

FIG.12

TBM vertical alignment before and after overcutter installation.



issues, the difficulty being the horizontal alignment control. The second concern of excessive wear of the TBM shield was also monitored and additional wear was detected on the grill bars, but this did not prove to be a hindrance to the TBM operation.

Conclusions

This paper outlines seven significant challenges the TBM tunnels faced on the Neelum Jhelum Project, from delivering the TBMs to the site up to the unusual circumstances of the 5/31 rockburst. These tasks were made much more difficult by the remote location of the project site, making both changes and or modifications to the TBMs or delivery of new products or equipment all the more taxing.

The successful recommencement of tunneling and modification of operating procedures and subsequent tunnel completion was only made possible by the full support of the client and close collaborative work among the employer, contractor and engineer.■

Fast and innovative mode of transportation in the Northeast Corridor — tunneling challenges

The Superconducting Maglev (SCMAGLEV) project is a proposed high-speed train system between Washington, D.C. and the city of Baltimore, MD, approximately 60 km (37 miles) long (Fig. 1). The segment from Washington, DC to Baltimore is the first leg of a route that eventually will be between Washington, D.C. and New York City. The envisioned route would include additional stations in Wilmington, DE and Philadelphia, PA, as well as at additional major airports along the route. With the Northeast Corridor (NEC) home to 17 percent of the U.S. population, and travel between the major cities of the NEC predicted to increase 115 percent by 2040, the SCMAGLEV is a technology that can help reshape transportation and commerce in the NEC and the United States.

FIG. 1

Conceptual rendering of the SCMAGLEV technology. Source: https://northeastmaglev.com.

The SCMAGLEV system operates using a combination of electromagnetic levitation (support), propulsion and lateral guidance rather than flanged wheels, axles and bearings as in conventional high-speed rail systems. The train system will cross several transportation corridors including interstate highways (I-95, I-195, MD 295 Baltimore-Washington Parkway, I-595, I-695, I-895), several state, city and local routes and railroad lines, as well as the Baltimore/Washington Thurgood Marshall International (BWI) Airport, with all crossings grade-separated. The project developer is the Northeast Maglev/ Baltimore Washington Rapid Rail (TNEM/BWRR) with WSP as the prime consultant and Gall Zeidler Consultants as the tunneling subconsultant.

An Environmental Impact Statement was initiated in the fall of 2016 in accordance with the National Environmental Policy Act with the Draft Environmental Impact Statement (DEIS) was expected to be published in in mid 2020 and the Final Environmental Impact Statement (FEIS) and Record of Decision (ROD) by mid-2021. Construction is envisioned to commence in 2021 with an estimated total cost of more than $10 billion.

Technology

The Baltimore-Washington Maglev Project provides new infrastructure, stations and facilities for a SCMAGLEV train system. The project will build on the safety practices and culture of system developer Central Japan Railway Company (JRC), which has operated the Tokaido Shinkansen bullet train between Tokyo and Osaka without a single fatality since 1964. JRC applied a similar safety approach to the development of the SCMAGLEV system. SCMAGLEV was certified by the Japanese government and has been in commercial operation since 2014. Safety systems for the Baltimore-Washington Maglev project will be developed through a collaborative process with the Federal Rail Administration Office of Safety and local emergency response forces.

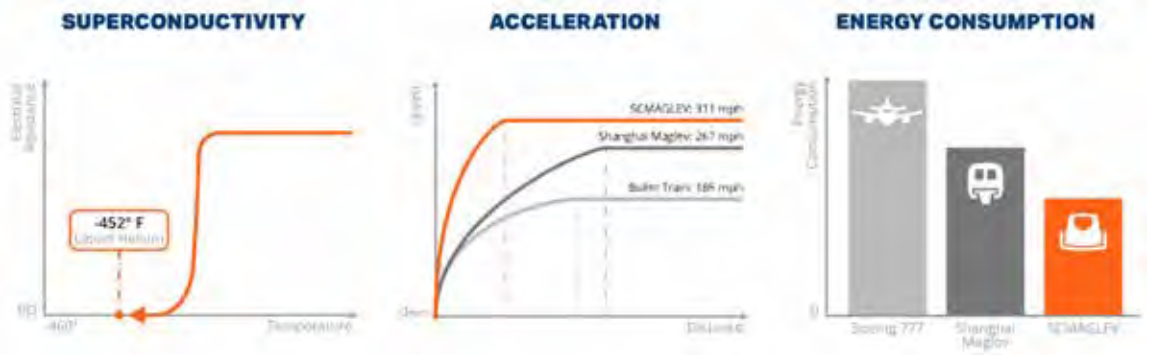
The primary elements of the project include superconducting magnetic levitation rolling stock and

Vojtech Gall, Nikolaos Syrtariotis, Timothy O'Brien, Cosema (Connie) Crawford and David Henley

Vojtech Gall, Nikolaos Syrtariotis (members UCA of SME) and Timothy O'Brien are principal, tunnel engineer and TITLE, respectively, Gall Zeidler Consultants Cosema (Connie) Crawford is senior vice president, WSP and David Henley is project director, Baltimore Washington Rapid Rail, email vgall@gzconsultants.com.

FIG.2

Depiction of key aspects of the SCMAGLEV technology that utilizes superconductivity, allowing for greater acceleration and less energy consumption than competing technologies.



systems, using a proprietary technology developed by CJRC and two guideways, borne by tunnel and viaduct structures. The system deploys technologies that are new to the United States or of previously limited application, including most notably an electromagnetic propulsion system. This technology is capable of accelerating trains to a top cruising speed of 500 km/h (311 mph) in approximately two minutes and allows for a driverless train operation. Additionally, the energy consumption for the train is far less than that of other ultra-high-speed travel options, such as a Boeing 777, or the operational Maglev in Shanghai China (Fig. 2). The train utilizes superconducting magnets for acceleration and lateral guidance of the train. It is estimated that the total trip duration from Washington D.C. to Baltimore will be 15 minutes and Washington, D.C. to New York City will take one hour, at a speed of 311 mph (511 km/h).

Alignment alternatives

The project is located in Washington, D.C. and Maryland, traversing a distance of approximately 60 km (37 miles) with three stations in Washington D.C., at BWI Airport and in Baltimore. The Washington, D.C. and BWI Airport station options are underground. There are above- and below-ground options for the Baltimore station. The SCMAGLEV system requires an independent and secured grade-separated right-of-way. Further, assuring the safety and comfort of passengers requires use of predominantly straight geometry with limited horizontal and vertical curvature consistent with the physical dynamics of ultra-high-speed travel. To accommodate the range of topographical and surface features, existing dense urban areas, utility mains and existing structures, the proposed construction is expected to consist of a below-ground structure(tunnel) for approximately 75-80 percent of the route, and elevated structures (viaduct) for the remainder.

FIG.3

a) Proposed alignment alternatives under consideration and b) Boreholes drilled along alignment alternatives for the preliminary boring program.

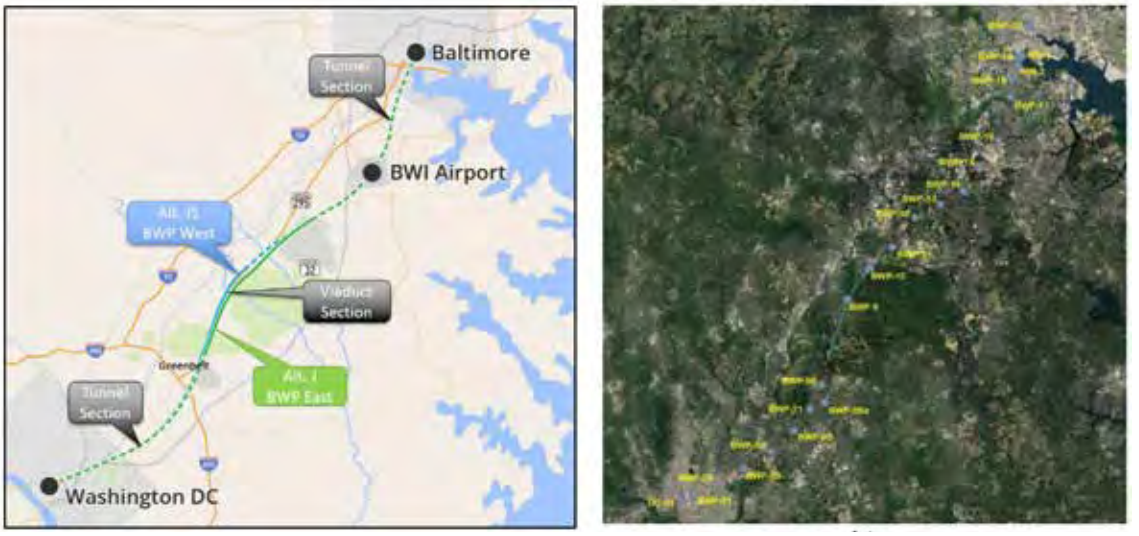
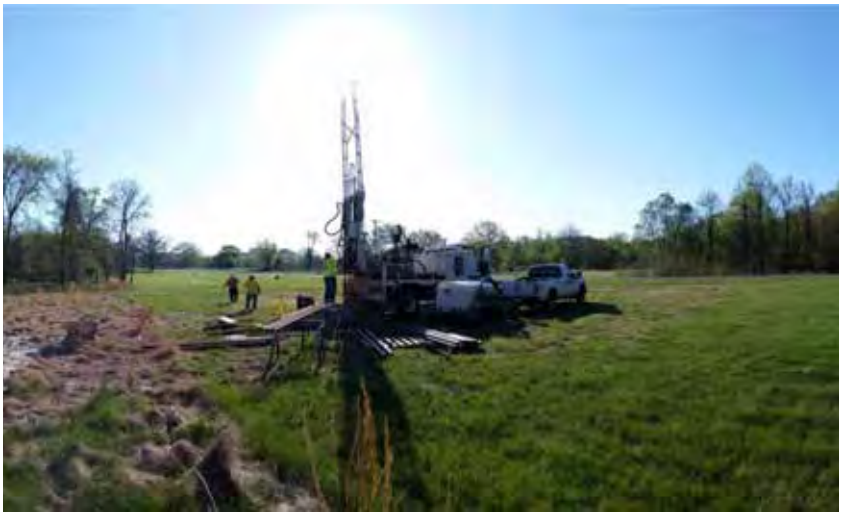


FIG.4

Borehole drilling for preliminary ground investigation program.



The train system incorporates two main guideways, three stations, one trainset maintenance facility, electrical substations, tunnel ventilation plants and emergency egress.

The environmental review process narrowed two alignment alternatives that generally follow the Baltimore-Washington Parkway (MD 295) (Fig. 3a), with a preferred alternative to be named in the DEIS in 2020. Preferred alternatives for station locations in Washington, D.C. and Baltimore will be named in the DEIS as well. At BWI Airport, the existing hourly parking garage will be demolished for station construction, with a replacement parking garage to be constructed prior to demolition of the existing one. The stations will have a platform length of approximately 400 m (1,312 ft), enabling accommodation of 16-car trains.

Ground conditions

A preliminary geotechnical exploration program was conducted along the two alignment alternatives in the spring and summer of 2018 and included 22 boreholes and geotechnical testing (Figs. 3b, 4). The program provided a preliminary look at the anticipated ground conditions for construction and tunneling along the alignments, and identified target areas of interest for the next phase of geotechnical investigation.

The proposed alignments are located within the Coastal Plain Physiographic Province, consisting of relatively soft strata. These strata lie on top of crystalline bedrock and thicken to the southeast on the order of approximately 150 m (500 ft) per 8 km (5 mile). The strata consist of sedimentary deposits of the Cretaceous-age Potomac Group, which includes clays, sands and gravels and Holocene-Pleistocene terrace gravels and loose granular soils. All sedimentary formations sit unconformably atop each other, with the oldest sediments (Patuxent Fm.) sitting unconformably atop bedrock. Bedrock ranges in age from Jurassic to Cretaceous and is exposed or encountered at shallow depths at the Fall Line, which is the boundary between the Coastal Plain and Piedmont physiographic provinces.

Ground water conditions are expected to vary widely across the alignments, from dry conditions to ground-water levels ranging from relative shallow depths of less than 3 m (10 ft), to depths in excess of 12 m (40 ft). Fluctuations in ground water levels across the alignment will occur seasonally due to variations in rainfall, evaporation, construction activity, surface runoff and proximity to adjacent streams and the Chesapeake Bay shoreline. Localized perched groundwater and isolated water-saturated sediment lenses can also be expected. Connectivity of the aquifers to rivers and creeks has been identified in various locations.

Tunneling is expected to occur primarily through the Patapsco, Arundel and Patuxent formations of the Potomac Group soft ground for most of the alignment. Bedrock was encountered in boreholes at portions of the alignment closest to the Fall Line, which includes the Washington, D.C. and Baltimore stations, as well as the central portion of the alignment alternatives approximate to the viaduct segment. Locally higher sections of the bedrock cannot be excluded, and would be a target of the next phase of geotechnical investigations. No unanticipated or abnormal geological features were encountered during the preliminary ground investigation program.

Tunneling challenges

The proposed alignment alternatives include approximately 40 to 45 km (28 to 30 miles) of generally deep tunnel sections. Considering the length of the tunnel sections and the required uniform geometry, it is anticipated that mechanized tunneling will be implemented for the majority of the alignment that will need to address the following challenges:

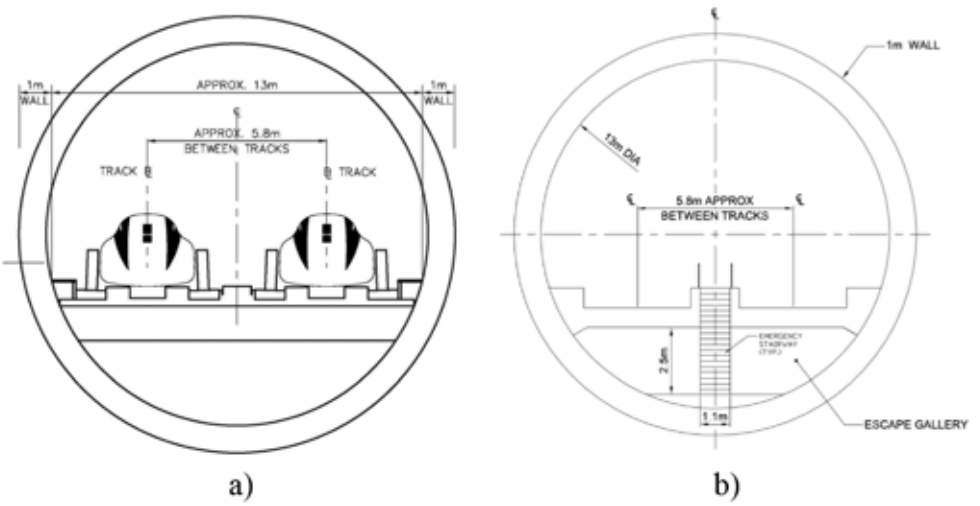
- Tunneling in soft ground, consisting of sands, silts, clays and gravels.
- High ground water level.
- Tunneling across urban areas and therefore under major infrastructure.

Considering the soil types and groundwater conditions expected along the deep tunnel sections, which require an active face support, the use of a closed-face tunnel boring machine (TBM) will be required. Based on the available preliminary information on the geological and hydrogeological conditions and the critical impact of groundwater to the tunneling activities, implementation of earth pressure balance machines (EPBM) is

considered, at this stage, most appropriate for the anticipated subsurface conditions. Alternatively, slurry and/or mix shield TBMs could be considered, as the alignment could encounter sections of mixed geology with hard rock potentially shallower at the two ends of the alignment, pending the next phase of ground investigations. The information acquired from the additional ground investigation program will be used to evaluate and select the TBM type and refine specifications.

FIG.5

a) Typical TBM tunnel cross section and b) cross section showing emergency escape gallery.



TBM tunnels in soft ground are generally supported by pre-cast segments, which are erected at the tail end of the TBM, producing a continuous lining over the tunnel length with a circular, uniform geometry. Segmental linings will be equipped with gaskets in the joints between the segments to inhibit groundwater inflow into the tunnel.

To minimize the construction footprint of the project and minimize surface disturbance and construction impact, while taking into consideration the spatial requirements for the train operation, a single-bore TBM tunnel with an outside diameter of approximately 15 m (50 ft) was considered as optimal compared to twin-bore tunnel configuration (Fig. 5a). Although tunneling with a large-bore TBM is a challenge in itself, the technology and capabilities of present-day TBMs allows for unimpeded tunneling and enhanced risk management. Within the past 10 to 15 years, large-bore TBM tunnels are an increasingly common option being utilized for major transportation projects, with recent successes on the Port of Miami Tunnel in Miami, FL (Bauer et al., 2013), Barcelona Metro Line 9 in Barcelona, Spain and the Shanghai River Crossing in Shanghai, China. Additionally, the alignment had been determined such that TBM tunneling would be performed under at least one tunnel diameter of ground cover to minimize surface impact.

Subdivision of the TBM tunnel alignment into sections with a length of 5 to 6 km (3 to 4 miles) is currently considered for enabling concurrent boring along various sections and providing flexibility for contracting and packaging of the project. This requires construction of additional launch sites, which are typically cut-and-cover structures. In areas where space restrictions do not allow for construction of launch boxes, launch shafts of adequate size are considered as an alternative. Ventilation shafts are planned to be used as launch shafts where possible to minimize cost and streamline construction. As the launch sites will be also used for stockpiling of the spoils, implementation of additional launch sites along the alignment will allow more efficient storage and transport of the spoils to the areas designated for disposition.

Short sections of cut-and-cover tunneling will be used for the stations and the transitions between the viaduct and TBM tunnel sections, including portals and TBM launch locations. Implementation of cut-and cover tunneling requires installation of excavation support of slurry walls, bored pile walls, soldier pile and lagging or shotcrete. The method of support of excavation (SOE) chosen will also be dictated by the local ground conditions, with slurry walls a likely choice where dewatering of the sediments is to be avoided to prevent settlement of any adjacent existing structures. Depending on the limits of disturbance, generally tie-back support or internal strutting is expected for deeper excavations. A waterproofing system will be installed to prevent groundwater inflow into the tunnel in the final permanent stage.

Due to the dense urban environment in Washington, D.C. and Baltimore, and the relatively deep alignment, construction of the stations with minimal surface impact and disruption to the city activities will be challenging and will require a well-planned design. Similarly, construction of the station under the BWI Airport without disrupting airport operations will pose a significant undertaking.

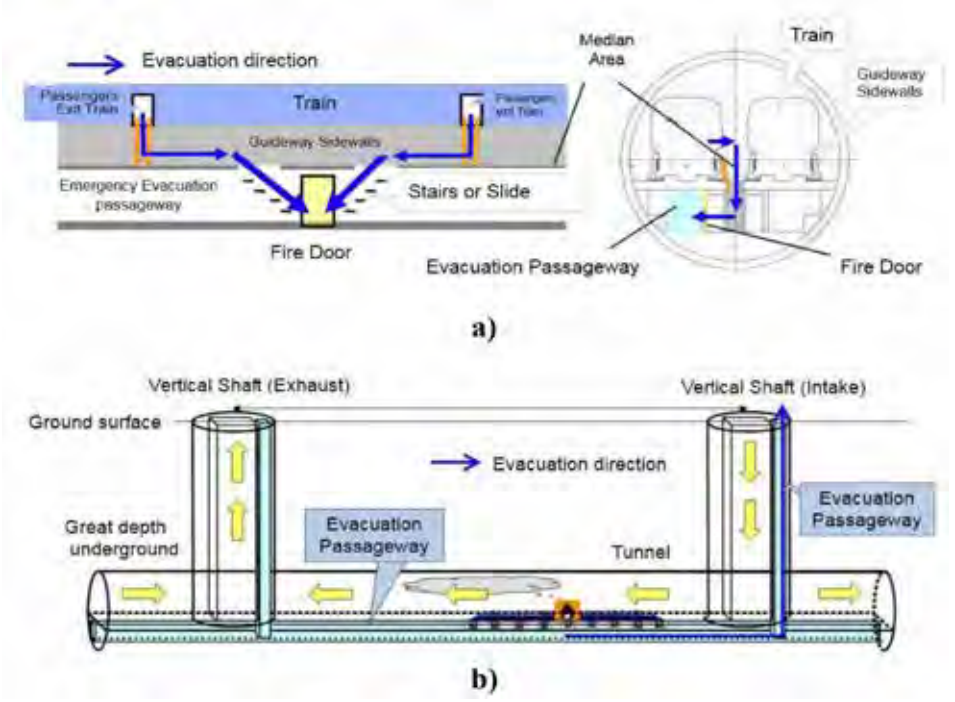
Fire and life safety

Design, construction and operations for the SCMAGLEV will be planned with a safety focus: safety of the traveling public, the construction and operations workforce and the adjoining communities that are impacted by the construction and operations of the system. Each area will be addressed in the planning and design of the infrastructure, core systems, facilities and operating and maintenance practices for the SCMAGLEV system.

Fire and life safety have been given full consideration

FIG.6

Schematic diagrams showing a) emergency egress gallery within a single bore tunnel and b) connection of egress gallery to ventilation plants for surface access.



and attention in the design since the inception phase of the project. Fire and life safety considerations factor into all aspects of the system design, including linear infrastructure (viaducts and tunnels), passenger stations and operations and maintenance facilities. The fire and life safety include elements and layout of egress and access paths in the tunnel system and definition of design fires for vehicles, cables and other equipment.

The design standards and guidelines addressing fire and life safety requirements for the structures of the project are:

- NFPA-130.
- NFPA-101.
- NFPA-502.
- Americans with Disabilities Act.
- Accessibility Guidelines (ADAAG).
- Maryland Building Performance Standards.
- Maryland State Fire Prevention Code.
- Washington D.C. Building Code and Construction Code.

To meet the requirements of the standards for Fire and Life Safety and NFPA-130, in particular, a safe emergency egress for passengers to a point of safety will be provided in the underground sections. This would be achieved by utilizing an escape walkway/gallery inside the tunnel envelope located below the guideway (Figs. 5b, 6a). The considered tunnel cross section provides sufficient space below the guideways to be used as an emergency evacuation chamber. The escape gallery would have an independent ventilation system in the event of a fire or other emergency and would have surface access via ventilation plants and shafts envisioned along the underground section of the alignment at an approximate distance of 5-6 km (3-4 miles) (Fig. 6b).

Due to the unique characteristics of the SCMAGLEV system, the standards and guidelines listed will be supplemented by Japanese codes and practices that have contributed to that country's exemplary safety record. Safety systems and practices researched and developed by JRC specifically for the SCMAGLEV system will be proposed for incorporation into the proposed project to ensure that the highest standards for safety are deployed.

Outlook

With the successful completion of the preliminary ground investigation program, the Draft Environmental Impact Study is underway with Record of Decision (ROD) anticipated in 2021. A positive ROD would mean forward movement on the next phase of ground investigation and preliminary engineering, with construction envisioned to commence in 2021 at an estimated total cost of more than $10 billion, which is less than for conventional high-speed rail. Long-term maintenance costs of the system are minimal because there is no mechanical contact and wear between the train and the guideway.

The proposed SCMAGLEV is a technically challenging but innovative project that will shorten commuting time between Washington DC and Baltimore, and later to New York City. The project will enhance mobility along the northeast corridor and could spur development and economic growth in the region. ■

References

Baltimore-Washington Rapid Rail. 2018. https://bwrapidrail.com.
Bauer, A., Gall, V., and Bourdon, P. 2013. Comparison of Predicted Versus Observed Structural Displacements of Existing Structures at the Port of Miami. In Proceedings of the Rapid Excavation and Tunneling Conference 2013, Edited by M.A. DiPonio and C. Dixon. Englewood, CO: SME.
The Northeast Maglev. 2018. https://northeastmaglev.com.

UCA of SME hosts Cutting Edge 2019 and George A. Fox conferences

In the opening keynote session of the 2019 Cutting Edge Conference in Miami, FL on Nov. 19, 2019, Arnold Dix, vice president of the International Tunneling Association, pointed beyond the technical challenges and benefits that come from creating tunnels and underground spaces and spoke about the importance that underground infrastructure provides to humanity.

"For its part of the social agreement with its citizens, the state will provide clean water, sanitation, security, transportation and access to food. It is this social contract that makes civilization function and the tunneling industry plays an integral part of this contract," said Dix, who is also a geologist, disaster investigator, trial attorney, dispute resolution practitioner, technical dispute avoidance board specialist and visiting professor of tunnel engineering at Tokyo City University.

More than 270 people attended the 2019 Cutting Edge Conference in Miami, Fl on Nov. 19. The conference featured technical sessions and an exhibit area.

Dix made these remarks to more than 270 tunneling and underground construction professionals at the 2019 Cutting Edge Conference, hosted by UCA of SME and *Tunneling Journal*. He was the first of three keynote speakers for the session titled "Extreme Tunneling for a Brave New World."

This fifth annual conference included two days of technical sessions covering all aspects of the tunneling industry, and the keynote provided an overview of some of the largest and most pressing issues for the industry.

Dix took a broad view, reminding the audience that by providing infrastructure the industry helps civilization to prosper. In first-world countries, a stable and clean water supply, sewage and transportation and utility tunneling below ground allow citizens above ground more freedom to engage in professional and recreational activities. On the contrary, Dix spoke about how third-world countries often lack the infrastructure that is taken for granted in many developed nations.

Dix said it is imperative that this infrastructure is not neglected and that funding for new infrastructure projects remains a top priority. He also spoke about how tunnels in remote, third-world regions can benefit the entire world. In addition to the humanitarian aspect of providing life-sustaining infrastructure to those who need it most, Dix said clean-water tunnels can also save established nations. Speaking on the sidelines of the conference to *T&UC,* Dix said there is evidence that a future pandemic will have devastating effects on the world's population. It is not known when or where such a pandemic will occur, but there is a high likelihood that it will begin in a third-world region. One of the best defenses against such a pandemic is clean water and sanitation.

Among some of the other challenges the world is facing is population growth that is predicted by the United Nations to take place in many countries around the world, including in the United States.

William Gleason, Editor

Dix said there will be a need for governments to adhere to the social contract for more people while the industry struggles with finding more engineers to do the jobs that create infrastructure. Automated machinery can help with this challenge, but that leads to issues of what to do with all of the data that is collected.

"We are crucial to maintaining society, and we must help others rise up to enjoy a good life. Seventy percent of the world are in the have-not category and that isn't good for any of us," Dix explained.

Lars Babendererde, of BabEng followed Dix and spoke about issues that arise from maintaining face support of tunnel-boring machines in special conditions. His talk pivoted to the more technical aspects of the industry, but he also spoke about the challenges facing the tunneling industry, including the lack of diversity and new engineers joining the ranks. The need for new engineers is not unique to tunneling; the mining industry is also struggling with the issue.

According to Babendererde, the governments of the world can help solve the issue by providing steady investment into infrastructure that will give students the confidence that when they graduate, the industry will still be strong. The tunneling industry can work to create an attractive working environment, be open to new technologies and implement continuous training. He also said the industry needs to attract more women.

James Utterback, with the Virginia Department of Transportation, provided an update on the evolution of the $3.3 billion Hampton Roads Bridge-Tunnel Expansion contract, which is the largest construction project in Virginia's history.

The project is an example of all the items that were discussed by Dix and Babendererde.

The current I-64 Hampton Roads Bridge-Tunnel (HRBT) is a 5.6-km (3.5-mile) facility with two two-lane immersed-tube tunnels connecting artificial islands, with trestle bridges to shore. The tunnels are approximately 2,300 m (7,500 ft) long. Traffic through the facility exceeds 100,000 vehicles per day during peak summer traffic. This corridor is one of the most congested in the region.

The expansion project, expected to be completed by November 2025, will widen the four-lane segments of the I-64 corridor in the cities of Hampton and Norfolk. Twin two-lane bored-tunnels will be built west of the existing eastbound tunnel; current eastbound and westbound tunnels will accommodate all westbound traffic upon completion of the project.

The massive project is made possible through unprecedented regional cooperation. In April 2019, the Commonwealth of Virginia signed a Project Agreement for Funding and Administration with the Hampton Roads Transportation Accountability Commission and a Comprehensive Agreement with Hampton Roads Connector Partners and the design-build team that will complete the 10 miles of expansion work.

Two full days of technical sessions followed the keynote with industry experts sharing advice on many aspects of the industry. Sessions included cutterhead interventions; ground control, face support and monitoring; developments in tunnel lining design and advances in TBM operation and excavation technology. UCA of SME chair Bob Goodfellow chaired two panel discussions — Big data and who wants it and TBM operation and face support. The conference also included a young members session that was created by the Young Members Group of the UCA of SME and included talks from finalists for the 2019 International Tunneling Association's Young Tunneler of the Year Award.

The 2019 Cutting Edge Conference was held one day after the International Tunneling Association 2019 Awards Conference & Banquet.

The Regional Connector Transit Project in Los Angeles, CA. It was named the Project of the Year (between €50 million and €500 million). The Regional Connector Transit Project is an underground light-rail system with three new stations. LA Metrolink estimates that the Regional Connector will increase ridership across the entire transportation system by 17,000 people per day and save commuters an average of 20 to 30 minutes by reducing the need to transfer to different lines. Major challenges were encountered during the work and consequently, a few innovations were implemented. The overall cost of the project is estimated at $1.2 billion.

- Major Project of the Year (over €500M): Tuen-Mun Chek Lap Kok Link — Northern Connection Subsea Tunnel Section, Hong Kong, China.
- Project of the Year (between €50M and €500M): Regional Connector Transit Project, Los Angeles, United States.
- Project of the Year incl. Renovation (up to €50M): Modernization of the Vladivostok Tunnel of the Far Eastern Railway, Russia.
- Technical Project Innovation of the Year: Toulouse Line A Underground Stations Extension, France.
- Technical Product/Equipment Innovation of the Year: Autonomous TBM, Malaysia.
- Innovative Underground Space Concept of the Year: Underground Green Farming, Switzerland
- Safety Initiative of the Year: Air Quality Working Group An industry-first Collaboration On Silica Dust Control, Australia.

2020 George A. Fox Conference

On Jan. 28, more than 370 tunneling and underground construction professionals gathered at the Graduate Center of City University of New York for the 19th George A. Fox Conference. The one-day conference has become a mainstay for the industry to exchange ideas and best practices and this year was no different.

The theme of the 2020 edition was Design & Construction of Complex Projects. With an abundance of projects taking place around the world, the planning committee was challenged with choosing the best projects for the conference.

Fox Conference chair Paul Madsen said the committee began with a wish list of projects and then contacted potential presenters, checking on their availability. "There are always some, where bureaucratic issues get in the way of having the project being presented, but we tried to have the theme reflected in the projects/presentation we selected."

The end result was a one-day program that included talks about some of the most challenging and exciting tunneling projects from around the globe including the Baltimore and Potomac Tunnel Replacement project; the Ohio Canal Interceptor Tunnel Project; the Plymouth SEM Tunnel; the proposed Baltimore to Washington, DC Maglev program and construction of the Montreal Express Link Tunnels.

2020 George A. Fox Conference chair Paul Madsen opened the conference and delivered the keynote address on Jan. 28.

Madsen, who pulled the conference together as the chair, also pulled double duty to kick off the conference when he filled in for Kim Anderson to speak about the Femren Link project, an 18 -km (11-mile) long immersed tunnel that will link Denmark and Germany. It is currently the longest subsea tunnel under construction in the world and when it is completed it will link Scandanvia to central Europe with a tunnel that include two tubes for pedestrian traffic and another for rail.

Madsen deflty spoke about the hugely complex challenges the project faces, from the technical issues of constructing an immersed tunnel with segments that are more than 200 m (656 ft) in length to the political issues that come with an international project that links Germany and Denmark. Among the issues are environmental impact statements and other issues such as citizen involvement, social responsibility, budget controls, environmental protection, climate adaptation, worker's health and safety, not to mention the challenges Madsen faced with learning the presentation just days before it was to be given.

"I was familiar with the project, at a very high level, but was required to get familiar with it in a hurry," said Madsen. "The original speaker, Kim Andersen, knows the project and presentation by heart. When he and I decided I should give it a try, he recorded the speech and sent me the audio file. I then spent the weekend before the conference locked up in my study transcribing the talk and practicing. Subsequently, I ended up learning about the project in greater detail than I had anticipated."

Despite the late challenge to the program, the conference was another success. ■

Are you **Down for That?**

Help UCA of SME recruit young engineers

Chances are, your company has booked a number of projects in the near future but might not have the engineering staff to get the work done. With more ambitious underground projects worldwide, the number of engineers needed to design and manage them is growing. Now is the time to expand the workforce to meet the demands of future projects, and UCA of SME is working to help your company find the talent you need with the Down for That initiative.

UCA of SME has created a campaign that is targeted to younger engineers. The campaign name, Down for That, was inspired by the challenge and mystique often associated with underground projects. The campaign website, undergroundcareers.org, promotes underground construction as a career choice and aims to be the most comprehensive resource for students and professors to explore underground construction and engineering. We are asking for companies and individuals to contribute their knowledge to encourage more young engineers to join the underground industry upon graduation.

In a recent survey by UCA of SME, members indicated one of the most challenging issues they face is recruiting. Down for That raises industry awareness among students and introduces them to the field while they are making career decisions as undergraduates. For undergroundcareers.org, the current goal is to populate the site with speaker and site tour opportunities along with case studies detailing innovations and the complex problems being solved. In addition, the site will be set up to provide valuable presentations, curricula and videos for professors to use in engineering classes to further pique the interest of engineering students.

A survey of 113 civil engineering college students indicated that the majority learn about engineering career options from their professors. Of the engineering professors we also surveyed, two-thirds of them said they were quite familiar with the underground construction field, but they also noted a lack of resources to share with students.

Among the most valuable resources professors sought were tours of tunneling sites, speakers and case studies of projects. These experiences, professors say, impact students' decisions, especially since they report that there is little or no coursework dedicated to underground construction and tunneling until the graduate level. When asked about how they deliver career guidance to students, one professor reported that they use field trips and specific case studies. Textbooks do an adequate job of introducing the disciplines, but they don't use many case studies. There is a lot of information that is proprietary, and they also tie this in with YouTube, which is phenomenal. Professors also reported that site tours impress students and open their eyes to the array of the problems and challenges of underground engineering.

Many professors noted value in hosting speakers for their classes, because it gave students a first-hand look at the broad scope of projects and a chance to explore the field. On-campus speakers and tours of tunneling and underground construction sites provide an introduction to the field that students rarely get during their undergraduate civil engineering coursework. The Down for That website, undergroundcareers.org, aims to be a destination to connect students and professors to information and empower them to pursue their own research.

(Continued on page 28)

Invite potential engineers to experience your work. Visit undergroundcareers.org to contribute and learn more. Photo: The Robbins Co.

Personal News

McMillen Jacobs Associates has announced nine promotions to Principal in the firm's Underground Division.

CHRISTOPHER BURKE is the firm's Boston office manager. He has 27 years of experience in engineering, construction, project management and forensic construction consulting. He provides claims services to owners, contractors, subcontractors, architects/engineers and their counsel.

KENNETH DOMBROSKI (SME) PE, is the firm's central regional manager and has 30 years of experience as a civil engineer. His primary areas of practice are storm water management and municipal engineering. He is one of the leading experts in the Great Lakes region regarding manufactured storm water treatment devices and methods for underground storm water detention. He has degrees in public administration and civil engineering.


DOMBROSKI

THOMAS HENNINGS (SME), PE, PEng, is the firm's East Region structural engineering practice lead. He has more than 28 years of structural experience with 21 of those years specializing in underground projects including tunnels and deep excavation support systems. He has degrees in structural engineering and civil engineering.


HENNINGS

GRANT FINN, PE, SE, CEng, MICE, has more than 19 years of civil engineering experience, with a focus on underground engineering projects. His background includes structural design for underground works, including excavation support design, deep and shallow foundation design, tunnel rehabilitation, seismic engineering and cut-and-cover facilities.

DOUG GRIMES, PGeo, PMP, is the firm's Vancouver office manager and has more than 30 years of experience in the design and construction of tunnel, hydropower, water supply and reclamation projects. He has served as project manager on some of Vancouver's most significant water and gas pipeline projects.

YUXIN (WOLFE) LANG, PE, GE, PEng, is the firm's geotechnical engineering practice lead for Pipelines and Infrastructure. He has more than 25 years of geotechnical engineering experience, focusing on water, waste water and conveyance projects.

LAURA MILES, PE, DBIA, is the firm's Portland office manager. She has 32 years of experience in civil engineering focusing primarily on alternative delivery and dispute resolution.

ANDREW MENCKE, PE, is the firm's civil and architectural design practice lead. He has 17 years of experience providing detailed design and project coordination on transit, water and waste water system expansions and upgrades. He has been involved in the Sound Transit East Link, Northgate Link and University Link projects.

YIMING SUN, Ph.D., PE, has more than 25 years of experience in civil, geotechnical and mining engineering. He has experience in the design of temporary and permanent support for tunnels, large caverns and deep shafts. He also has extensive experience in numerical modeling for seismic, geotechnical, structural, groundwater, slope stability and thermal analyses.

The Deep Foundations Institute elected two new members to the DFI Board of Trustees, **PETER FAUST**, Dipl.-Ing., and **FRANZ-WERNER GERRESSEN**, Dipl.-Ing. Faust is vice president of business development at Malcolm Drilling Co. and has more than 25 years of experience in the design and construction of foundations. He has been involved in the project management/engineering of large infrastructure projects in Asia and Europe and the design and construction of foundation projects throughout the United States.

Gerressen is the director of the Construction Methods Development Department at Bauer Maschinen. He joined Bauer in 1992 and has been head of the CSV-Soil Stabilization Department, the Soil Improvement Department, the Diaphragm/Cut-off Walls Specialist Department and the testing laboratory for building materials. ■

Kerr receives Young Tunneler Award

AMANDA KERR, UCA of SME member, was named the Young Tunneler of the Year at the International Tunneling Association's 2019 Awards Conference and Banquet in Miami, FL. Kerr, a 2016 graduate of Arizona State University, is the first woman to win the prestigious award. She is a senior/project engineer at Michels Corp. in Brownsville, WI. She led teams of young engineers, organized and implemented tunneling optimization programs resulting in repeated increases in production. She also negotiated project change orders with the client, and identified and oversaw numerous design improvements. ■


KERR

CSM offers tunneling short course

Registration is open for the Colorado School of Mines' (CSM) Tunneling Fundamentals, Applications and Innovations short course, Oct. 19-22, 2020. Last year's course sold out with more than 150 participants and 32 speakers from around the world.

Forecasts show tremendous growth in tunnel projects in the next decade — water and waste water, transportation, energy, utilities and loop/hyperloop. The comprehensive four-day agenda includes topics ranging from planning to design to the construction of tunnels for all purposes and across all types of ground conditions. Technical leaders will teach key principles and the latest innovations. Upcoming U.S. and international tunneling projects will be highlighted. Five owner-representatives will provide insights, and CSM faculty and students will share the latest research and development innovations, including results from a major rapid-tunneling technology initiative underway.

The short course is located on campus and capitalizes on CSM's state-of-the-art laboratories and facilities. Hands-on labs each afternoon include earth pressure balance (EPB) soil conditioning, EPB TBM simulator, rock cutting, abrasivity and wear, shotcrete, and annulus grouting. There will be opportunities to network with students studying to enter the industry. To view the full agenda and to register for the course, visit: http://underground.mines.edu.

The Colorado School of Mines Center for Underground is a multidisciplinary group of faculty and students from the civil engineering, geology and geological engineering, mechanical engineering, mining engineering, geophysics and computer science, with an interest in education and research in underground engineering. ■

DFI and Terracon announce a new scholarship

The Deep Foundations Institute (DFI) Educational Trust and the Terracon Foundation announce the establishment of the DFI Educational Trust/Terracon Consultants Scholarship Fund that will provide scholarships to engineering students attending any U.S. college or university. The endowment was established through a $50,000 National Partner Grant from the Terracon Foundation. The Foundation's pledge will be used annually to award a $2,000 scholarship.

The Terracon Foundation encourages employees to submit grant requests each year for organizations focused on education and the built and natural environment. Andrew Verity, national account manager for Terracon's transportation and infrastructure sector and member of the DFI Educational Trust Board of Trustees, championed the grant application.

Verity presented the check to Theresa Engler, executive director of DFI, on Jan. 13, 2020.

Several DFI Educational Trust Scholarships, including the Terracon Consultants Scholarship, will be awarded this year through the trust's at-large scholarship program. The 2020 application period for these scholarships will open on April 1, 2020. More information is available at www.dfitrust.org. ■

Down for That

(Continued from page 26)

Help build the engineering workforce of the future

UCA of SME would like you and your company to be in on this project and ask for your contributions to build the content library of the site. We are looking for projects and case studies to publish and members of UCA of SME to be profiled, and we aim to build a list of speakers and tours for professors and students to access. We would also like to include video footage of projects and stories of engineers in the field. Being included as a resource in this initiative builds your influence and helps position your company as a great place for young engineers to work.

Submissions and materials are being accepted and considered now. For more information or to contribute to the project, please email downforthat@ucaofsme.org. The website is expected to be fully launched in time for the North American Tunneling Conference in June 2020. ■

Site visits make a huge impression on engineers who have chosen a career underground. UCA of SME's Down for That shares information and access to the work being done in the underground construction industry with students and professors. Photo: The Robbins Co.

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

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

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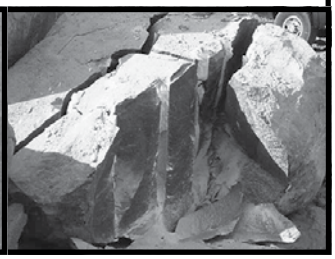

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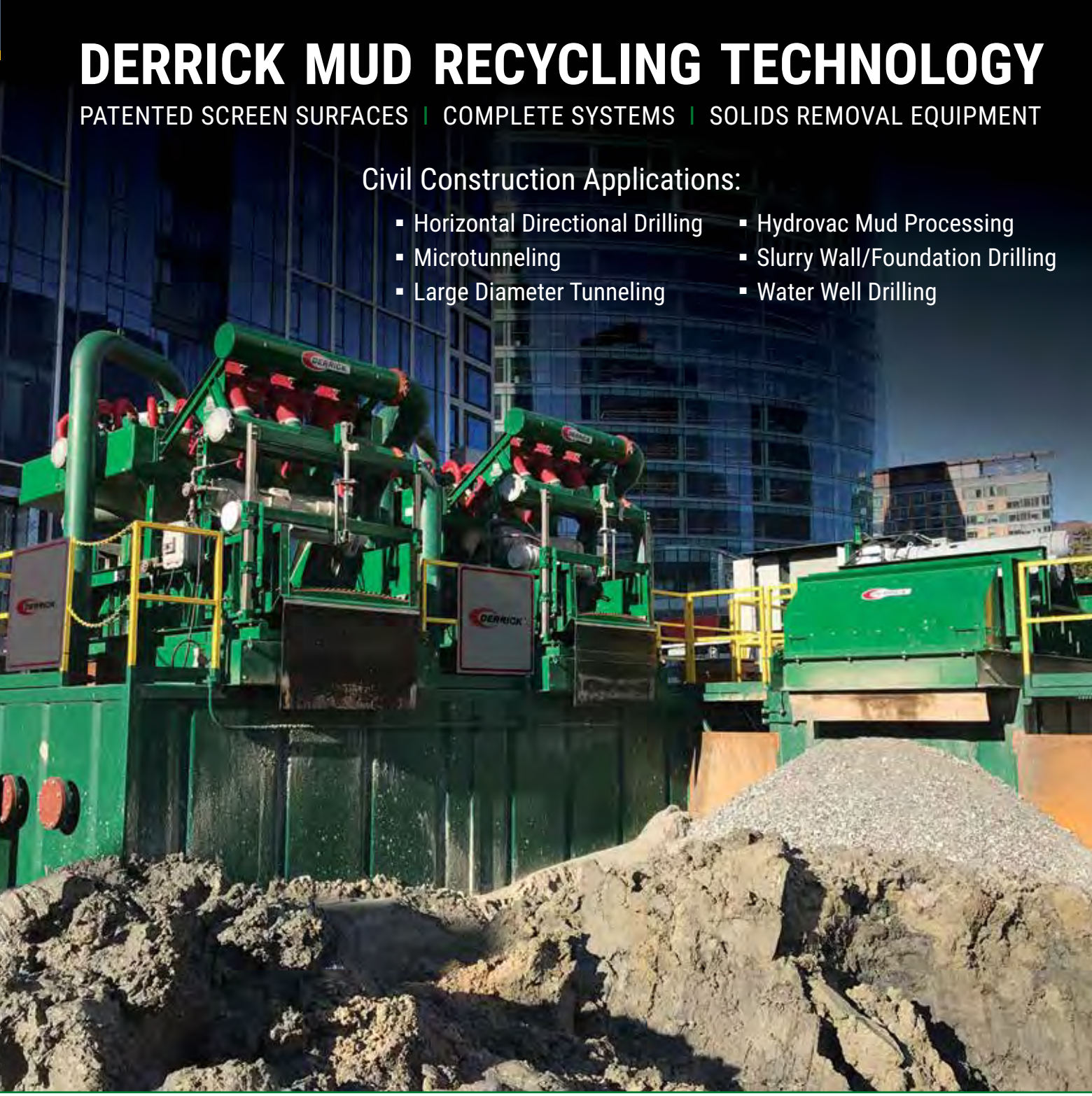

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For more information, please visit: https://www.master-builders-solutions.basf.com

Dragados TBM Bertha
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TungsteMet manufactures standard and custom-molded carbide products for many different industries.

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DEMANDING CONDITIONS

DEMAND JENNMAR.

JENNMAR CIVIL™

Jennmar has been the innovative leader in ground control for the mining industry for more than forty years. Over the past decade, our growth has led us to above ground for structural buildings, implementing the same vigor and detailed processes. Our Jennmar Civil arch systems, girders, liner plates and Impact Resistant Laggings® are backed by experienced engineers and technicians who are with you every step of the way, from initial consultation to qualified instruction and on-going technical support. And, of course, our customer service is second-to-none. That's something we've always demanded of ourselves.

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ANTRAQUIP CORPORATION – your reliable, innovative partner

Antraquip Corporation continues to solidify its position as a leading designer, manufacturer and supplier of roadheaders, hydraulic rock cutting attachments, shaft sinkers, specialty tracked machines with a variety of boom options and ground support solutions for NATM tunnels.

Within Antraquip's rock cutting attachment product line, Antraquip has introduced diamond and carbide saw attachments for excavators ranging from 1 to 60 tons. Additionally, Antraquip has designed and manufactures the world's most powerful rock cutting attachment with 400 kW+ cutting power for excavators in the 80+ ton weight class. By continuing to invest heavily into research and development Antraquip strives to be able to cut hard rock which has previously not been possible with mechanized excavation methods.

As to roadheaders, Antraquip offers not only standard roadheaders in the 12 – 85 ton class but is proud to offer project oriented engineering solutions whenever requested and necessary. Some of the recent projects have included AQM roadheaders equipped with customized drilling attachments, fully automated remote control systems and automated guidance systems.

Within its ground control program, Antraquip specializes in any support product needed for NATM tunnels like lattice girders, steel ribs, specialized rock bolts, spiles, wire mesh and arch canopy systems (barrel vault system or arch pipe system).

In addition to offering project consultations, innovative cutting and support solutions, Antraquip recognizes the importance of after sales service. Their commitment to offering the best service and technical support is carried out by highly proficient and experienced service engineers and technicians, all reinforced with large spare part inventories at hand. Innovation, reliability and experience offered by Antraquip makes them a reliable partner for any tunneling project.

Antraquip's main goal is: SAFETY, SAFETY and again SAFETY! Antraquip continues to strive to offer innovative products to make any job safer, faster and increase the bottom line for any contractor and owner.

Antraquip is well represented all over the world, but takes pride in paying detailed attention to any local tunneling challenge small or large.

IN THE FUTURE, THE WORLD WILL NEED MORE AND MORE TUNNELS – AND ANTRAQUIP INTENDS TO BE AN IMPORTANT, RELIABLE PARTNER FOR ANY UNDERGROUND PROJECT!


AQ6 Hydraulic Cutting Attachment


AQC180 on CAT336


Antraquip AQM175 Roadheader

ANTRAQUIP® CORP

Experienced, Innovative & Reliable

HIGH PERFORMANCE, DELIVERED

ROCK & CONCRETE CUTTING ATTACHMENTS

DIAMOND & CARBIDE DEMOLITION SAWS

Proudly Made in the USA

HYDRAULIC ROCK & CONCRETE CUTTING ATTACHMENTS

THE ULTIMATE CONTRACTOR'S ATTACHMENT

ROADHEADERS
Weight Class 13 - 85 tons

NATM TUNNEL SUPPORT PRODUCTS

Lattice Girders • Arch Canopy System
Pipe Roof System • Barrel Vault
Spiles and Rock Bolts • Steel Fibers
Steel Ribs • Wire Mesh

Leading Manufacturer of Roadheaders, Hydraulic Cutters and Tunnel Support System

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ANTRAQUIP® CORP

MAPEI Corporation

MAPEI's Underground Technology Team (UTT) provides the construction market with a range of products dedicated to underground construction work. MAPEI's UTT group and the products it represents were created to meet the expectations of these challenging environments.

From the project specification to the admixtures for shotcrete and concrete to the final protective coatings, MAPEI's UTT group and technology are there "for the whole job," said Bill Allen, UTT Business Development Manager — Tunneling. The UTT group is a successful division of MAPEI Group, which has provided proven construction system solutions for more than 80 years.

MAPEI's UTT products were used to help a tunnel boring machine dig the Anacostia River Tunnel, which extends for 2.37 miles from Robert F. Kennedy Stadium in northeast Washington, D.C., to Poplar Point in southeast D.C.

Established in 1937, MAPEI Group is a global corporation, based in Milan, Italy, and with 87 subsidiaries that include 81 plants in 35 countries. MAPEI is the world-leading manufacturer of mortars, grouts and adhesives, as well as complementary products for installing floor and wall coverings. MAPEI manufactures chemical products for building, including waterproofing products, admixtures for concrete and repair products, and decorative and protective exterior coatings — as well as the UTT product line.

"The UTT group started in earnest in the U.S. in 2015," stated Wesley Morrison, UTT Regional Manager – North America. "But the business has grown substantially since then."

In the underground industry, speed is essential – not only of the products themselves, but also of the evolution of technology. MAPEI reinvests a considerable percentage of its annual profits back into research and development to maintain a leading technological advantage.

MAPEI's commitment to R&D ensures that the UTT line comprises the most innovative and technologically advanced products available. In addition to the latest in cutting-edge products, the UTT team is trained in their use.

The UTT product line is divided into six categories: Concrete; Injection, consolidation and anchoring; Waterproofing; Renovation, maintenance and repair; Coatings for underground construction; and Mechanized tunneling.

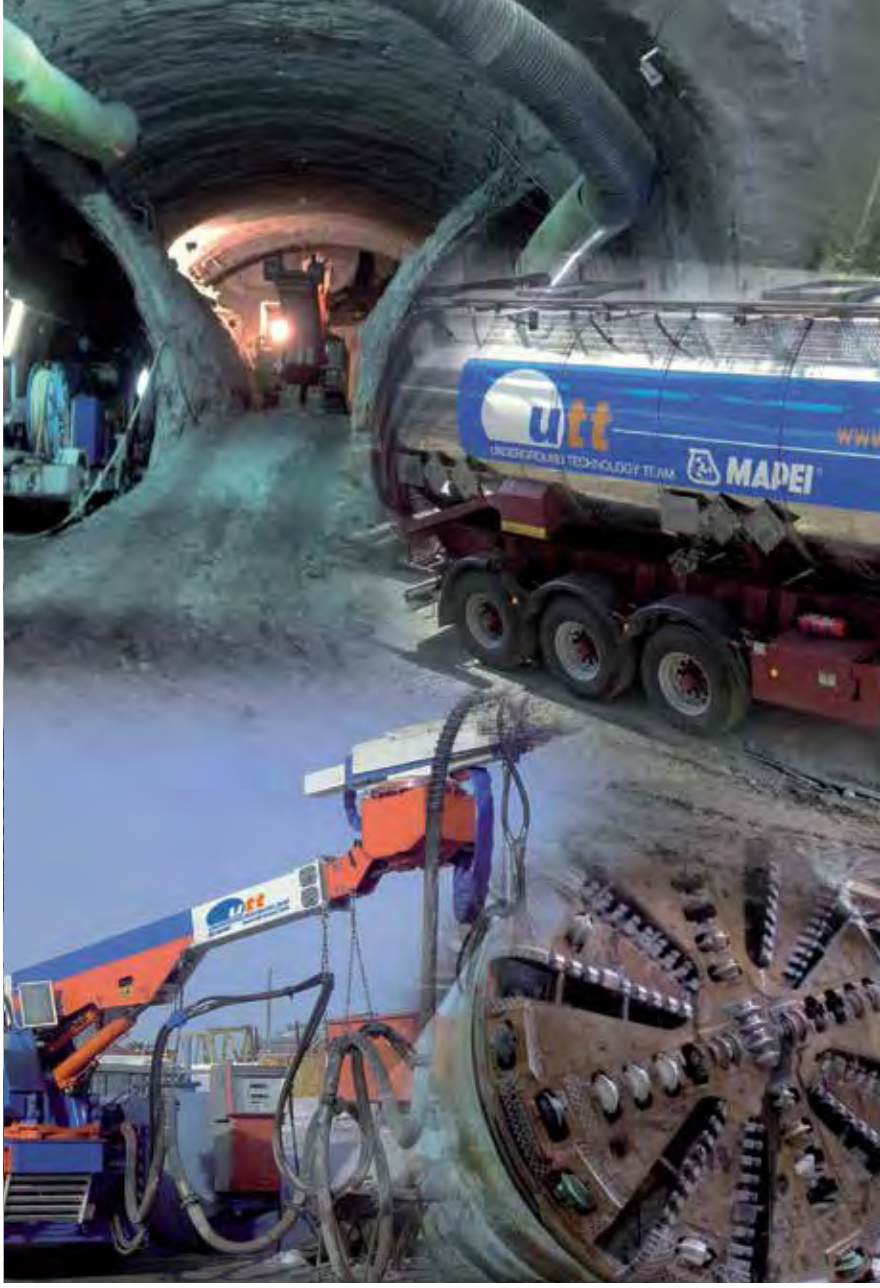
No matter the division or the product line, MAPEI is known for quality products and for providing system solutions. As Allen stated, "The distinguishing point for UTT is our field support, and our applied technology in the field. Simply put, we don't just sell a product, but rather we go into the field and help our customers use our products – on their jobsite, with their conditions, personnel and equipment."

Morrison concurred, agreeing that UTT's technical services and agility are unbeatable. "We service a project from the very beginning to the very end like no one else in the industry does," he said. "We also have the agility to adjust to the customers' needs when necessary."

For more information, contact MAPEI's UTT group at www.utt.mapei.com.

Proven Technology for

Underground Construction



Our commitment is the detail that makes the difference.

Reliable technology and expertise for underground construction

- Alkali-free set accelerators and admixtures for shotcrete
- Products for mechanized tunneling: foaming agents for soil conditioning, polymers, sealants and lubricants
- Products for grouting and consolidation
- Products for concrete repairing, protection and coating
- Products for waterproofing: synthetic waterproofing membranes and waterproofing accessories

Discover the world of MAPEI: Visit www.utt-mapei.com or email us at hq.utt@utt.mapei.com

MAPEI USA

utt
MAPEI

Local Presence. Global Competence.

DSI Tunneling LLC offers a complete selection of ground control solutions for the Civil, Mining and Foundation markets. We have been a leader in the underground support business in North America since 1920.

A global leader in tunnel and shaft construction, we focus on engineered and tailored products to support our customers and the industry.

For Tunneling our core product line ranges from steel ribs and liner plates to lattice girders, rock bolts and pre-support products. Each support system is customized and professionally engineered to your specific application. Our ground support systems are designed to make tunneling safer. Thanks to our local presence around the globe, we can satisfy your needs for ground control quickly and efficiently - no matter where you are.

DSI Tunneling LLC is proud to bring an expanded group of products to the job site:

- **ALWAG** - Support Systems
- **Biomarine** - Tunnel Rescue Equipment
- **Boart** - Probe and Roof Bolting Equipment
- **Condat** - Ground Conditioning Chemicals and Lubricants

DSI - Steel Ribs, Liner Plates, Lattice Girders, Lagging and Miscellaneous Support Items

- **Dywidag** - Bolts and Accessories including DSI Threadbar, Friction Bolts and Omega (inflatable) Bolts
- **Hany** - Grouting Systems
- **Montabert** - Excavator Drilling Attachments and Replacement Drifters
- **Promat International** - Fire Protection Products
- **VikOrsta** - CT-Bolts - Double Corrosion Protection

DSI UNDERGROUND

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DSI UNDERGROUND

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NEW – Injection Chemicals for *Tunneling* Applications!

You want to advance your operations efficiently. To improve safety. To minimise downtime and maximise productivity and performance. We have the people and the products for every challenge, and a supply chain you can rely on to deliver. Working alongside you, we help you progress towards your objectives – quickly, reliably, cost-effectively.

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Kiewit

As a construction, mining, and engineering leader, Kiewit is a FORTUNE 500 company consistently ranking in the ENR's Top 10 Contractors. Kiewit, through its operating companies, brings a wealth of diverse resources and track record for delivering the highest quality results – on budget and on schedule. Kiewit's size and experience provides the stability, predictability and knowhow our clients and partners expect – and the flexibility and overall best value they deserve.

Kiewit Infrastructure Co.
1926 S 67th Street, Suite 200
Omaha, NE 68106
(402) 346-8535

Kiewit has been constructing underground facilities for over 60 years, offering some of the most highly skilled and experienced teams in the industry. We have completed hundreds of underground projects, totaling several billion dollars of contract revenue in the markets of transportation, water/ wastewater facilities, power, mining and telecommunications. In addition, Kiewit has the resources to construct cut-off walls, structural slurry walls, drilled shafts and various ground improvements. We perform these operations with our fleet of specialty equipment and the management resources of one of the top builders in North America. Through the use of cutting-edge technology, industry-leading safety performance and the wide range of capabilities, we offer our clients an innovative, one-stop shop for all their tunneling needs.

Our projects range from fast-track rehab jobs to billion dollar rail tunnels. No project is too large or small when it comes to meeting our clients' needs. Our clients in these markets have come to expect the industry's safest work environments, the highest- quality delivery and superior compliance with requirements of all types. Behind it all are the core values that have shaped how we manage our business – for our clients and other key constituents.

Kiewit

JOBS DONE WELL.

For more than 50 years, Kiewit has built some of the most complex tunneling and underground projects in North America. We have the capabilities to self-perform soft ground and hard rock TBM tunneling, along with conventional tunneling techniques such as SEM and Drill and Blast. At the heart of these projects is a workforce dedicated to industry-leading safety performance and unmatched quality excellence. From the unique, complex projects we build, to the committed professionals who design, engineer and construct them, Kiewit ensures the ordinary is always extraordinary.

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The Ruggedized High-Speed Network Used in the World's Largest Tunneling Project Is Now Available in the US

When the ambitious Brenner Base Tunnel, a 40-mile railway project through the base of the Eastern Alps between Austria and Italy, got underway, N-Connex was the modular network selected to provide the data backbone and application support. While it was chosen for many reasons, the fact that N-Connex's plug-and-play and pre-terminated IP67 Ethernet and fiber optic cables can be deployed and changed by non-technical personnel ranked high on the list. By offering the lowest cost per installed mile and its support of many applications, including voice and data communications, tracking, machine telemetry, controls & automation, tele-ops, video and emergency/safety alerts, N-Connex emerged as the clear choice.

Upon completion, the Brenner Base Tunnel will be the longest underground railway connection in the world, ultimately extending 64 KM (40 miles) under the Southern Alps. N-Connex's versatile high-speed network is providing the backbone and solutions to support this unprecedented effort.

This award-winning network, available in the US and Africa through Matrix Design Group, is easy to install, expand and maintain with pre-terminated cables and extenders eliminating the need for on-site splice repairs. And the modular components allow tunnel projects to customize their network based on environmental conditions and communications requirements.

N-Connex is the most comprehensive and flexible gigabit network on the market today. Used by forward-thinking tunneling and mining companies around the globe, N-Connex offers a core network to which multiple solutions can be added. N-Connex's unique design allows third-party electronics and hardware integration, providing a one-stop shop for add-on solutions and eliminating the need for sourcing components.

Tomorrow's communications have arrived

N-Connex's voice and data comms over Ethernet and Wi-Fi enable private calls, PTT broadcast, IP intercoms, phones, tablets, laptops, wireless adapters, input/output devices, tracing tags, radios and more. Reception is crystal clear and calm with multiple channels over which you can talk individually or as a group. Additionally, being able to transfer data and get updates provides the ability to make changes mid-shift to enhance efficiency and productivity.

Second, the N-Connex tracking solution offers a reliable, detailed and flexible approach to locating personnel, vehicles and assets throughout a project. Tracking also interfaces with a suite of emergency features such as N-Connex's alarm module and advanced evacuation technology. These features alert and help provide the exact location of all personnel in the event of an emergency.

Most anything you can imagine

N-Connex's suite of solutions is incredibly diverse. For example, it also offers a multi-level map interface and zone management, as well as video, real-time condition and environmental monitoring. All of this functionality is packaged in a ruggedized enclosure, specifically designed to withstand harsh environments.

Lowest cost to invest – lowest cost to advance

N-Connex has created a highly affordable networking solution with the lowest cost-to-advance rate on the market. And since you can install a core system, then add on the adaptable modular features as you go, the network gives you financial flexibility. The simple beauty of the N-Connex system is its ability to meet your exact needs today *and* address your expansion or available resources tomorrow.

Matrix is a safety and productivity technology leader for underground mining, tunneling and industrial applications. Headquartered in Newburgh, Indiana, Matrix has offices in Lexington, KY, Johannesburg, South Africa and service locations throughout its mining regions. Matrix is also an ISO 9001 certified manufacturer, which ensures a quality product and high level of service from an outstanding field service team. For information on N-Connex: sales@matrixteam.com or 812-490-1525.

Why Was the N-Connex Network Chosen for the World's Largest Tunneling Project?

Because there is no high-speed ruggedized integrated network solution easier to deploy and support!

- N-Connex is a ruggedized fiber optic, Ethernet and Wi-Fi network like no other
- A "plug and play" network built and supported by your existing staff using pre-terminated cables
- It provides clear, reliable communications via IP Phones, Smart Phones, IP Radios, Laptops and Tags
- Start with the core system, then add solutions as required, including: tracking, emergency/safety alerts, controls & automation, machine telemetry, tele-ops and video – as well as condition and environmental monitoring
- Lowest cost per installed mile

The Brenner Base project, extending under the Alps between Austria and Italy, is the world's longest railway tunnel (34-miles). **N-Connex** was the network of choice for this complex operation.

PHOTO FROM BBT SE

Matrix is the authorized sales and service distributor of NLT N-Connex in the United States and Africa.

MATRIX

Phone: 812.490.1525 • Email: sales@matrixteam.com

www.matrixteam.com

Herrenknecht: Pioneering Undergound Together

With the experience of more than 4,100 projects, Herrenknecht is a technology and market leader in the area of mechanized tunnelling technology. Herrenknecht is the only company worldwide to deliver cutting-edge tunnel boring machines for all ground conditions and in all diameters – ranging from 0.10 to 19 meters. The product range includes tailor-made machines for traffic, supply and disposal tunnels, technologies for pipeline installation as well as drilling equipment for vertical and inclined shafts and deep drilling rigs.

The Herrenknecht Group achieved a total output of 1,316 million euros in 2018. The independent family-run business employs over 5,000 people worldwide, including around 180 trainees. With around 80 subsidiaries and associated companies working in related fields in Germany and abroad, Herrenknecht is able to provide a comprehensive range of services close to the project site and the customer, quickly and in a targeted way. Under the umbrella of the Herrenknecht Group, a team of innovative specialists offers integrated tunnelling solutions with project-specific equipment and service packages upon request: separation plants, belt conveyor systems, navigation systems, rolling stock systems as well as segment moulds and even turnkey segment production plants.

As a reliable project partner, Herrenknecht supports its customers with an extensive range of services from the beginning of the project to breakthrough. From the initial project idea through manufacturing, transport, assembly, tunnelling support and spare parts service to disassembly, Herrenknecht accompanies the process at the customer's side. Even personnel solutions for the temporary supplementing of jobsite crews are provided if required. With competent service specialists and and more than 40 years of experience in the tunnelling industry, the company regularly supports around 300 jobsites worldwide and offers customized service packages tailored to individual project requirements.

Road, metro, and railway tunnels for efficient traffic network.

By the middle of this century, the world´s population is expected to reach nine billion, and two thirds of these people will live in large conurbations. To keep people and goods on the move, the way ahead for new efficient infrastructures is leading underground. With state-of-the-art technologies, efficient infrastructures are created exactly where they are needed, even in cramped and complex jobsite conditions. Herrenknecht technology pushes the boundaries of feasibility and creates new tunnelling standards worldwide. Herrenknecht technology extends existing transport networks and creates new connections in urban and rural areas – under mountains or deep beneath water.

Innovative solutions for underground supply and disposal systems.

As the world's population grows the need for underground supply tunnels is also increasing; in emerging and developing countries as well as in modern metropolises. That is why more than 850 Herrenknecht Utility Tunnelling Machines are in operation around the world constructing or laying water and wastewater systems, gas and oil pipelines, as well as conduits for electricity and telecommunications. Here, trenchless tunnelling technology offers a range of advantages compared to conventional construction procedures: transport, business and the environment remain mostly undisturbed when Micromachines, HDD rigs or shaft sinking equipment are being used. Innovations such as Direct Pipe® set new standards in the semi-trenchless installation. The new technology E-Power Pipe® allows the secure and quick installation of underground cable protection pipes with smaller diameters and long advance lengths. Innovative HDD tools simplify pipeline construction operations at key sections. The Herrenknecht product portfolio is completed by a broad range of equipment for the areas of mining (construction of underground infrastructures around raw material deposits) and exploration (oil, gas and geothermal energy).

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HERRENKNECHT
Tunnelling Systems

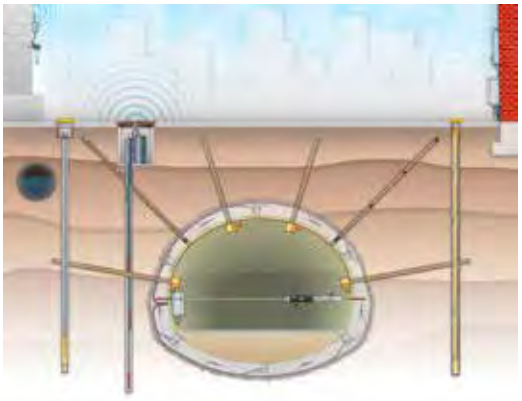
Geokon

GEOKON is a recognized world leader in geotechnical instrumentation. Founded in 1979, the company offers a full complement of products for a wide range of applications including tunnels, dams, mines, piles, pipelines, embankments, foundations, landfills, bridges and wind turbines. GEOKON's worldwide network of over 45 agencies distribute globally to North and South America, Europe, the Middle East, China, Russia, Asia Pacific and Australia/New Zealand.

With over 100 associates, GEOKON incorporates state-of-the-art manufacturing processes and equipment to produce the highest quality and performing products on the market. Geotechnical, mechanical, electrical and software engineering teams collaborate to develop the highly innovative, accurate and reliable instrumentation. As a result, GEOKON has been awarded ISO 9001:2015 registration from both ANSI•ANAB, USA and UKAS of Great Britain. GEOKON's calibration program complies with the ANSI/NCSL Z540-1 Calibration Laboratory and Measuring and Test Equipment General Requirements and all products have achieved Russian GOST certification for safety.

Specific for the tunnel and tunneling industries, GEOKON offers a full range of instrumentation including:

- NATM-style pressure cells
- Convergence meters
- Tape extensometers
- Multiple-point borehole extensometers
- Instrumented rock bolts
- Piezometers
- Strain gages



- Load cells
- Inclinometers and tiltmeters
- Crackmeters
- Settlement systems
- Dataloggers and Web-based software

All products are backed with a full 13-month warranty and supported by an experienced team of factory-trained associates ready to assist in instrument design, selection and installation. For more information, please visit www.geokon.com, email us at info@geokon.com or call +1-603-448-1562.

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Advanced Concrete Technologies, Inc.

– We Add Profitability to the Mix

Advanced Concrete Technologies, Inc. (ACT) is a single source supplier of turnkey concrete batching and mixing plant solutions that draws on over 55 years of experience and more than 5,000 concrete plant installations worldwide. ACT provides the industry's most flexible and proven solution for producing highest-quality, central mixed concrete and backfill grout for on-site construction, tunneling and mining projects. ACT's MobilMat batch plants, come in ten different sizes, ranging from 30 up to 240 cubic yards per hour concrete output. We offer high intensity HPGM counter-current mixers and DWM twin-shaft mixers, advanced WCS control automation, commissioning services as well as an industry leading training & support program.

ACT's plant solutions deliver superior quality concrete with the ideal combination of proven components, engineered by one of the world's most respected names in the industry – Wiggert & Co. GmbH.

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RUEN Drilling

Ruen Drilling provides drilling services including surface, underground, and horizontal directional core drilling for the geotechnical, exploration and geothermal industries throughout the United States. Drilling equipment includes truck, track, skid, and helicopter supported core drills. Rig capacities are to 10,000 feet vertical or angle and 3,000 feet horizontal. Crews all have extensive safety training, are trained in achieving a high degree of core recovery and are experienced in the installation of instrumentation and geophysical testing.

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AKKERMAN: OUR EQUIPMENT SYSTEMS

Akkerman develops, manufactures and supports powerful and versatile guided boring, microtunneling, pipe jacking, sliplining, tunneling and earth pressure balance underground construction solutions that accurately install a variety of pipe in an extensive range of ground conditions and project challenges.

Since 1973, our industry-leading equipment has enabled contractors worldwide to productively and cost-effectively install water, wastewater, and other infrastructure.

DRIVEN FOR CUSTOMER SUCCESS

Symmetry with contractors has been the backbone of our business and a point of distinction above our competition. Before Akkerman the equipment manufacturer there was D. H. Akkerman Construction Company. To satisfy their need to accurately install pipe under crossings, the manufacturing branch of Akkerman was founded over forty-seven years ago.

Akkerman employees have a personal investment in our customers' success. Our sales team has the pulse on industry demands and will guide you through the process to select equipment solutions to address your project's challenges. Our in-house engineering department delivers innovative designs with advanced technology, and robust specifications which are expertly manufactured on-site.

SERVICE & SUPPORT

We back our equipment systems with a powerhouse of skilled sales, engineering and technical professionals dedicated to superior reliability and responsive service.

Akkerman factory certified field technicians represent an extensive portfolio of hands-on equipment experience to train your crew on the project site.

Aftermarket parts sales are efficiently dispatched to minimize project delays and ensure that your equipment is prepared for optimal performance.

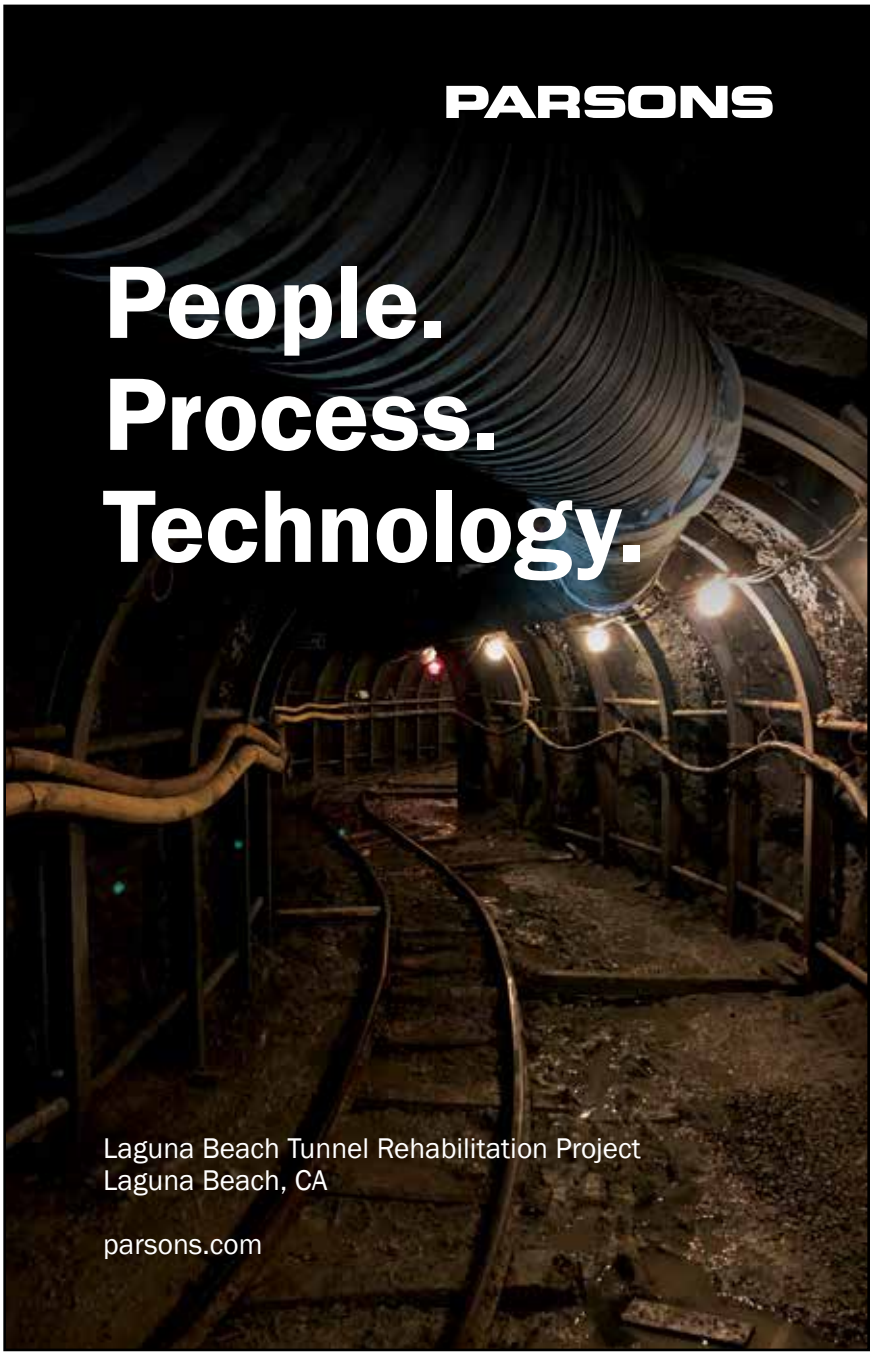
Contact us at (800) 533.0386 to discuss your next project and visit akkerman.com.

Industry leaders. Delivering innovative solutions.

Parsons is a technology-driven engineering services firm with 75 years of experience in the engineering, construction, technical, and professional services industries. The corporation is a leader in many diversified markets with a focus on infrastructure, defense, and construction. Parsons delivers design/design-build, program/construction management, systems design/engineering, cyber/converged security, and other professional services packaged in innovative alternative delivery methods to federal, regional, and local government agencies, as well as to private industrial customers worldwide.

We have successfully delivered some of the largest and most complex tunneling and underground construction projects in the world. From planning and design through construction management and operations, Parsons provides a complete range of services for water, wastewater, and transportation tunnels. Whether your project involves soft ground, rock, or mixed-faced conditions, our dedicated staff of more than 100 tunnel professionals have the experience and skills to manage the risks and deliver safe, economical, and innovative solutions. Our recent award-winning projects, such as Lake Mead Intake No. 3, Anacostia River Tunnel and Ohio River Bridges-East End Crossing Tunnel, demonstrate Parsons' position as an industry leader and our dedication to delivering on challenging projects.

Learn more at parsons.com.



ABC Industries, Inc.

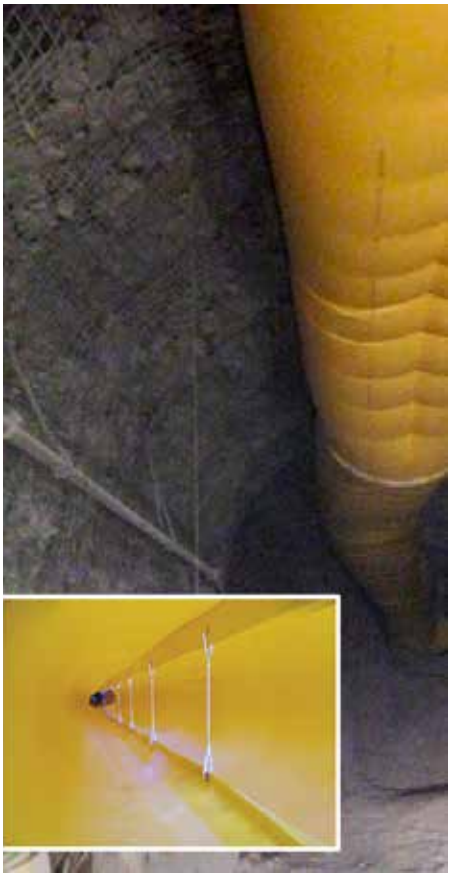
For over 90 years, ABC Industries continues to be a leading supplier of high quality, customized ducting solutions in many of the largest mine, tunnel and underground construction operations worldwide. ABC's complete line of layflat blower tubing, ducting, brattice, fly pads, blast curtains, fans and accessories offer a complete ventilation solution for underground professionals. As tunneling and underground construction continue to evolve, ABC proactively collaborates with industry professionals to engineer unique, premium ventilation products exceeding the needs of the industry.

Our featured MineVent® and TruOval MineVent® ducting products, with their welded construction, eliminate air loss and weakening associated with conventional sewn ducting. Our available RipStop substrate technology option prevents small tears from expanding into sizable holes. ABC's ducting also features several easy-to-handle accessories that are more cost-effective, require less space and smoothly transfer air through bends and turns. To view more of our innovative products, please visit our website at: **www.abc-industries.net.**

RIGIDUCT®

Filament-Wound Fiberglass Tubing

A leader in tunnel ventilation, ABC provides high quality, customized solutions such as our RigiDuct® filament-wound fiberglass tubing. Its excellent strength under high degrees of negative pressure, high resistance to attack from acid or alkaline conditions, and its UV-stabilized rubberized elastic gaskets resist degrading while remaining pliable in cold weather conditions. Learn about our other tunnel offerings, such as MineVent® and TruOval MineVent® layflat blower tubing by visiting us at abc-industries.net.



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RigiDuct®, MineVent®, and TruOval MineVent® are registered trademarks of ABC Industries, Inc.

Premier Pipe Systems Manufacturer for 95 Years

Since 1925, Naylor Pipe Company has been the premier manufacturer of Spiralweld pipe systems.

Naylor Spiralweld is available in diameters from 4" through 96" and wall thickness from 14 Ga. through 1/2" wall. The Spiralweld pipe is complemented with all types of fittings, fabrications to specification, and joint connections, including the exclusive Naylor Wedgelock Coupling, to complete your pipe system.

Naylor Spiral Buttweld pipe features two welds along the spiral seam. This creates a pipe structure in which the weld is as strong or stronger than the parent metal.

The Naylor manufacturing process creates a pipe that maintains an accurate diameter throughout its length. The uniformity of the pipe ends speed connection, whether mechanically coupled or welded.

Uniform wall thickness is assured because tolerances of steel strip are governed by the standards established by the American Iron and Steel Institute. In addition, the pipe is furnished in any required length with a cutting tolerance of plus or minus 1/8". In addition to carbon steel, spiralweld pipe can be formed from many steel grades, including abrasion resistant, weathering (A-588) and stainless.

Every length of Naylor Pipe is inspected and where required hydrostatically tested to applicable ASTM specifications. The pipe is available in lighter weights than other pipe making it possible

to save money, not only on initial cost, but also in transportation, handling and installation. By sizing the diameter of the pipe to the exact requirements, with exact lengths and factory-sized ends, the greatest economies can be realized.

Quotations are immediately available on inquiry.

Naylor Pipe Company
1230 East 92nd Street
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www.naylorpipe.com

Mining Equipment Ltd.

Mining Equipment Rolling Stock for Columbus, Ohio

"Rolling for more than 35 years"

Mining Equipment continues to supply the tunneling and mining industries with top-quality rolling stock, Jetair fans and steel ventilation ducting, as well as a large inventory of rebuilt equipment such as scooptrams, trucks, drill jumbos and other underground gear.

Mining Equipment is based in Durango, Colorado, with a main shop facility in Farmington, New Mexico. They also have steel fabrication capabilities near Shanghai.

Mine Hoists International, a sister company of Mining Equipment, is based in North Bay, Ontario. They boast the world's largest inventory of used mine hoist and large capacity stage winches for mining and shaft sinking projects. Their new 20,000 square foot shop in North Bay, Ontario can handle the largest of hoist and winch rebuilds.

Mining Equipment 10 Ton Locomotives for Columbus, Ohio

Drill Tech Drilling & Shoring, Inc.

Drill Tech Drilling & Shoring, Inc. is a recognized leader in the foundation and excavation industry in the United States. The same guiding principles that helped Drill Tech become a top 10 Foundation Contractor, according to ENR's Top Specialty Contractors, can be seen in Drill Tech's Mining & Tunneling Division (DTM&T).

On the Barrick Range Front Declines, DTM&T has almost completed over 18,000 feet of twin declines almost six months ahead of schedule. Rock conditions varied in strength along the decline and while the contract was initiated using Roadheader excavation methods, DTM&T has utilized both drill & blast and roadheader techniques to overcome these varied rock strengths. Throughout the execution of the work, DTM&T focused on building a safe project ahead of schedule that met the quality expectations of Barrick. Drill Tech's efforts were recognized by Barrick and additional work was issued to Drill Tech's contract.

In addition to the twin declines, DTM&T performed contract work for other contractors on the project site that included Mass Excavation of 129,314 CY of rock and the application of 15,995 CY of shotcrete. During the course of these projects, DTM&T has performed safely for 814 days.

For more information, please visit www.drilltechdrilling.com, email us at dtds@drilltechdrilling.com or call at 925.978.2060
Drill Tech Drilling & Shoring, Inc.
2200 Wymore Way
Antioch, CA 94509

CDM Smith – A Leader in Tunnel Engineering

Urbanization and rapid population growth have increased demand for tunnel and underground engineering to address infrastructure needs and maintenance challenges facing metropolitan areas worldwide. CDM Smith is a leader in underground space and tunnel engineering. Working collaboratively with our clients, we employ our extensive global tunnel design and construction experience to develop holistic and optimal solutions for a wide range of projects.

Tunneling Expertise

With our experience encompassing soft ground, mixed face, and rock tunnels and excavations, CDM Smith offers a unique perspective and skillset that addresses the specific needs of each project. Our capabilities are comprehensive and include:

- Tunnel engineering: Tunnel and trenchless engineering
- Lining design: segmental, sprayed and cast-in-place
- Soil-structure interaction: 2-D & 3-D numerical modelling
- Ground improvement and ground freezing
- Deep excavations and ground support
- Groundwater modelling and control
- Shafts and caverns
- Documenting and baselining geotechnical conditions

To support our clients, we offer consulting, engineering and construction support services including:

- Environmental, permitting and planning process
- Preliminary design through bid/construction support
- Value engineering and peer review
- Program/construction management
- Inspection and rehabilitation of underground structures
- Risk management
- Cost estimation and life cycle cost analysis

Market Sector Experience

Tunneling and ground engineering is unique – it crosses market sector boundaries. CDM Smith's global tunneling assignments are executed within all market sectors, including:

- Transportation (rail, highway, aviation)
- Environment
- Water/Wastewater (utilities and conveyance)
- Mining (access adits and mines)

Michael Schultz, PE | SchultzMS@cdmsmith.com | 617-453-6399
Mahmood Khwaja, PE | KhwajaM@cdmsmith.com | 617-452-6391

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2020 Annual Short Course GROUTING AND GROUND IMPROVEMENT

JULY 20-23, 2020
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GOLDEN, COLORADO

This three-and-a-half-day course covers engineering, equipment, materials and methods for grouting and ground improvement in civil and geotechnical engineering, underground construction, tunneling and mining projects. Participants will have access to classroom presentations by internationally-recognized experts, as well as laboratory demos, an offcampus field demo and hands-on testing of grout and grouting methods all held at the renowned facilities at the Colorado School of Mines.

Whether you're a seasoned professional or just starting in the field, this course is designed to provide the latest in industry innovations. Owners, planners, designers, contractors, consultants and suppliers involved in civil and geotechnical engineering, transportation, underground, tunneling and mining projects will benefit on the job from this course.

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Our short course presents a unique opportunity to learn from the most experienced and innovative talent in the tunneling industry. This is a three-and-a-half day course that covers engineering, equipment, materials and methods for grouting and ground modification used in civil and geotechnical engineering, underground construction, tunneling and mining.

Don't miss this opportunity for professional development and high-level networking — all while earning 2.4 CEUs!

Hands-on labs and workshops will give you the real-world experience you need to elevate your skillset and take your place at the cutting edge of the field. Learn more at underground.mines.edu.

Brokk 200 packs power of 3-ton machine into a 2-ton package

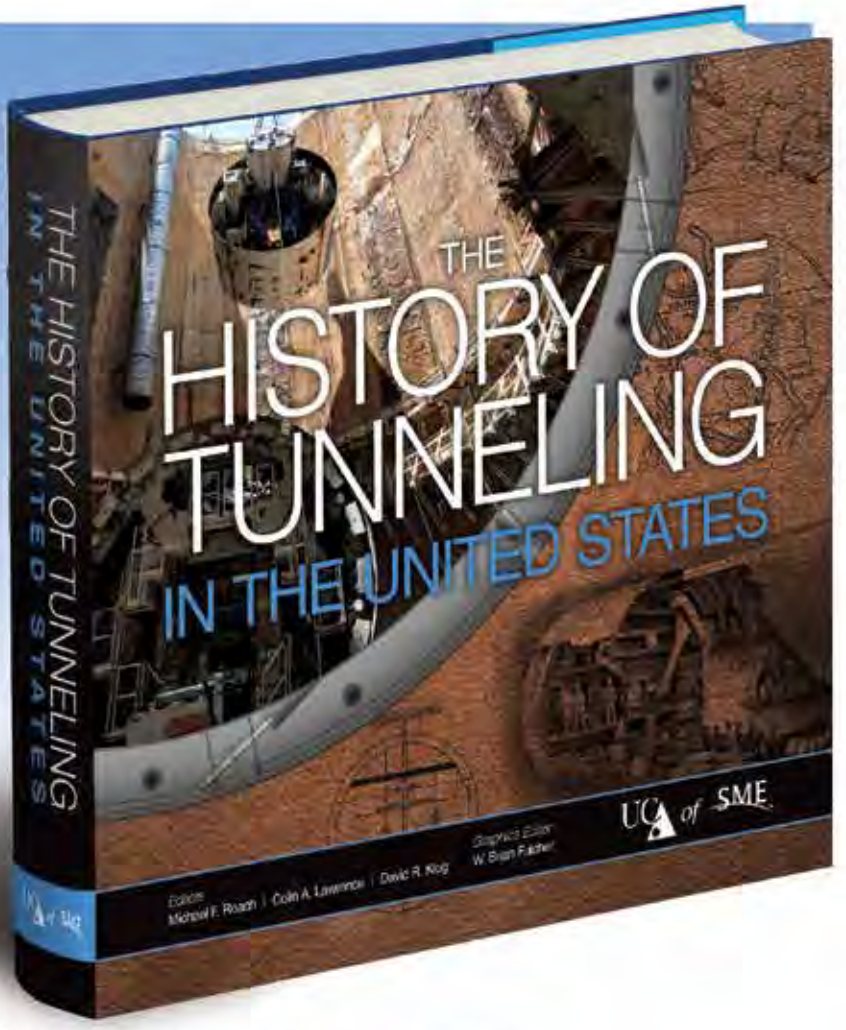
Brokk has been the world's leading manufacturer of remote-controlled demolition machines and attachments for over 40 years. Through continuous innovation in engineering and design, Brokk is able to offer unique solutions to multiple industries worldwide, including construction, demolition, mining and tunneling, cement and metal processing, nuclear and other specialty applications.

Brokk offers the Brokk 200, a new weight class of machine, ideal for heavy duty, difficult-to-access projects and applications and represents the new standard in compact remote-controlled power. The new model packs the power of a 3-ton Brokk machine into a 2-ton package. It is equipped with Brokk's signature SmartConcept™ technology for increased efficiency. SmartConcept includes the extra power of SmartPower™, the added reliability of SmartDesign™ and enhanced ergonomics and productivity of SmartRemote™. The 27.5-kilowatt machine operates tools with requirements typical of one weight class above. When paired with the new Brokk BHB 305 breaker, the unit's hitting power is increased by 40%. The new class of machine delivers 450 foot-pounds (610 joules) with each blow of the 650-pound (295-kilogram) hydraulic breaker. Additionally, the Brokk 200 offers 15% longer vertical and horizontal reach in a compact footprint similar to the Brokk 170. The extra chassis length and machine weight ensures proper balance, even when wielding heavy attachments.

For more information:
Brokk Inc., 1144 Village Way, Monroe, WA 98272; 800-621-7856; info@brokkinc.com; www.brokk.com; Facebook:@BrokkUSA; YouTube: @BrokkIncUSA; LinkedIn: Brokk Inc.; Twitter @BrokkUSA; and Instagram: @BrokkUSA.

Brokk introduces the Brokk 200, a new weight class of machine. The new model packs the power of a 3-ton Brokk machine into a 2-ton package

New Book Chronicles 200 Years of Tunneling in the United States



What has surprised most of us within the underground world is actually the success story that has unfolded as we unearthed surprises and unexpected achievements that were long forgotten by the tunneling industry.

Klug, Lawrence, Roach, Fulcher

The History of Tunneling in the United States

This beautifully illustrated book, edited by tunneling industry experts Michael Roach, Colin Lawrence and David Klug, chronicles 200 years of tunneling in the United States. The combination of text, breathtaking photography and illustration by graphics editor W. Brian Fulcher, will bring the history of tunneling and underground construction alive through:

- A Timeline of Tunnel Milestones
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- Benefits to Society
- Innovations, Railroad, Transit, Highway, Water and Wastewater Tunneling – and more!

Order yours today and take a rich look into tunneling's past, as well as a glimpse of where the future of tunneling might be taking us.

UC of SME

Strata Worldwide

Strata Worldwide is a global leader in advanced safety systems and communication technologies for underground working environments. To enhance worker safety in tunneling, Strata offers a collection of support products including emergency refuge chambers, communication and remote monitoring networks, and proximity detection systems. These solutions can be used independently, or uniquely interfaced to expand functionality and deliver a higher level of overall operation awareness.

Strata refuge chambers, for the immediate shelter of workers in emergency situations, can be integrated with Strata's networking systems to provide communication connectivity, environmental monitoring and live video feeds while shelters are in use.

HazardAvert proximity detection and collision avoidance systems help to prevent machinery-to-machinery and machinery-to-person accidents and collisions. They can be interfaced with Strata's wireless networking technology to pull data off machine systems and stream to the surface.

Strata Worldwide is headquartered in Atlanta, Georgia USA and offers global distribution.

For more information please visit our website at www.strataworldwide.com or contact us at 770.321.2500

Brookville

BROOKVILLE 27-Ton MSHA Permissible Locomotives Boosting Safe Work Environment at Major Los Angeles Tunneling Project

Brookville Equipment Corporation (BROOKVILLE) recently shipped three 27-ton MSHA-permissible tunneling locomotives to the Walsh-Shea Corridor Constructors for use on the Crenshaw/LAX Transit Corridor Tunnel Project in Los Angeles. By design, the locomotives reduce the risk of explosion due to geological conditions that may host the presence of methane and other combustible gases. Cal-OSHA has classified the tunnel drives on this project "gassy", mandating the use of MSHA permissible locomotives.

The 27-ton locomotives' special safety features include air start, an enclosed engine block, an exhaust filtration system, wiring and piping guards, and an intake flame arrestor, among other upgrades, to fully comply with MSHA's permissibility requirements. Featuring an 8.3L Cummins six-cylinder diesel engine and four-speed transmission, the 185-horsepower locomotives operate on 36-inch rail gauge underground for Walsh-Shea Corridor Constructors.

"BROOKVILLE was selected based on past performance, simplicity of operation and diagnostics, their ability to communicate locally with MSHA, and knowing we would be dealing with the good people of Brookville, PA, U.S.A," said Walsh-Shea Corridor Constructors Tunnel Construction Manager David Girard, P.E.

Northwest Laborers-Employers Training Trust – Safety and Hazard Awareness for Tunnels (SHAFT) program

The Safety and Hazard Awareness for Tunnels (SHAFT) program, developed by the Northwest Laborers-Employers Training Trust with input from a team of industry experts and stakeholders, is comprised of a blend of classroom discussion and interactive use of materials and mockups.

The curriculum offers comprehensive safety training for both new and experienced tunnel professionals; classes focus on tunnel safety, rail, and utilities.

The training facility, located in Elma, Washington, features a TBM mockup, rail, and access to 1,400' of 12' diameter tunnel – providing students with a unique educational experience.

Northwest Laborers-Employers Training Trust
+1 (800) 240-9112 www.nwlett.org

David R. Klug & Associates, Inc.

David R. Klug & Associates, Inc. provides international and national manufacturers representative services to the underground heavy civil and mine construction industries. The company specializes in the sale and coordination of specialty products, equipment and services for soft ground, conventional and NATM/SEM tunneling practices. Expertise is offered in the supply of various componentry used in the manufacture of one pass precast segmental tunnel linings inclusive of EPDM gaskets, plastic and steel connectors, grout lifting assemblies and precision steel segment casting moulds plus final lining forming systems for C-I-P final lining applications. Through their distribution company, Klug Construction Systems, LLC offers GFRP rock bolts and soft-eyes, steel and synthetic fiber reinforcement, prefabricated welded wire fabric and rebar reinforcing panels plus specialty grout systems for various tunnel backfill grout requirements for highway, rail, subway, water and CSO tunnel construction applications.

David R. Klug & Associates, Inc.
6000 Waterdam Plaza Dr, Ste 120
McMurray, PA 15317 USA
Phone: (724) 942-4670
Fax: (724) 942-4671
Email: information@drklug.com
Website: www.drklug.com

HÄNY
Mixing and Injection Technology

Haeny, Inc.

Haeny, Inc., the North American subsidiary of Hany AG (Jona, Switzerland) has entered into the U.S. market, supplying grout mixing and injection equipment to the tunneling and foundation grouting industries. The new Irondale, Alabama facility serves as the U.S. headquarters with operations including equipment sales and rental, parts distribution, as well as service and technical advisement.

Family owned and operated for over 140 years, Hany AG is a leading provider of pumping, mixing and injection equipment. The extensive product line ranges from large automated mixing plants and high-volume pumping systems to compact mobile grouting units to serve any size job. The company currently operates in 27 countries and is excited to expand their network to serve customers in the United States, Canada, and Mexico.

For more product information please contact Haeny, Inc. (205) 201-5505, or visit www.haeny-inc.com.

Grindex

Grindex is a world leader in electric submersible pump technology used for demanding applications such as construction and mining – known worldwide for the high reliability and dependability. The built-in starter and motor protection unit make the pumps easy to install and the air valve allows longer periods of dry run time extending life of the pump. Available standard drainage pumps range in 2hp to 140 HP, with some models available in stainless steel and slurry pumps to meet any dewatering needs. Since 1989, Grindex North America (subsid.) has been servicing USA and Canada.

grindex

Bradshaw Offers Innovative Tunnel Engineering and Construction Technology

Bradshaw Construction Corporation strives to apply the most appropriate tunneling technology to each project based on its purpose, subsurface conditions and surface restrictions. The company's management team is proud of its ability to construct any type of tunnel in any soil condition both above and below the water table. From small hand mined, wood-box and liner plate tunnels to large NATM shotcrete-lined tunnels; from small pilot tube guided auger bores to large rib-and-board shield and tunnel boring machine (TBM) tunnels; from conventional pipe jacking to slurry microtunneling (MTBM) to earth pressure balance (EPB) TBM tunnels; and from hand mined drill and blast to rock tunnel boring machines (TBMs), Bradshaw Construction has a solution.

For your next project, let our knowledgeable staff of tunnel engineers and construction professionals create the most cost effective, safest, and highest quality solution for your unique tunneling needs.

Bradshaw Construction Corporation
175 West Liberty Road
Eldersburg, MD 21784 USA
Telephone: +1-410-970-8300
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www.bradshawcc.com

Gall Zeidler Consultants

Gall Zeidler Consultants (GZ) is a worldwide leader in geotechnics, tunnel design and engineering, and tunnel construction management, with special expertise in transportation and infrastructure projects. GZ offers exceptional expertise in urban tunneling with shallow overburden and the related protection of neighboring structures and surface operations by innovatively combining conventional (SEM / NATM) and mechanical tunneling methods (TBM) with ground improvement and state-of-the-art waterproofing techniques.

The company specializes in mastering difficult ground conditions by using cutting-edge ground improvement methods such as dewatering, grouting, and ground freezing. GZ has a history of over 300 miles of successfully completed national and international tunneling projects. The company's expertise has consistently been sought after by major contractors and project owners in the industry developing tailored tunnel solutions and to assist with the mitigation of risks associated with tunneling.

GZ's selected recent and ongoing projects include East Side Access, New York, East Link Extension in Seattle, WA, California High Speed Rail, CA, BART Extension to San Jose, CA, High Speed Rail 2, United Kingdom, and the Riyadh Metro, Saudi Arabia. GZ was involved in the recently completed Bellevue Tunnel, Northgate and University Link Extensions in Seattle, WA, Caldecott Tunnel 4th Bore Project in Walnut Creek, CA, Dulles Metrorail Extension, Washington, D.C., Cable Tunnels in London and Singapore and multiple underground station upgrades in London.

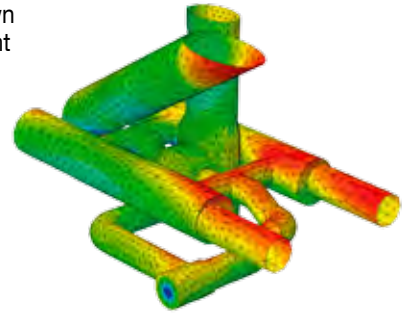
Dr. Sauer & Partners

Dr. Sauer & Partners is a specialist, independent consultancy providing the full range of design and construction management services for tunnels, shafts and caverns. Delivering innovative, cost-effective and environmentally aware designs, the company has over 30 years' experience providing solutions for some of the world's most challenging tunnelling projects for Metro, Highway, Water, Rail and Mining, for urban and rural tunnels in any type of geology.

Services delivered include initial consultation and feasibility studies, final design, supervision and construction management, tunnel inspection and condition surveys, rehabilitation, waterproofing and water control, geotechnical engineering, and mining support services.

Current and recent projects include: Chinatown Station (USA), Ottawa Light Railway (Canada), Bank Station Capacity Upgrade (UK), Crossrail (UK), Red Line (Israel) and Eglinton Crosstown LRT (Canada).

www.dr-sauer.com



COMPILED BY JONATHAN KLUG, DAVID R. KLUG & ASSOCIATES

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Gateway Tunnel	Amtrak	Newark	NJ	Subway	14,600	24.5	2022	Awaiting funding
2nd Ave. Phase 2	NYC-MTA	New York	NY	Subway	16,000	20	2021	Under design
2nd Ave. Phase 3-4	NYC-MTA	New York	NY	Subway	89,600	20	2022-27	Under study
Kensico-Eastview Connection Tunnel	NYC-DEP	New York	NY	Water	10,500	27	2024	Under study
Flushing Bay CSO	NYC_DEP	New York	NY	CSO	13,200	20	2026	Under study
Bay Park Conveyance Project	NY DEC	New York	NY	CSO	18,500	8	2020	RFQ, 4th quarter, 2019
Cross Harbor Freight Tunnel	NYC Reg. Develop. Authority	New York	NY	Rail	25,000	30	2022	Under study
Metro Tunnel Program - Northern	Boston MRWA	Boston	MA	Water	23,760	10	2027	Under study
Metro Tunnel Program - Southern	Boston MRWA	Boston	MA	CSO	50,160	10	2028	Under study
Narragansett Bay CSO Phase III - Pawtucket Tunnel Conveyance Tunnel	Narragansett Bay Commission	Providence	RI	CSO	 13,000 8,800	 28 10	 2020 2024	Short list Announced Under design
Amtrak B&P Tunnel	Amtrak	Baltimore	MD	Rail	40,000	32	2021	Awaiting funding
Hampton Roads Bridge-Tunnel Project	Virginia DOT	Hampton Roads	VA	Highway	7,500	42	2019	Dragados JV awarded
Alex Renew Long-Term Control Plan	City of Alexendria	Alexandria	VA	CSO	10,500	20	2019	Short list announced
Potomac River CSO Tunnel	DC Water and Sewer Authority	Washington	DC	CSO	24,000	18	2022	Under design
Superconducting Maglev Project - Northeast Corridor	TNEM/BWRR	Washington	DC	Rail	146,520	43	2021	Under design
Olentangy Relief Sewer Tunnel	City of Columbus	Columbus	OH	Sewer	58,000	14	2019	Under design
Alum Creek Relief Tunnel Phase 1 Phase 2	City of Columbus	Columbus	OH	Sewer	 30,000 21,000	 18 14	 2019 2020	 Under design Under design
Shoreline Storage Tunnel	NEORSD	Cleveland	OH	CSO	16,100	21	2021	Under design
Shoreline Consolidation Tunnel	NEORSD	Cleveland	OH	CSO	11,700	9.5	2021	Under design
ALCOSAN CSO Ohio River Allegheny River Monongahela River	Allegheny Co. Sanitary Authority	Pittsburgh	PA	CSO	 10,000 41,700 53,900	 14 14 14	 2022 2023 2024	 Under design Under design Under design

T&UC Tunnel Demand Forecast

To have your major tunnel project added to the Tunnel Demand Forecast, or to update information on a listed project, please contact Jonathan Klug at jklug@drklug.com.

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Enbridge Line 5 Tunnel	Enbridge	Traverse City	MI	Oil	23.760	12	2020	Contractor selected
I-70 Floyd Hill Highway Tunnel	Colorado Dept. of Transportation	Denver	CO	Highway	15,840	60 x 25	2022	Under design
W-6: Highway 90 to SW Military Drive	San Antonio Water Systems	San Antanio	TX	Sewer	28,000	10	2020	Under design
D2 Subway - 2nd Light Rail Alignment	Dallas Area Rapid Transit	Dallas	TX	Highway	3,000	22	2020	Under design
Ship Canal Water Quality Project	Seattle Public Utilities	Seattle	WA	CSO	14,250	19	2018	Lane/Salini awarded
West Seattle to Ballard Extension	Sound Transit	Seattle	WA	Transit	10,500	18	2022	Under design
Speulvada Pass Corridor	Los Angeles MTA	Los Angeles	CA	High/Trans.	55,500	60	2020	Shortlist announced
Folsom Area Storm Water Improvement	SFPUC	San Francisco	CA	CSO	4,000	12	2022	Under design
California Waterfix 1 California Waterfix 2	Delta Conveyance Design and Const.	Sacramento	CA	Water	39,905 403,400	28 40	2020 2020	Delayed Delayed
Newell Creek Dam	City of Santa Cruz	Santa Cruz	CA	Water	1,500	14	2020	Under design
Ashbridges Bay Outfall Tunnel	Metrolinx	City of Toronto	ON	CSO	11,500	23	2018	Southland/Astaldi JV Awarded
Yonge St. Extension	Toronto Transit	Toronto	ON	Subway	15,000	18	2016	Under study
Massey Tunnel	City of Toronto	Toronto	ON	CSO	20,000	18	2018	Under design
Inner Harbour West	City of Toronto	Toronto	ON	CSO	18,400	19	2021	Under design
Scarborough Rapid Transit Extension	Toronto Transit Commission	Toronto	ON	Subway	25,000	18	2018	Under design
Green Line LRT	City of Calgary	Calgary	AB	Transit	26,250	20	2018	RFQ submitted
Second Narrows Tunnel	City of Vancouver	Vancouver	BC	CSO	3,600	14	2013	Traylor/Aecon JV awarded
Annacis Island Outfall	City of Vancouver	Vancouver	BC	Water	8,000	10	2017	Pomerleau/Bessac Awarded
Millennium Line Broadway Extenstion	Metro Vancouver	Vancouver	BC	Subway	18,700	18	2020	Short list announced
Eagle Mt. Pipeline	Fortic BC Woodfibre	Vancouver	BC	Oil	29,500	13	2020	Short list announced
Northern Gateway Hoult Tunnel	Enbridge Northern	Kitimat	BC	Oil	23,000	20	2014	Under design

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Presented by: Abani Samal, GeoGlobal LLC

Wednesday, March 18, 2020
10:00 AM - 11:00 AM MST

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Presented by: Jenny Bring & Anne Ketz, 106 Group

Tuesday March 31, 2020
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As far as the east is from the west, so far hath he removed our transgressions from us. Psalm 103:12