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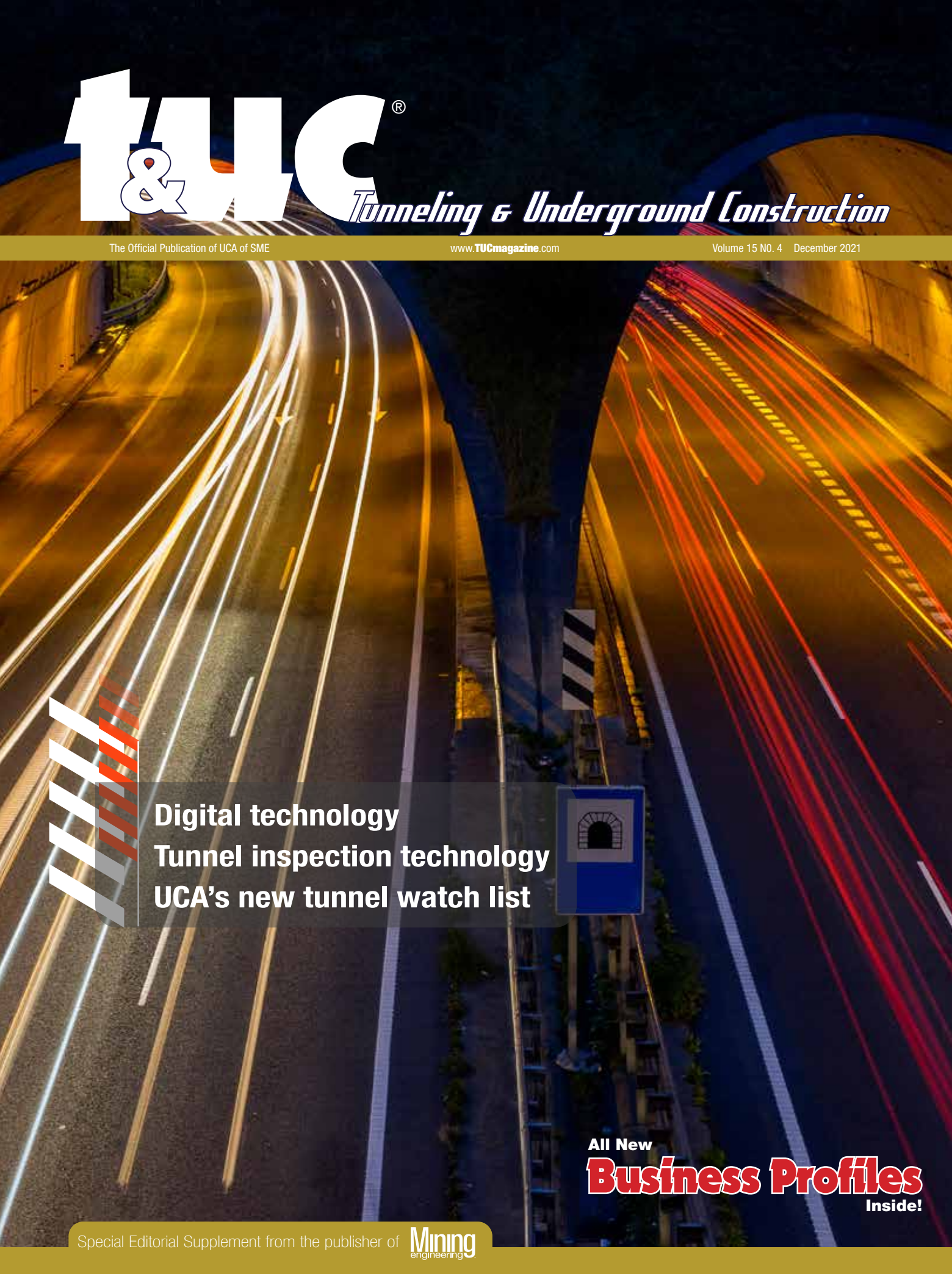

Digital technology
Tunnel inspection technology
UCA's new tunnel watch list

All New
Business Profiles
Inside!

Special Editorial Supplement from the publisher of Mining engineering

CLEAN RIVERS PROJECT, WASHINGTON, DC

METICULOUSLY UPGRADING THE UNDERGROUND

The new 28 kilometers of tunnel are aiming to reduce 96% of combined sewer overflows (CSO's) into Washington DC's waterways – the Anacostia and Potomac Rivers and Rock Creek. Four Herrenknecht EPB Shields are building a tunnel system to store and convey overflows to one of the largest wastewater treatment plants in the world. Through careful monitoring, the Herrenknecht TBMs are able to navigate the underground of the city.

› herrenknecht.com/cleanrivers

Client:
› DC Water
Contractor:
› North East Boundary Tunnel – Salini Impregilo / Healy JV
› First Street Tunnel – Skanska / Jay Dee JV
› Anacostia River Tunnel – Salini Impregilo / Healy / Parsons JV
› Blue Plains Tunnel – Traylor / Skanska / Jay Dee JV

PIONEERING UNDERGROUND TOGETHER

HERRENKNECHT
Tunnelling Systems

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Cover Story

In This Issue

As many tunnels around the world are in need of repair, digital technology is being used to keep tunnels safe and operational. In this issues are articles focused on high speed tunnel inspection using a 3D scanning system as the use of a high-frequenct InSar Displacement Monitoring.

Feature Articles

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Anna Merkulova
CEO

Putting the focus on workforce sustainability

The title of this issue's Chairman's Column reflects one of the three key pillars of the UCA's new strategic plan. Workforce Sustainability is a key thrust in our strategic objectives to promote the industry and provide a competent workforce. Now, I tend to sometimes shy away from "sustainability" because it tends to be used too often. In this case, I really like it because there is a bit of a double entendre effect: our programs have the joint objective of sustaining a workforce for the industry, as well as sustaining members within the workforce.

There are five UCA programs that are part of the Workforce Sustainability pillar. These are important programs for the future of the industry, that all hold special emphasis for me as Chair. Listed alphabetically:

- Down for That
- Inclusion and diversity
- Teach the Professors
- Women in Tunneling
- Young Members

It's my duty as Chair to directly support these initiatives. Each program revolves around drawing people to our great industry and empowering and supporting them when they get here.

Down for That, helmed by Paul Schmall of Keller, can best be understood by visiting www.undergroundcareers.com, which I encourage you to do. It's a robust platform for students, professors and industry professionals, providing a myriad of resources to understand what's going on in tunneling and to help inform and inspire curious students to learn more, to put tools in their hands, and to encourage them to join the industry upon graduation. Scholarship opportunities can be found at Down for That. Tunnel project tours can be arranged and industry profiles are provided.

Mike Mooney of Colorado School of Mines leads the Teach the Professors program. Recognizing that their school/college mentors impact heavily on what career path a student will take, we understand that we, in turn, need to impact and empower those mentors with knowledge of tunneling and what a career can offer their protégées. This program runs annually, is associated with our conferences in the summer (RETC and NAT), and is back on for NAT 2022 (June 19-22, Philadelphia, PA) after a COVID-19 pandemic hiatus.

The Young Members (YM) group is designed for the industry's great minds in the age group of 35 and under. Vojtech Ernst Gall, of Gall-Zeidler, currently chairs this committee. Building from an ITA initiative, our UCA group is known for its ongoing webinar series and social gatherings at conferences that enable this cohort to network and support each other.

The rest of us need to assist as many young members of the industry to connect with the YMs. As I travel to various projects, I meet new entrants to tunneling. Curious, bright, energetic all, I'm always a bit disappointed to find how many of them do not know about the YMs or even the UCA. So, fellow UCA members, please consider making a special effort to encourage your young colleagues to join UCA, to join the YMs and to attend conferences. Yes, there is a cost involved and funds are not unlimited. I understand. At the same time, isn't it better to make that investment now and retain that resource in the industry to sustain the growth that we are seeing? We are always challenged in seeking people. Let's develop what we have. Some

(continued on page 9)

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US House passes $1 trillion infrastructure bill

The U.S. House approved a $1 trillion bipartisan infrastructure bill that includes billions of dollars to improve the nation's transportation networks, water and power systems and Internet connections.

The infrastructure bill includes about $16 billion for "major projects that are too large or complex for traditional funding programs," but that have big economic benefits, according to the White House.

The legislation includes at least $12.3 billion for New Jersey's roads, bridges and transit, which would include billions of dollars that can be tapped to build the Gateway Tunnel under the Hudson River, *NJ.com* reported

The vote was 228-206, with 13 Republicans joining all but six Democrats in voting yes.

The Senate passed the infrastructure measure in August, but House leaders rebuffed demands from moderate lawmakers to take up the legislation without also voting on a separate bill that would fight climate change, expand health care and increase funding for child care and preschool, the *Washington Post* reported.

In addition to new spending on highways and bridges, the broader infrastructure package includes what the White House calls the nation's biggest investment in transit and clean energy transmission in U.S. history, as well as billions for replacing lead pipes and extending broadband. It includes investments in passenger rail, electric vehicle infrastructure, and programs to address past environmental damage, reduce road deaths and improve airports and waterways.

Transportation Secretary Pete Buttigieg called it "the most significant investment in jobs and infrastructure in my lifetime," saying the bill will "rebuild and replace infrastructure that is decades, or even a century, old."

There would be more than $60 billion set aside for Amtrak, some of which could fund new passenger routes, including through New Jersey to connect Scranton, PA and the Lehigh Valley with New York City.

Stephen Sigmund, spokesman for the Gateway Program, said the first two projects — a planned Portal North bridge over the Hackensack River in New Jersey and a new tunnel under the Hudson River — have financing plans in place and are not dependent on the infrastructure bill. Still, Sigmund added, the billions in additional funds the bill will provide to the U.S. Transportation Department's Capital Investment Grants program will be "a great help to the project."

Later phases of the Gateway Program, including far-reaching track improvements and other bridge projects, could benefit from the megaprojects fund and other large pots of money in the bill, Sigmund said.

The critical Northeast rail corridor "narrows down to this old straw that gets crimped in various places," Sigmund said. "The whole idea is to establish a four-track system between New York and New Jersey, which would replace the current two-track system — one track in, one track out — which is 110 years old."

The bulk of transportation funds in the infrastructure bill will flow through existing programs in which states get money according to federal formulas and have discretion over how they use the money. It will allow states to make progress on routine projects, such as repaving roads, upgrading bridges and buying new

Rio Tinto's hydropower tunnel project breaks through

A tunneling project that began in the early 1990s reached a major milestone for Rio Tinto's Kemano T2 hydropower project in British Columbia, Canada when the Herrenknecht tunnel boring machine (TBM) broke through to complete its journey.

The Kemano T2 Project completed a second tunnel to carry water into the Kemano Powerhouse, to ensure the long-term reliability of the power supply for Rio Tinto's BC Works smelter in Kitimat.

The TBM cut 7.6 km (4.6 miles) through the rock in remote mountains over 30 months, completing the route for a 16-km (10-mile) tunnel that was started in the early 1990s.

"This is a significant milestone toward finishing the second tunnel and securing the long-term reliability of hydropower for Rio Tinto's smelter in Kitimat, which produces some of the world's lowest-carbon aluminium," Kemano T2 project manager Alex Jones said in a release. "Boring this tunnel is a highly skilled and technical feat that has been achieved in an extremely remote location that is only accessible by air or sea. We thank all of our partners who are supporting this important project — from our employees, to contractors, First Nations, government and community members. It will ensure our operations continue to make a significant contribution to British Columbia's economy into the future. We look forward to celebrating the completion of the project next year."

The 1.3-kt (1,400-st) Herrenknecht tunnel boring machine is named tl'ughus by the Cheslatta Carrier Nation after a legendary giant monster snake and is decorated with artwork by Haisla Nation students. It is 190 m (623 ft) long and more than 6 m (20 ft) in diameter.

The tunnel will be filled with water in the middle of next year, with the project expected to be complete in the second half of 2022.■

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BART Phase II Project receives federal funding

The Federal Transit Administration selected the Bay Area Rapid Transportation (BART) Phase II Project through San Jose, CA for expedited funding of more than $2 billion, the Valley Transportation Authority (VTA) announced.

The project funding plan includes 25 percent of the costs to be funded with federal grants and the remaining 75 percent from state and local sources.

BART's Phase II Project, which includes four stations, a maintenance facility, and five miles of subway tunnel, will extend BART service from the newly opened Berryessa Station in northeast San Jose through downtown San Jose into the City of Santa Clara. Passenger service is planned to begin in 2030.

The letter of intent announced Oct. 25 affirms the federal government's intention to obligate federal funds for the project, according to the VTA. This step is the precursor to the actual funding.

"After decades of planning and strong public support, VTA is honored to have the Federal Transportation Administration acknowledge the substantial merits of the BART extension to downtown San Jose and Santa Clara," said Glenn Hendricks, chair of VTA's board of directors. "We are excited to continue to move this important project forward."

This step gives VTA the authority to incur costs for advancing engineering activities, utility relocation, real estate acquisition, construction, and other nonconstruction activities such as the procurement of vehicles. This milestone also defines the confidence the U.S. Department of Transportation has in VTA's technical capacity and capability to effectively manage the Phase II Project.

VTA said it will proceed with contract advertisements and awards, including the largest procurement, the tunnel contract, which includes the design and construction of the subway through downtown San Jose with a large-diameter tunnel boring machine.

"This auspicious milestone gladdens the hearts of all of us who have been working — and many more who have been waiting — to bring BART to downtown San Jose and Santa Clara," said San Jose Mayor Sam Liccardo, who is also a member of the VTA board of directors and former chairperson.

VTA's funding plan, developed in 2020 and submitted to federal transportation officials, included an expedited funding request of $1.735 billion based on a $6.9 billion eligible budget, and this could increase as construction materials increase in cost in future years.

Federal transportation officials intend to obligate up to $2.287 billion or 25 percent of the final project cost, whichever is less.

The letter will be in effect for two years, and during that time VTA will continue to advance design, receive actual contractor bids, identify and mitigate or eliminate perceived risks, finalize an overall cost estimate, and solidify the funding plan to ultimately achieve full funding. ■

Crossover TBM sets world records in Turkey

In October 2021 a 13.77-m (45.18-ft) Robbins XRE tunnel boring machine (TBM) set world records for fastest boring by day, week and month at the Esme-Salihli Railway Tunnel in Turkey. The machine set records of a best day of 32.4 m (106 ft), a best week of 178.2 m (584.6 ft), and a best month of 721.8 m (2,368 ft). Launched in March 2021, the machine bored 3.05 km (1.90 miles) on the Esme-Salihli Railway Tunnel as part of the Ankara-Izmir High Speed Railway Project for the TCDD.

"When the strength, force and torque generated by our Crossover TBM are taken into account, we consider it to be a beast. It has performed extremely well in this tunnel," said Onur Kansu, TBM manager for project contractor Kolin Construction. He added "We are proud we have accomplished such high performance."

The machine began its bore in altered gneiss, then passed through mélange consisting of gneiss, sandstone, claystone, mudstone, quartz and silt. By the end of the bore the machine was excavating in mainly mudstone. Core drillings were taken every 200 m (656 ft) prior to boring so the crew felt confident with the geology—just one of several factors that contributed to the record rates. "A proper geological analysis, choosing the right TBM, a professional crew and a contractor who believes that they can break records are all key," said Kansu. "Scheduled maintenance periods, an expert team, availability of sufficient spare parts, and good logistics also made it possible for us to reach our targeted advance rates."

The project is particularly important for the Turkish tunneling industry, showing what is possible at larger TBM diameters. "We have disproved the idea that it is difficult to reach high advance rates while boring in EPB mode with large-diameter TBMs. Crossover TBMs enable us to find quick solutions in changing ground, so we believe they will be the preference for future projects," said Kansu.

With tunnel excavation finished, work will continue on the 508-km (316-mile) line that will connect Polatli in Ankara Province to Izmir, the third most populous city in Turkey. Once complete, the Ankara-Izmir High Speed Railway will be the longest rail line in the country, conveying passengers at top speeds of 250 km/h (160 mph) in a railway journey of about 3.5 hours. ■

Liebherr reaches new tunneling milestone

With its main bearing for Shanghai Tunnel Engineering (STEC), a Chinese system provider of tunnel boring machines (TBMs), Liebherr has reached the next dimension in tunnel construction. With a diameter of almost 8 m (26 ft) and a weight of 40 t (44 st), the roller bearing is to be used in one of the largest TBMs. At the same time, the bearing is the largest TBM main bearing of its kind produced by Liebherr to date.

Used in the cutter head of a TBM, it helps to bore a tunnel about the height of a six-story building. This is possible due to its double rollers in the bearing track, extremely precise internal gearing, as well as due to 20 pinions that drive the bearing on the inner ring.

In addition to the main bearing, Liebherr also manufactures the erector bearing for the TBM. With a diameter of 7.3 m (24 ft) and a weight of 5.2 t (5.7 st), it may not seem quite as big in comparison, but it still has an important function in tunnel construction. It sits behind the cutter head and ensures that precast concrete elements are placed all around the wall during tunneling. The concrete elements primarily have the task of securing the tunnel. In the second step, these concrete elements support the TBM when moving forward.

With a height of 15.5 m (51 ft) the 8-km (5-mile) tunnel in the city of Foshan in the south of China will ensure that vehicles can travel back and forth in three lanes on two superimposed roadways. In more and more cities, the infrastructure is being newly developed and expanded. Therefore, the demand for subway construction or road tunnels is growing worldwide. Also tunnel systems for mining, hydro power, as well as supply and disposal systems are currently in great demand, showing strong growth. For Liebherr, the production of the TBM main bearing is a step in the right direction. ■

Expanded plans for Las Vegas Loop approved

Nevada's Clark County approved plans for 46-km (29-mile) network of tunnels beneath Las Vegas, NV.

The tunnels will be built by the Boring Co. and are an extension of the 2.7-km (1.7-mile) Las Vegas Loop that currently shuttles passengers beneath the Las Vegas Convention Center via Telsa autos driving through the tunnels.

The *Las Vegas Review Journal* reported that the approval of a 50-year franchise agreement between the county and the Boring Co. sets the stage for the permitting process to begin, which would lead to the start of construction of the dual loop system that would operate mainly in the resort corridor with stations at various resorts and connections to Allegiant Stadium and UNLV.

The county's approval is only for the alignment of the proposed route. Each one of the planned 51 stops will need separate land use permits approved before being developed.

The Boring Co. also will need a separate franchise agreement with Las Vegas for the portion of the system that runs underground in the city.

The approval of the Vegas Loop is the largest project to date of the Boring Co., which has ambitious plans to build underground roadways in a number of cities. ■

Chair's Column: Growing the workforce

(continued from page 4)

companies, I have observed, are very good at this. Let's all aspire to that goal.

Leadership of the Women in Tunneling (WIT) committee has recently changed into the hands of Elisa Comis, of McMillen-Jacobs. She has also accepted double-duty and represents the UCA on SME's Inclusion and Diversity Committee. WIT has grown from earnest beginnings into a flourishing team with increasing membership and plans for the future. Anyone who attended the WIT event at RETC in Las Vegas had the opportunity to network, hear good speakers and feel the momentum that is building. I expect the events at future conferences to only grow, and anyone is welcome to attend. I hope that all women in the industry may engage with this group. I guarantee that there will be mutual benefit.

Inclusion and Diversity (I&D) is a very important topic for us all, and a very broad one. Much has been and will continue to be written about it, and forward-thinking discussions take place on an ongoing basis across all facets of society and industry. I'm pleased that we have dynamic representation from the UCA, leading our perspective with the SME. I&D is the right thing to do, for individuals, groups and the industry as a whole. At the end of the day, it's also good business.

All of these programs are at various stages of gestation on their journeys to grow, to evolve, to contribute, to make a difference. All are open to input and participation. Should you wish to learn more, or contribute, please do not hesitate to reach out to the leaders mentioned above, or to myself. You'll find a receptive audience.

Tunnel on. ■

Mike Rispin
UCA Chair

TBM completes first mile of London's HS2 tunnels under Chilterns

The first mile of tunneling on the HS2 high-speed railway linking London, the Midlands, the North and Scotland was completed near the end of September by the Herrenknecht tunnel boring machine (TBM) named Florence.

Launched in May, the 170-m (560-ft) long TBM covered the first mile cutting through a mix of chalk and flint beneath the Chiltern hills just outside of London, HS2 said in a release.

A second machine, named Cecilia is a short way behind, with both TBMs expected to break out in around three years' time.

Designed specifically for the geology of the Chilterns, each machine is a self-contained underground factory, digging the tunnel, lining it with concrete wall segments and grouting them into place as it moves forward.

Welcoming the progress, HS2 Ltd project client Rohan Perin said: "The 10 mile Chiltern tunnel will take HS2 underneath the hills and safeguard the woodlands and wildlife habits above ground as well as significantly reducing disruption to communities during construction and operation of the new railway. Once complete, HS2 will offer low carbon journey options linking London with the major cities of the north and releasing capacity for more freight and local trains on our existing mainlines. It's great to see how much progress has been made over the summer and I'd like to thank the crew of Florence and all the tunneling team for their hard work."

The first two TBMs are operated by HS2's main works contractor, Align – a joint venture formed of Bouygues Travaux Publics, Sir Robert McAlpine, and VolkerFitzpatrick.

A crew of 17 people keep the machines running, working in shifts and supported by more than 100 people on the surface, managing the logistics and maintaining the smooth progress of the tunnelling operation.

"I am delighted with the progress that Florence has made since its launch in May, with Cecilia not far behind. All the spoil from the TBMs is converted into slurry before being pumped back to our South Portal site, just inside the M25, where it is processed and used for landscaping on site. This is, and will continue to be, a huge logistical challenge, as Florence and Cecilia continue their journey through the Chilterns," Align project director Daniel Altier said: "Florence reaching the 1 mile point is a great achievement, however we still have a long way to go."

Each of the separate northbound and southbound tunnels will require 56,000 precision engineered, fiber-reinforced concrete wall segments, which are all being made at the south portal of the tunnel, next to the M25. During the first mile, Florence and its crew have installed more than 5,500 separate segments, each weighing around 8.5 t.

Approximately 2.7 million m^3 of material will be excavated during the construction of the tunnels and used for landscaping around the south portal site. Once construction is complete, this will help create around 90 hectares of wildlife-rich chalk grassland habitats. Chalk grassland used to be widespread across the hills of southeast England and are considered habitat of international conservation significance with just 700 ha left across the Chilterns.

In total there will be 10 TBMs on the HS2 project working to create 64 miles of tunnel between London and the West Midlands including major tunnels on the approach to London and Birmingham.

More than 20,000 jobs and over 650 apprenticeships are already being supported by HS2, which is set to transform transportation links between Britain's major cities, free up space on the rail network for more freight and local services and support the UK's transition to net-zero carbon emissions. ■

Gateway Tunnel project work could begin in 2023

The Gateway Project connecting New York and New Jersey could be one of the first major tunneling projects to benefit from the $1 trillion infrastructure bill that was signed into law in November with construction on the tunnel beneath the Hudson River starting as soon as 2023.

Financing for the project could be in place by the end of 2022, said Balpreet Grewal-Virk, Gateway Development Corp. (GDC) co-chairwoman.

"It's been an incredible few months and a productive year with the Biden administration moving it forward," said Grewal-Virk. "We are looking to enter into engineering next year and hope to get a (federal) full funding grant by December and a summer of 2023 start."

The cost of the project stands at $9.8 billion for new tunnel construction and $1.8 billion to rehabilitate old tunnels, for a grand total of $11.6 billion.

Construction of new tunnels and rehabilitation of the existing tunnels is estimated to be completed in 2035, said Frank Sacr, GDC interim executive director.

NJ.com reported that there are still hurdles for the project. Officials said the project's ranking needs to be raised by the Federal Transit Administration (FTA) to qualify for federal grants.

"We're under review. We hope it will come next year," Grewal-Virk said. "We have a great working relationship with the FTA and we're in constant communication and answering any questions they have."

The tunnel project had received a low rating under the Trump administration that precluded it from qualifying for federal funding.

Railroad and other infrastructure loans that would comprise New Jersey and New York's share of the project also need to be applied for and approved.

The states received a boost from changes to those programs that would allow the loans to be paid off over 75 years, considering the lifespan of major railroad infrastructure projects, instead of an original 35-year payback period.

A "letter of interest" to start the application process for an estimated $6 billion in infrastructure loans is being prepared and could be submitted in the next couple of months, Sacr said. ■

High-speed 3D subway tunnel inspection;
A San Francisco BART case study

The trend in tunnel condition assessment is toward comprehensive 3D measurement combined with high-quality images that document and quantify damages to a tunnel's surface. This work can create a cohesive set of data of the structural conditions of a tunnel and can also be gathered throughout the tunnel's lifespan. In addition, the faster such on-site measurements can be made, the less of an impact they have on the traffic conditions of these sophisticated subway systems.

One such device used to conduct these measurements, the Dibit high-speed 3D scanning system, is based on photogrammetry and light detection and ranging (Lidar) remote sensing technology. Performing an assessment with this system enables users to gather data in tunnels and the system can operate at speeds of up to 96.561 km/h (60 mph). Tunnel shutdowns can be drastically reduced while tunnel safety is increased because of the high rate of speed in which the system can operate. The photorealistic texture of the 3D-models generated also allows for the identification and analysis of small material damage to the tunnel (e.g., cracks > = 0.3 mm wide).

FIG. 1

The stop-and-go scanning system on a BART subway tunnel.

This article illustrates the technology and 3D results of this innovative system and is based on measurements performed in the subway tunnels of the Bay Area Rapid Transit System (BART) in San Francisco, CA (total length 66.23 km (4.1 miles).

Heiner Kontrus, Jérôme Steinkühler and Thomas Peal

Heiner Kontrus and **Jérôme Steinkühler** are president and engineering director with Dibit Messtechnik GmbH and **Thomas Peal** is project manager with Dibit Measuring Technique USA, Inc., email jerome.steinkuehler@dibit-scanner.com.

Advantages of subway tunnel scanning and monitoring

Subway tunnels undergo assessment testing in distinct time intervals. This is primarily conducted manually by surveying critical cracks and other features of the tunnel, thus reducing its usability and reliability. Traditionally, tunnels must be closed for surveys and inspections, which

FIG. 2

The cameras of the FSC 6100-SRmF10 and the LED flashlights are aligned perpendicular to the surface to be measured as shown here at the BART 19th Street/Oakland railway station.

is difficult to do in busy cities and on modern subway systems. Therefore, shutdowns usually occur at night, when traffic is reduced. On larger projects, inspection crews may work several days or weeks at night, thus requiring resources and leading to higher costs because the work is performed outside of regular work hours.

Modern scanning systems can significantly reduce tunnel closure times because they employ enhanced survey speeds. Because this requires less effort than traditional modes of measurement, the structural health and monitoring of the tunnel can be intensified. More frequent measurements increase the overall safety of subway tunnel systems. With 3D models, the tunnel operator receives precise and comprehensible data for determining needs like maintenance, revision and construction (Kontrus and Mett, 2019).

Thus, 3D tunnel scanning is economical and efficient. Time, personnel and tunnel closures can be reduced or even avoided. The time it takes to conduct measurements and the preparation needed are short as well.

Another positive aspect of using digital scanning systems is that most of the inspection time is shifted from the tunnel to a virtual 3D environment in an office. Cracks, tunnel installations and other issues can be analyzed independently from the often rough and sometimes dangerous tunnel environment. The faster tunnel scans can be conducted, the better for tunnel operating companies.

The main task of tunnel scanning systems is the continuous survey of tunnel surfaces and the subsequent 3D reconstruction of tunnel structures. In addition, modern scanning systems provide information about the surface of the tunnel in the form of high-resolution photos that enable recognition of even the finest cracks (> = 0.3 mm) and the classification of tunnel objects, such as construction joints and further installations.

Scanning systems used for tunnel monitoring

There are currently three approaches for the 3D measurement of tunnel structures and the monitoring of their surfaces.

The oldest and most common approach is laser scanning. Laser data images are available in gray scale. Thus, laser scanners cannot capture tunnel surfaces in true colors or red, green or blue (RGB) values. In laser scanning the measurement of crack profiles of relevant crack widths (0.3 to 1 mm) is possible because of the intensity and contrast differences in the images. Established laser scanning systems can achieve geometrical accuracies of up to 5 x 5 mm for the measurement of clearance profiles, etc.

The second approach is the use of photogrammetric systems, where 3D geometry and photo surfaces are created from the photos of digital cameras. Photogrammetric systems can be used for 3D reconstruction (e.g., tunnel construction) (Bauer et al., 2015) and can operate at high speeds (Mett et al., 2019). However, when the measurements are conducted at speed, a bright illumination and flash technique are required in these inspections. Therefore, such devices are not well established in the market. In general, only a few photogrammetric systems are currently used in the field

FIG. 3

FSC 6100-SRmF10 mounted on a railway truck during the BART measurement campaign.

of tunnel construction. These devices are stationary and operate from a fixed point without movement. One such example is the 3GSM shapemetrix (with commercially available cameras) and the Dibit Handheld 3D-complete system. The shapemetrix TBM is used for documenting the digital rock-face for tunnel boring machine (TBM) rock excavation.

The third approach is a hybrid system that combines geometric data from the laser measurements and photo textures received from digital cameras. These can either be operated as stop-and-go systems, which scan one tunnel section from a constant position and then proceed to a further position (Fig. 1), or as kinematic systems, which scan the tunnel while continuously moving. Some well-established systems include the SPACETEC TS3 and the Dibit LSC 4100-SRMF2. Both are configurable for road and track use, achieve geometric accuracies of around 10 x 10 mm and photo resolutions of up to 1 x 1 mm. Both systems reach speeds of up to 4 km/h (2.5 mph) at walking speeds. The newly developed Dibit dynamic system contains industrial cameras and light-emitting diode (LED) flash technology for the 3D measurement and monitoring of tunnel surfaces at walking speed.

Dibit high-speed system for monitoring subway tunnels

The Dibit high-speed 3D measuring system FSC 6100-SRmF10 is able to measure tunnel structures at speeds of up to 96.561 km/h (60 mph). It can be operated in various configurations in subway, rail and road tunnels. The scanner consists of a photogrammetric unit with high-speed cameras and LED flash technology, a laser and an optional thermal imaging unit.

In this measuring system, the longitudinal axis is arranged horizontally, which means that cameras and lasers are aligned orthogonally to the tunnel surface to be measured (Fig. 2). The high-performance cameras are installed in a helical arrangement, which enables 360-degree coverage of the surface. The flash modules are designed with such an intensity that the overall illumination of a two-lane railway/subway tunnel is guaranteed.

The focus ranges of the lenses are set by default in such a way that tunnel surfaces in an area between 2 and 6 m (6.6 and 19.7 ft) can be shot with sharp photo resolution. The focus area can be adjusted for special tunnel cross-sections or for short or long distances to the tunnel surface.

The FSC 6100-SRmF10 system can be flexibly arranged and operated in different configurations during measurement in subway tunnels. If the entire tunnel space is to be covered 360 degrees all around, the system is attached to a carrier vehicle on a specially developed, extendable and height-adjustable support arm around 2.5 m (8.2 ft) above the track bed.

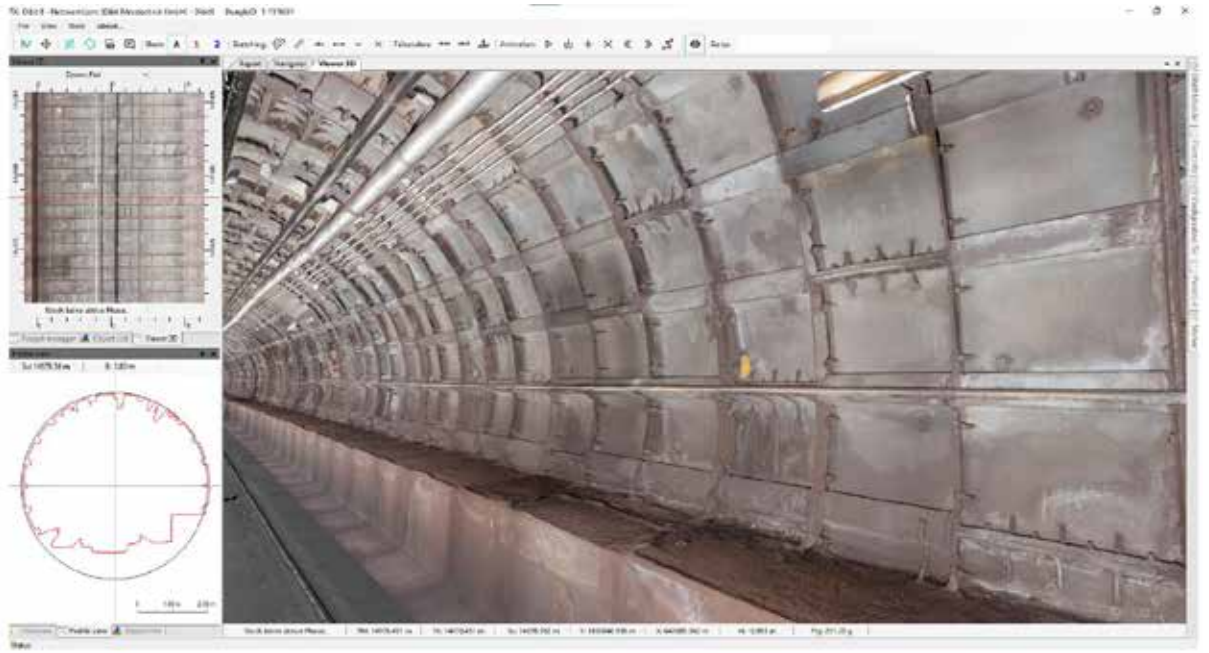
For the BART project, Dibit USA used a hybrid-vehicle measuring system that can drive on the road and on tracks. This so-called railway truck was operated at speeds of up to 50 mph (Fig. 3).

The BART project

Dibit Measuring Technique USA, Inc. was contracted

FIG. 4

A 3D-view of the BART tunnel surface in the Dibit8 mapping software profile with a 2D view on the left.



to provide a detailed inspection of approximately 40.23 km (25 miles) of the tunnels within the BART subway system in San Francisco and Oakland, CA.

In February 2020, Dibit scanned 19.3 km (12 miles) of M-Line BART tunnels. This inspection was done using a system that combines Lidar scanning and photogrammetry to create a high-definition and accurate 3D model of the tunnel, which can be used to assess deficiencies, spalling, cracks, etc. These data were acquired with a customized cart that can be pushed along the rails at about 1 mph. The subway tunnel was accessed via a station platform that was used as a staging area. Once the scanning system was assembled and the last train for the night had passed through, the system was lowered on a rail cart and onto the track. After a quick system calibration, the data acquisition was initiated. This scanning took eight four-hour nightshifts to complete.

In July 2020, Dibit scanned 13 additional miles of M-Line, R-Line and the Oakland Wye BART tunnels using the FSC 6100-SRmF10, a new photogrammetric system. In the week prior to the scanning, Dibit and BART employees worked to mount and secure the 159-kg (350-lb) scanning device onto the back of a high-rail vehicle. Each night, once the operating window began, the high-rail vehicle was set on the rails at a maintenance way and driven to the desired track area for scanning. The scanning was performed during track shutdown and took five four-hour nightshifts to complete.

The final submittals to the client included a high-resolution 3D point cloud and tunnel maps showing the lining deficiencies (Fig. 4). The client also received the Dibit8 mapping software to classify features such as corrosion, leakage and cracks as tunnel information system (TIS) objects. Any tunnel features like emergency doors, lights or power supply cables can be mapped in the software (Fig. 5).

Software computation of 3D tunnel models

Processing and analysis of the 3D data are performed with Dibit8 tunneling software, which is designed for use with the high amount of measurement data generated from the high-speed FSC 6100-SRmF10 system.

The database part of the Dibit-TIS is a core component of the software. In combination with the Dibit-viewer, 3D tunnel data can be analyzed and visualized. Within the scope of the BART project, Dibit-TIS enabled the recording and mapping of components (blocks, niches, etc.), installations (lamps, traffic control systems, etc.) and damaged areas (cracks, spalling, etc.).

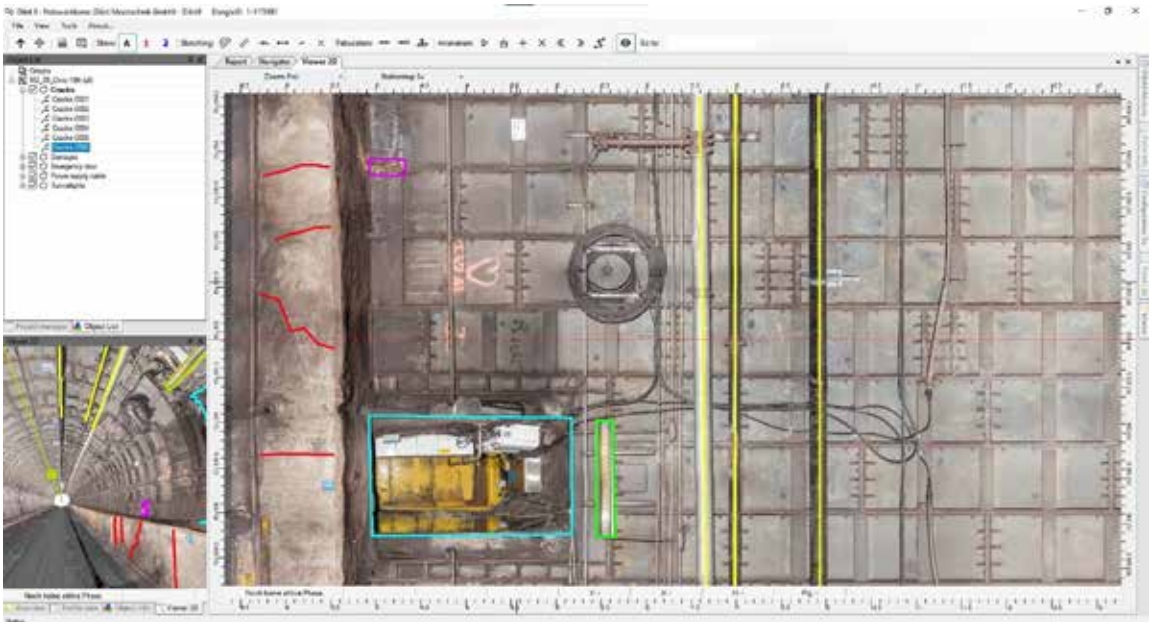
To analyze the data, images are drawn either manually on the 2D orthophoto of the tunnel or on the photo-textured, high-resolution 3D tunnel data (Fig. 5). The software allows the user to make linkages with measurement or inspection images and can then determine needed inspection or remediation protocols (e.g., injection protocols of crack remediation).

Changes in the tunnel's surface can also be made visible by overlaying photorealistic tunnel images of different epochs (or phases, i.e., recording times) in the Dibit-viewer. Spatial and temporal changes can be quantified (4D change detection) and serve as a basis for subsequent inspection and rehabilitation activities.

One of the features of the Dibit-TIS is its ability to capture the structured, spatially thematic assignment and

FIG. 5

A 2D view of the 3D data of the BART tunnel surface in Dibit8 mapping software including TIS objects.



visualization information found in complex tunnels. The information gathered is assigned to object classes and layers. Depending on the task involved, the data can be systematically included in tunnel analysis and exported by means of automated reports or used for next steps and planning.

The objects are saved with coordinate information in Dibit-TIS, and can be annotated in the form of open and closed polylines. The marking of objects as surfaces, circles and points is also possible. The positions, lengths, areas and various other parameters of individual objects can be exported in tabular form from the TIS, and thus can be further statistically evaluated.

The measurement data can also collect images of objects with freely selectable descriptive attributes, e.g., water occurrences, the appearance of sintering, crack width and much more. This allows for thematic filtering and individual aspect evaluation.

It is also possible to link a large number of different sensor data with the spatial tunnel models. In the future, these could include Georadar data, thermographic data, and multi- or hyper-spectral data, as well as conventional manual measurements and structural information.

The Dibit8 software processed the BART measurement data with true-color 3D point clouds and/or textured 3D mesh models that were exported in various data formats (e.g., E57, LAS, OBJ) or ortho image data (i.e., TIFF, JPG) for further analyses in CAD (computer-aided design) or BIM (building information modeling) software (Mett et al., 2019).

Conclusion

This high-speed tunnel monitoring project conducted on the BART was the first time this type of work was done in the United States. The FSC 6100-SRmF10 defines new technical standards regarding measurement velocity, measurement accuracy and image resolution. Use of this high-measurement capability has the potential to reduce and minimize tunnel closure times.

With the help of Dibit8 software, tunnel characteristics such as cracks, surface damage and tunnel installations, for example, can be analyzed in a virtual 3D environment. The results are valuable information for objective tunnel analysis conducted by engineers. By comparing tunnel measurements of different epochs, change detection (i.e., the growth of cracks) can be performed and developed for future maintenance and rehabilitation work. Furthermore, this digital tunnel surveillance project had a positive effect on tunnel safety and the proper operation of the BART system. ■

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High-frequency InSAR displacement monitoring and trend detection analysis

Remote sensing data, and particularly space-based interferometric synthetic aperture radar (InSAR), is being integrated into many monitoring programs for tunneling projects. Interferometry is a remote sensing technique employed to detect and track deformation of the ground's surface over time (Gabriel et al., 1989; Massonnet and Feigl, 1998; Bamler and Hartl, 1998; Rosen et al., 2000). The technique provides regional-scale data on ground settlement with millimeter accuracy, which allow it to be analyzed alongside ground leveling and other conventional survey techniques.

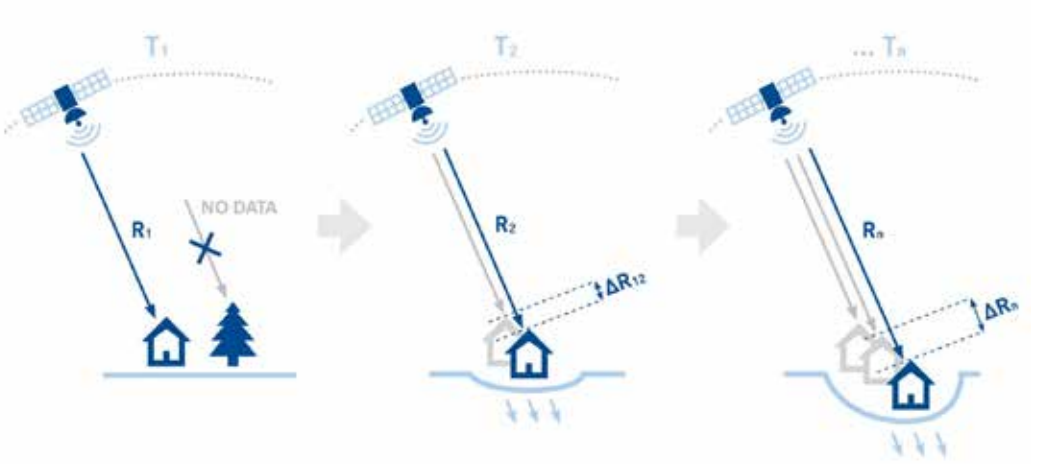
Early InSAR techniques were applied to study ground settlement in cities shortly after the launch of the first synthetic aperture radar (SAR) satellite in the early 1990s (Solari et al., 2018; Ferretti et al., 2006) and since the early 2000s, multitemporal stacks of SAR imagery have been processed with advanced techniques to track ground deformation as often as every new satellite passes. Frequent monitoring updates have generated a requirement for new methods of data management and analysis given the increasing size of InSAR datasets.

Widely adopted industry guidelines, such as the "ITAtech Guidelines for Remote Measurements Monitoring Systems" (Schneider et al., 2015), give recommendations on the inclusion of earth observation and other remote sensing techniques in geotechnical programs for tunneling projects. The birds-eye view of the alignment, its surroundings and the greater region allow InSAR to complement measurements collected by in situ instrumentation such as GPS stations, extensometers and total stations.

This article offers a short overview of InSAR technology and focuses on recent advances in techniques for identifying and categorizing key areas in InSAR datasets over urban tunneling projects. The future of SAR satellite missions and their impact on InSAR technology for tunneling projects is also discussed.

FIG. 1

An illustration showing the relationship between ground displacement and signal phase shift. This is the basic principle of InSAR for measuring ground movement.



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InSAR technology

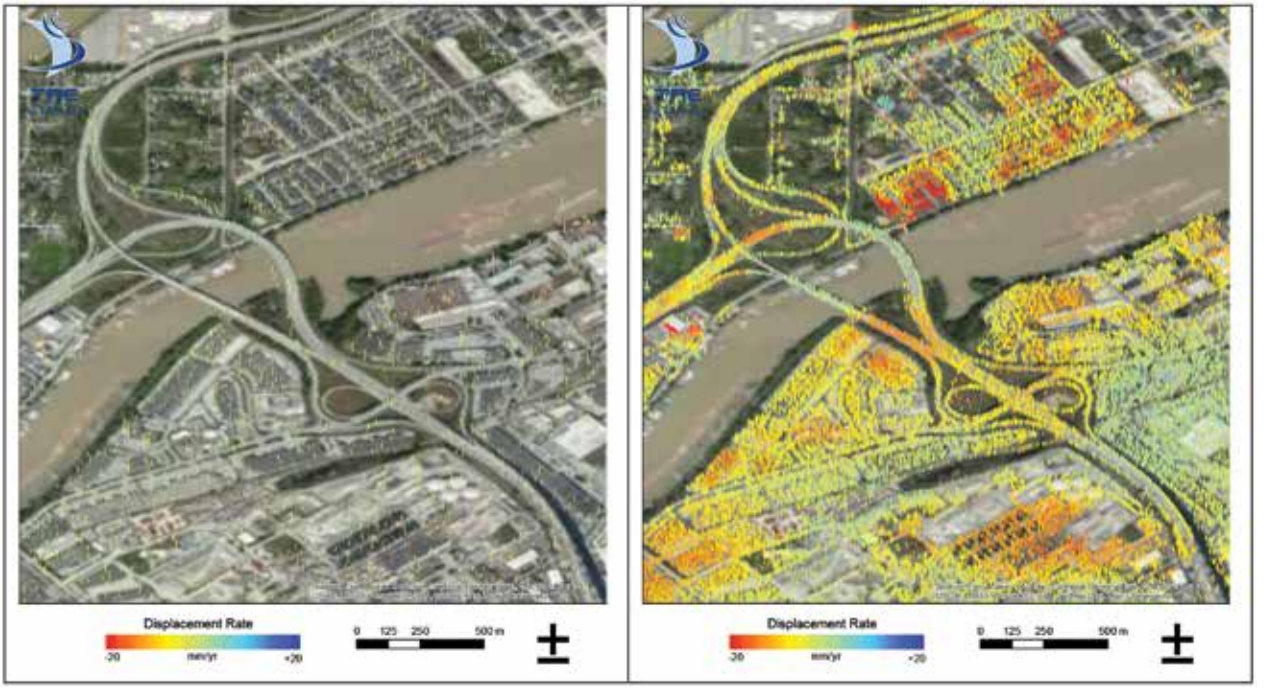
Satellites equipped with SAR sensors continuously circumnavigate the earth on a polar orbit and acquire images of the Earth's surface by emitting electromagnetic waves and recording the reflected signal.

Basic Differential InSAR (D-InSAR) techniques compare two SAR images acquired at different times over the same area. The difference in phase between these two images is related to the displacement of the radar target along the direction of the sensor-target line-of-sight (LOS) (Fig. 1).

The emergence of advanced D-InSAR (A-D-InSAR) techniques in the late 1990s, allowed for processing multiple images acquired over the same area, providing the ability to estimate and remove the largest sources of

FIG. 2

Low-resolution Sentinel-1 data (left) and high-resolution TerraSAR-X data (right) over a same urban area. The displacement patterns are in agreement despite the difference in measurement point density.



noise affecting D-InSAR outputs, including signal travel-time delays caused by the atmosphere. This provided more accurate displacement measurements, with a precision in the order of less than a millimeter. Persistent scatterer interferometry, the first A-D-InSAR technique, identifies point-wise permanent scatterers (PS), allowing for pixels that show both consistent amplitude and coherent phase in the entire stack of analyzed images to be monitored

FIG. 3

SqueeSAR results over a railway tunnel in the Alps (Italy). The preliminary planned entrance of the tunnel was modified to avoid an area with evidences of active slope movements.

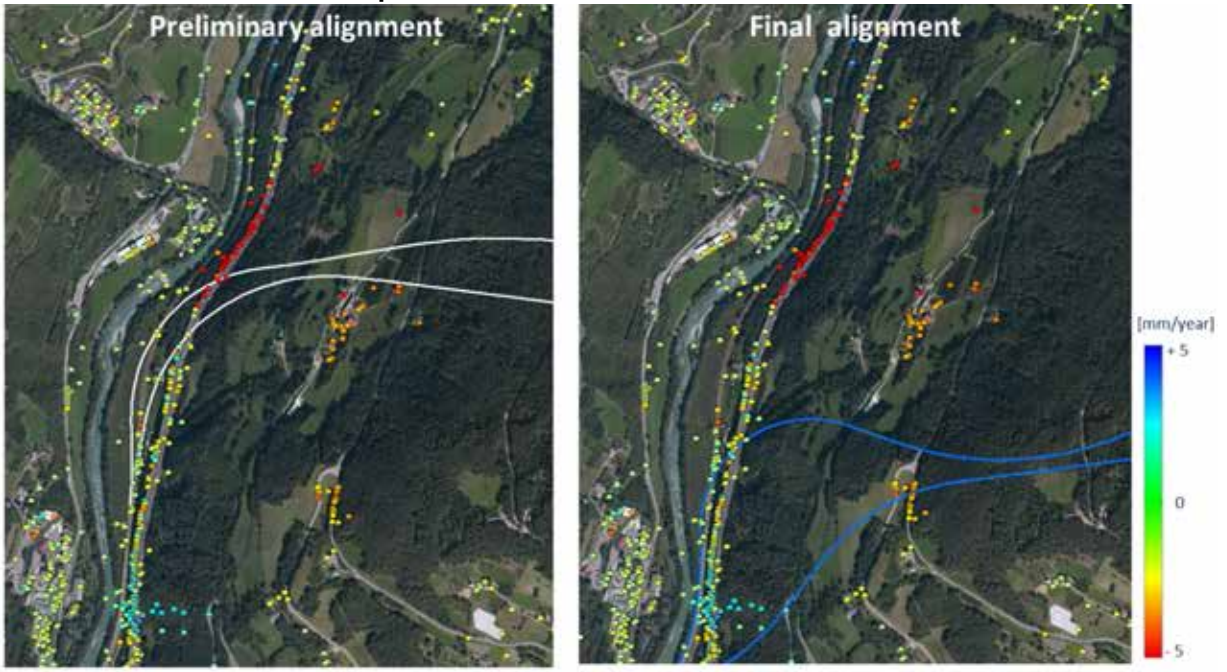
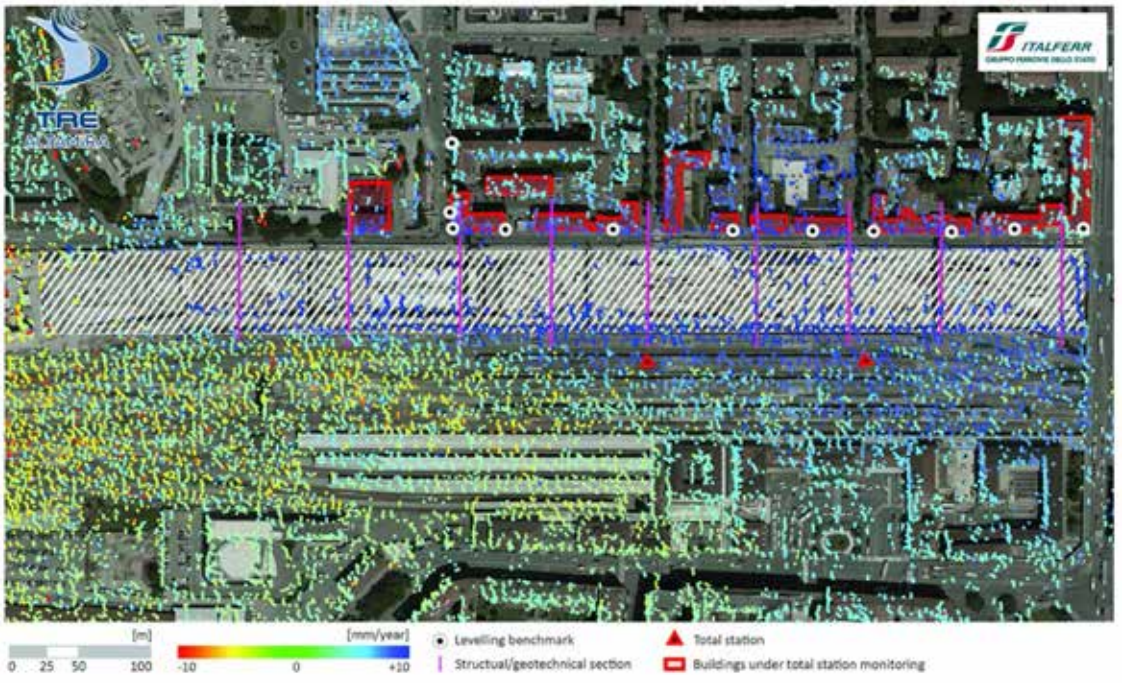


FIG. 4

SqueeSAR monitoring during the contruction of an underground high-speed rail station in a historical city center. The removal of pre-existent masonry buildings on the surface caused the ground surface to rebound, with movement extending beyond the area monitored by the insitu instrumentation (leveling benchmarks and total stations).



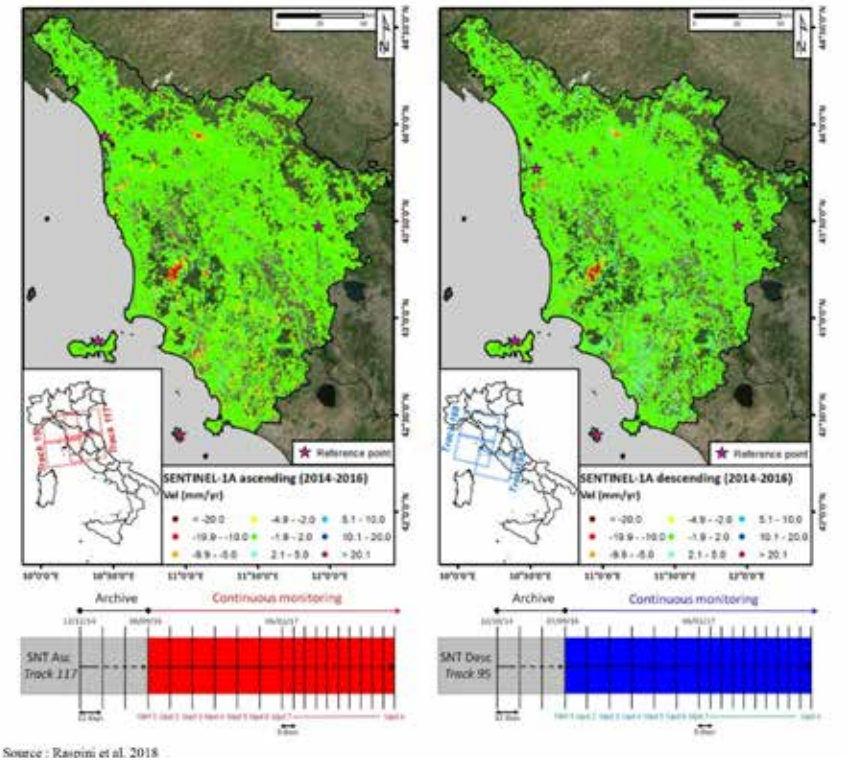
over time (Ferretti et al. 2000, 2001). PS, or natural radar targets, are typically manmade structures (buildings, streetlights, transmission towers, etc.) as well as rocks, bare surfaces, and linear structures such as roads or bridges that can reflect a signal back to the satellite.

With the aim of increasing measurement point density in rural areas with less infrastructure and the presence of some vegetation, a new technique known as SqueeSAR was presented by Ferretti et al. in 2011. This technique supplements the PS approach by obtaining information from distributed scatterers (DS). Together, the PS and DS measurements provide a network of radar benchmarks, much like a global positioning system (GPS) network. Such datasets can be employed to monitor the displacement of individual buildings or infrastructures as well as entire cities, regions or states.

There are many low-resolution SAR image archives going back to the early 1990s that are now in the public domain, making InSAR highly accessible and leading to its extensive use. Since the mid-2000s, several commercially operated satellites have collected high-

FIG. 5

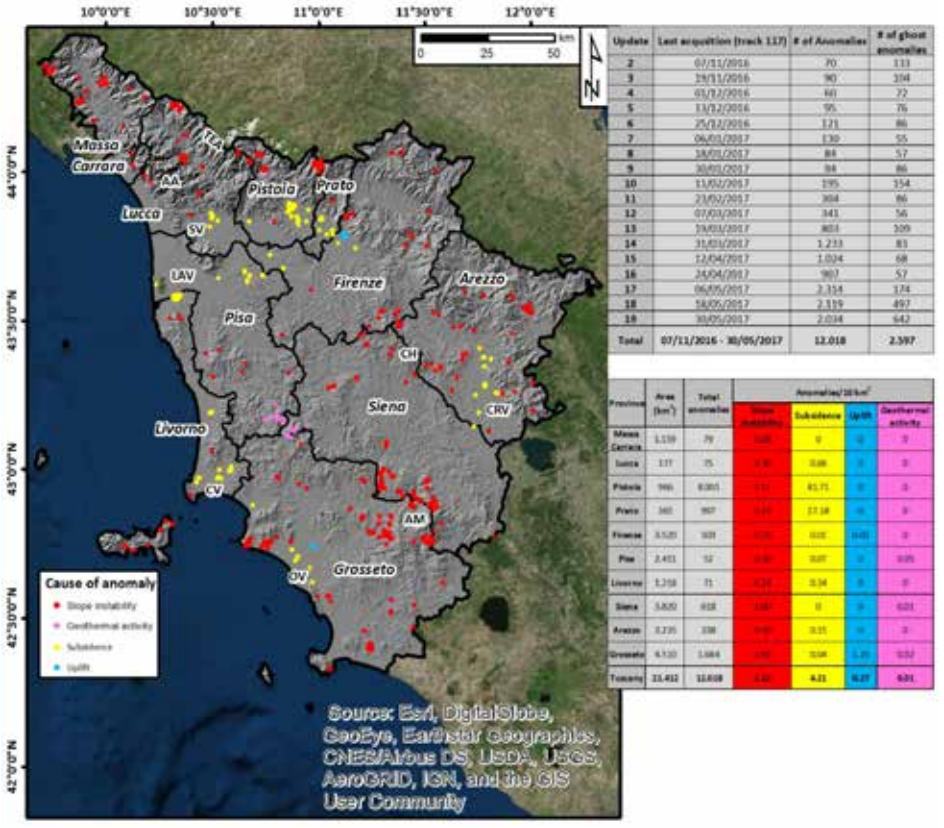
Ground deformation maps showing the results of the high-frequency SqueeSAR monitoring service currently being provided to the regional government of Tuscany, Italy using data from two satellite orbits. (Source: Raspini et al., 2018)



Source : Raspini et al. 2018

FIG. 6

High-frequency monitoring results in Tuscany. The anomalies are color-coded according to the cause of displacement: slope instability, subsidence, geothermal activity or uplift. (Source: Raspini et al., 2018)



Update	Last acquisition (track 117)	# of Anomalies	# of ghost anomalies
2	07/11/2016	70	133
3	19/11/2016	90	104
4	01/12/2016	60	72
5	13/12/2016	95	76
6	25/12/2016	171	86
7	06/01/2017	130	55
8	18/01/2017	84	57
9	30/01/2017	84	86
10	11/02/2017	195	154
11	23/02/2017	304	86
12	07/03/2017	341	56
13	19/03/2017	803	109
14	31/03/2017	1.233	83
15	12/04/2017	1.024	68
16	24/04/2017	907	57
17	06/05/2017	2.314	174
18	18/05/2017	2.319	497
19	30/05/2017	2.034	642
Total	07/11/2016 - 30/05/2017	12.018	2.597

Province	Area (km²)	Total anomalies	Anomalies/100 km²			
			Slope instability	Subsidence	Uplift	Geothermal activity
Massa Carrara	1.159	70	0.00	0	0	0
Lucca	177	75	0.00	0.00	0	0
Pistoia	965	6.005	0.00	43.71	0	0
Prato	365	907	0.00	17.18	0	0
Firenze	3.520	103	0.00	0.00	0.00	0
Pisa	2.451	52	0.00	0.07	0	0.05
Livorno	1.258	71	0.00	0.24	0	0
Siena	3.800	618	0.00	0	0	0.03
Arezzo	3.235	198	0.00	0.15	0	0
Grosseto	4.510	1.664	0.00	0.04	0.15	0.02
Tuscany	22.452	12.018	0.00	4.21	0.27	0.01

resolution imagery, contributing to spatially dense InSAR data over many tunneling projects. In urban areas, InSAR provides a density of thousands of measurement points per square kilometer (Fig. 2). With the increased frequency of satellite data availability and new developments to processing algorithms, it is possible to receive highly precise ground displacement data updates with each new image acquisition (Raspini et al., 2018).

InSAR monitoring of tunnels

Many contemporary geotechnical monitoring programs for tunnel excavation projects now incorporate InSAR data. The synoptic, birds-eye view provided by the high-density point cloud output typically complements a selection of total stations, GPS and other instrumentation installed at discrete locations. The measurement density of InSAR datasets depends on the natural reflectivity of the ground, and in urban environments, buildings and infrastructure act as strong reflectors of the satellite's radar signal.

SAR data have been collected for more than two decades, and large archives exist in many parts of the world, thus providing an opportunity to study historical ground deformation since the early 1990s. At the tunnel planning stage, this is often used to examine pre-existing ground deformation near the proposed alignment.

In the case of the railway from Venice to Trieste in Italy, historical InSAR data were used to characterize landslides along the proposed alignment. Modifications to the proposed alignment were made based on the detection of an active landslide (Fig 3).

Once tunnel construction is underway, InSAR is employed to complement the in situ monitoring instrumentation. It offers wide-area coverage beyond the tunnel alignment, potentially capturing displacement induced by the tunnel excavation, dewatering or reactivated slope instabilities. These types of movement can extend for hundreds of meters or even kilometers from the project area. An example of ground settlement more than one city block from a tunnel excavation in a historical city center in Europe is shown in Fig. 4.

Once excavations have been completed, InSAR is employed as a longer-term monitoring tool for periodic checks of ground stability, supporting structural health monitoring and providing early warnings of changes in settlement rates.

High-frequency updates

Significant advances to data processing algorithms, coupled with cloud computing, can now produce updated measurements within hours of each new satellite image acquisition. With new image acquisitions occurring every six to 12 days from a single satellite, the combined use of multiple satellites can provide near-daily revisits. This increased image frequency, along with major advances to InSAR processing algorithms and the advent of cloud computing have made it possible for updated measurements to become available the same day that a satellite image is acquired.

These advances in delivery speed and frequency have brought new challenges related to the management of large amounts of datasets and the extraction of relevant information. Every update typically includes hundreds of thousands to millions of measurement points in urban environments, meaning that it is necessary to design tools to identify and highlight critical information in a timely

manner.

The regional government of Tuscany, in central Italy, was one of the first public administrations to implement the use of a high-frequency InSAR service. Figures 5 and 6 show time series of displacement that are continuously updated with every new image acquisition from the Sentinel-1 satellite, every 12 days. These advances in delivery speed and frequency have brought new challenges for timely data interpretation and implementation, particularly in urban environments, where datasets can contain millions of measurement points. A method for identifying and highlighting key areas quickly is critical.

Deformation trend variation algorithm

The development of a deformation trend variation tool designed to rapidly examine millions of points, and flag only those where changes in ground deformation trends have occurred, has become an integral part of risk mitigation procedures in high-frequency monitoring. The tool triggers an alarm that draws the attention of the stakeholder and potentially activates further investigation.

The deformation trend variation algorithm uses a series of parameters and movement thresholds that are application dependent and customized to the project, and are continuously updated and refined throughout the life of the project. Urban environments are particularly sensitive to risks and constraints associated with tunneling activities due to the high density of elements at risk and public safety requirements. Even relatively small displacements need to be flagged, thus necessitating very low sensitivity thresholds for the trend variation tool, typically in the range of 2 to 4 mm, within a one- to three-month period.

FIG. 7

Example of high-frequency monitoring coupled with trend detection analysis over a tunnel excavation in an urban enviroment. Updated ground deformation maps are provided every 11 days and the trend variation analysis is set to $\Delta v \geq 3$ mm/yr.

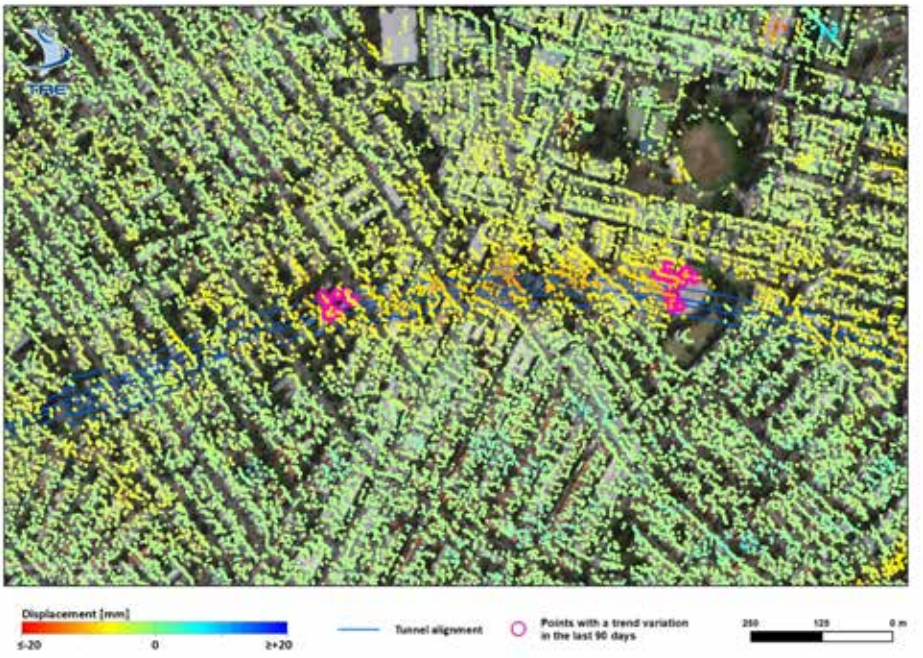


FIG. 8

Examples of time series flagged by the trend detection tool. Both points show a change in the deformation rate in the last 90 days.

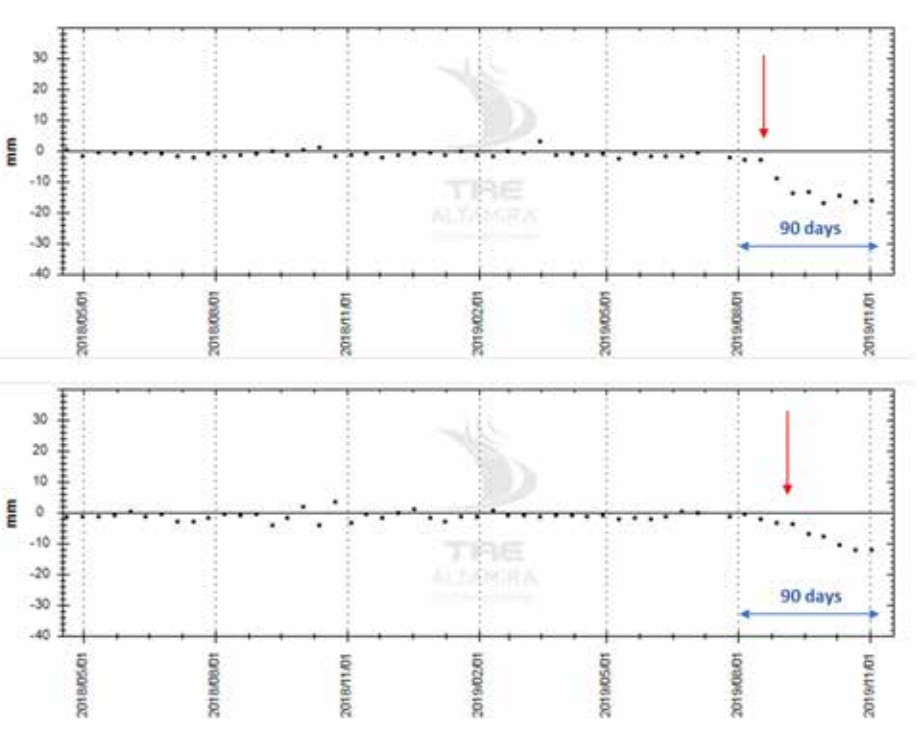


Figure 7 shows an example of a current high-frequency monitoring service for a twin tunnel excavation. The service uses high-resolution satellite imagery and provides updated deformation time series for close to 1 million measurement points every 11 days. The service is coupled with an automated trend variation analysis to automatically identify and flag measurement points with a change of at least 3 mm/yr in the displacement rate (Fig. 8). The output highlights areas of acceleration (pink circles) over the entire tunnel alignment and is compared to the localized in situ monitoring results.

The future of InSAR monitoring

Advances in SAR technology have seen a drastic reduction in the size of satellites along with improvements in their capabilities. Early SAR satellites weighed in the order of tons while the new satellites being developed weigh tens of kilograms, making them much more affordable to launch. Furthermore, while previous satellites were mainly owned and operated by national space agencies, new private startups have started designing constellations of satellites that may soon revolutionize SAR remote sensing.

The next few years will see the advent of hundreds of so-called "nano-satellites" orbiting the earth that will provide SAR imagery on a daily and even hourly basis, allowing near-real time, satellite-based ground displacement monitoring, coming closer to mirroring the data update frequencies of other geotechnical monitoring methods.

Conclusions

Surface deformation monitoring is a key component in the identification and mitigation of risks related to tunnel excavation. Space-based InSAR is now being regularly included into comprehensive geotechnical monitoring programs for tunneling projects as it offers a synoptic, wide-area view that, coupled with localized, sparse in situ real-time systems, offers a comprehensive solution for spatially and temporally dense ground deformation data.

Ground deformation updates can now be available within hours of each new satellite image acquisition. The advent of high-repeat updates has spawned the development of sophisticated deformation trend variation tools to sift through very large, spatially dense datasets and immediately identify critical areas of concern.

Future SAR satellite missions will give the geotechnical monitoring community access to daily and hourly InSAR ground deformation data, placing even more importance on trend variation tools that can analyze and highlight critical areas during tunnel excavation work. ■

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Robbins develops rectangular tunnel boring machine for silver mine in Mexico

by William Gleason, Editor

At Mexico's oldest silver mine, Fresnillo Plc., in Fresnillo, Mexico the Robbins Company is unveiling the latest innovation in tunnel boring machines (TBM), with its rectangular TBM, known as the MDM5000 (standing for Mine Development Machine with dimensions of 5 m by 4.5 m or 16 ft by 15 ft).

The MDM5000 is making headway at the mine, according to Robbins. Fresnillo chose the MDM5000 because it is capable of excavating a flat tunnel invert for immediate use by rubber-tired vehicles. The MDM5000 is boring a mine access tunnel in andesite and shale with quartz intrusions that have defied earlier attempts using roadheaders. The successful operation is the result of extensive discussions between Robbins, which designed and supplied the machine, with TOPO machinery and Fresnillo Plc.

Developed by Robbins for use in rock up to 200 MPa UCS, the MDM5000 excavates with a reciprocating cutterhead and swinging cutterhead motion to create a rectangular cross-section tunnel.

Developed by Robbins for use in rock up to 200 MPa UCS, the MDM5000 excavates with a reciprocating cutterhead and swinging cutterhead motion to create a rectangular cross-section tunnel.

"We decided to work with Robbins for their experience. A lot of people have tried to provide these kinds of machines but nobody has done it. Robbins used their experience and their skills to provide us with a rectangular profile machine," said Fidel Morin, projects superintendent for Fresnillo Mine.

The technology is not only useful for the mining industry, but also for many applications in civil tunneling. While other machines have been developed for soft ground, the MDM5000 represents the first successful foray into rectangular hard rock tunneling.

"We're very pleased to add noncircular tunneling to our wheelhouse of solutions that continues to include TBMs, conveyors, cutters, and more. We see applications for the MDM wherever a rectangular profile is needed, such as train tunnels requiring a flat invert. In a traditional circular tunnel, the invert is filled or an invert segment is needed, but with the MDM 30 percent less rock is required to be removed from the profile," said Robbins president Lok Home.

With more than 1,700 m (5,575 ft) of advance thus far at rates of up to 52 m (170 ft) in one week and 191 m (627 ft) in one month, the MDM is significantly faster than drill and blast excavation. "We're making history. Fresnillo is always looking for new technology, and we believe that the usage of the MDM5000 is going to be something extremely successful, not only for our company but also for the industry," said Morin.

The MDM5000 has undergone major component enhancements during the course of its successful bore at Fresnillo mine. It was first transported to the -695 m level of the mine and underwent final assembly and launch in a cavern, where sections of the MDM were moved by crawlers and pieces were lifted by hoist. The machine is now boring a 270-degree spiral that will end above the original tunnel. It will then be backed up to the original tunnel and continue driving straight ahead.

The MDM5000 is particularly useful wherever a rectangular profile is needed, such as train tunnels requiring a flat invert. The rectangular profile requires 30 percent less rock to be removed as compared with a circular cross section.

The MDM5000 utilizes disc cutter technology proven on traditional, circular TBMs. During excavation, a reciprocating cutterhead and swinging cutterhead motion create a rectangular cross-section tunnel.The MDM offers a number of advantages over drill and blast. MDM tunneling has advance rates of roughly twice those of a drill and blast heading, and results in smooth tunnel walls, less overbreak, and minimized ground support. The increased advance rates are partly due to the machine's continuous progress, unlike drill and blast operations, where crews must exit the tunnel during blasting for safety. In addition, simultaneous ground support installation further increases overall advance rates compared with drill and blast operations that must install ground support sequentially. ■

UCA creates Tunnel Watch List to highlight the benefits of tunnels and underground construction

by William Gleason, Editor

Simply stated, modern society could not exist as we know it without the many benefits that come from the tunnels beneath our feet. However, for many people their only exposure is to the transportation tunnels in the world's most densely populated areas and many people are unaware of other benefits, like providing freshwater or for the storage of wastewater for treatment.

These many benefits of tunnels are well known to members of the Underground Construction Association (UCA), a Division of SME, and this year the Division formed a committee to create the inaugural Tunnel Watch List, a list of some of the most important tunneling and underground construction projects in the United States with a goal of shining a light on the positive impact these projects bring the general public.

The projects on the list cover the entire United States, from the east coast such as the MBTA Red Line Blue Line Connectors to the Ala Moana tunnel in Honolulu, HI and LA Westside Purple Line Extension in Los Angeles, CA. The 30 projects include well-known multibillion-dol-

(continued on page 25)

2021 Tunnel Watch List

Project	City	State	Owner	Status	Tunnel use
Ala Moana	Honolulu	HI	City of Honolulu	Planning	Wastewater
Ballard to West Seattle	Seatlle	WA	Sound Transit	Planning	Railroad
Banks Lake Pumped Storage Project	Grand Coulee	WA	Columbia Basin Hydropower	Planning	Energy
Delta Conveyance	Sacramento	CA	California Dept. of Water Resources	Environmental Impact Assessment	Water
Detroit-Windsor	Detroit	MI	CRG	Planning	Railroad
Floyd Hill Tunnel - I70	Denver	CO	DOT	Planning	Highway
Ft Lauderdale Connector	Ft. Lauderdale	FL	City of Ft Lauderdale	Planning	Transit
Gordon Butte Pumped Storage Hydro Project	Martinsdale	MT	GBEP	Design	Energy
Harlem River Drive Ramp	New York	NY	NY DOT	Planning	Highway
Houston Flood Control Tunnels	Houston	TX	Harris County Flood Control District	Planning	Water
Howard Street Tunnel	Baltimore	MD	CSX	Planning	Freight rail
I-35 Capital Express Central Project	Austin	TX	Texas DOT	Planning	Highway
LA Westside Purple Line Extension - Phase 4	Los Angeles	CA	LA Metro	Planning	Transit
MBTA Red Line Blue Line Connector	Boston	MA	Mass. Bay Area Transit Authority	Planning	Transit
NEC - Northeast Corridor	Philadelphia	PA	Federal Railroad Administration	Planning	Railroad
Northeast Maglev Project Phase 1	DC to Baltimore	MD	SCMAGLEV	Planning - EIS on going	Railroad
Railyard Alternatives and I-280 Boulevard	San Francisco	CA	City of San Francisco	Planning	Transit
Sepulveda Pass	Los Angeles	CA	LA Metro	Feasibility design	Transit
Steel Bridge Replacement Tunnel (Tri-met Tunnel)	Portland	OR	Tri-County Metropolitan Transportation District of Oregon (TriMet)	Planning	Transit
Vermont Transit Corridor	Los Angeles	CA	LA Metro	Planning	Transit

(continued from page 24)

lar transportation projects that will eventually carry millions of people underground as well as combined overflow sewage projects that very few people will ever see the inside of.

"Each project has its own unique benefits, these vary in type from economic, to job creation, improved mobility, reliability/resilience, improved efficiency and environmental benefits," said Mike Rispin of Strata Worldwide and UCA chair and member of the selection committee. "The projects provide everything from providing safer water supply and sewage disposal systems, cleaner rivers, to inter-state rail and road links and transit systems that are safe and do not interfere with surface activities."

Rispin is joined on the committee by Robert Goodfellow, Aldea Services Inc.; Grover Vargas, Sika Corp.; Jonathan Klug, David R. Klug and Associates; Michael Vitale, Mott MacDonald; Mark Johnson, Jacobs; Michael Roach, Traylor Bros. Inc.; Jim Rush, Benjamin Media and Erika Moonin, Moonin and Associates. The committee, which has combined professional tunneling experience of more than 275 years, considered a number of factors when picking projects for the list including cumulative benefits of the project both regionally and nationally with an emphasis on societal and environmental benefits and not just economic benefits. Geography was a factor as well as the need to help promote projects that may need funding or are particularly important to their local community, or any other reason to justify why the public needs to be aware of the need for this infrastructure.

A pass/fail criteria was used to prioritize projects that have passed the initial concept design hurdle and are at least into preliminary engineering, the committee said.

The overall goal of the project is to raise awareness of the importance of tunnels to the United States.

"For every pair of eyes it reaches, it raises awareness," said Vargas. "That's our most significant challenge with the public — what we've done, what we are doing, what we need to do … and the benefits these all have provided or will provide to society. Depending on the public's infrastructure needs, there is always an answer that the tunneling industry can provide, since there is no one-size-fits-all solution."

"Far too often the benefits of tunnel remain out of view and out of mind. It is very important for the public to understand that tunneling has been and still is a critical enabling technology for some of the most important infrastructure projects in history," said Goodfellow. ■

A call for UCA volunteers

Calling all UCA Members. We need your expertise and participation as a division representative to several SME committees, including: Government & Public Affairs, Information Publishing, Journal Oversight, Research, and the Robert E. Murray Innovation Award. These are typically three-year terms starting March 1, 2022, immediately following the MINEXCHANGE 2022 SME Annual Conference & Expo in February.

If you are ready for more serious involvement, we are also seeking members for the UCA Executive Committee to start July 1, 2022 for a four-year term ending June 30, 2026. The UCA Executive Committee comprises of four officers, serving two-year terms, and 16 members serving alternating four-year terms. The executive committee is intended to represent owners, contractors, engineers, suppliers and other members-at-large.

Specifically, for this round, we need nominations for the categories of contractor and owner. Once on the executive committee, you will be eligible to serve two consecutive four-year terms. It is a challenging role requiring a current membership in the UCA, a time commitment to attend a minimum of two executive committee meetings annually held in conjunction with the George Fox Conference and the North American Tunneling Conference (NAT) or the Rapid Excavation and Tunneling Conference (RETC) biennial conference. Additionally, you should also be able to demonstrate a desire to be involved in the leadership of the organization and have a strong interest in one or more UCA activities including educational conferences, publications, promotion, and outreach of the tunneling business, and/or interest in international activities such as the International Tunneling Association.

Despite the challenge and time commitment, most members find serving on the executive committee to be extremely fulfilling and want to serve a second term.

If you have an interest in volunteering on an SME Committee, please reach out to Genny Homyack (homyack@smenet.org) for more information at any time. If you would like to be nominated for the UCA Executive Committee, or know of someone who might, please think about submitting a letter of interest, a photo and brief bio for consideration to Homyack (homyack@smenet.org). To see the current members please visit www.smenet.org/UCA/About-Us/UCA-Committees/UCA-Executive-Committee UCA of SME Executive Committee. Thank you in advance for your participation in this very important society activity. We appreciate your membership and commitment to the underground community. ■

ITA award finalists named

After the success of the six first editions of the ITA Tunnelling and Underground Space awards, in Switzerland, Singapore, France, China, the United States and last year as a digital event, the ITA Awards 2021 will be this year again a digital event. The event last year gathered altogether 700 participants with an exhibition with eight sponsors. This digital event has been a success allowing people who generally do not participate to take part in the celebration of the tunneling industry success. The finalists have been unveiled. The digital award winners will be celebrated on Dec. 2, 2021.

Major project of the year - budget more than 500 million €

- Ismailia Tunnels under Suez Canal, Egypt
- Klang Valley Mass Rapid Transit (KVMRT) Putrajaya Line Underground Works, Malaysia
- Shantou Bay Tunnel Project, China

Project of the year - Budget between 50 and 500 million €

- Large-diameter shield tunnel engineering project in karst strata of sea area, China
- Ping'an Tunnel on Chengdu-Lanzhou Railway, China
- South extension of the metro Line 14 in Paris – GC02 contract, France

Project of the year including renovation - budget up to 50 million €

- Long Term Recycled Water Release Plan Stage 1 – Gold Coast Seaway, Australia
- Relocation of Shatin Sewage Treatment Works into Caverns Hong Kong, China
- Tangjiawan Dananshan Emergency Shelter Project, China

Technical innovation of the year

- A cloud-based intelligent system for fully automated real-time design of tunnel supporting system, China
- MISSIONOS for the Shaft & Tunnel Excavation Monitoring System for the DTSS2 Project, Singapore
- O'Dive PRO services: decompression procedures monitoring, France
- Riachuelo Lote 3 – Innovative method for the construction of sea outfall projects – The Risers Concept, Argentina
- Virtual Master Rings, Replacing a tradition, Germany

Beyond Engineering

- Is shield tunneling spoil a waste? A novel solution says no, China
- Xueshan No.1 Tunnel Project of Huashixia-Dawu Highway, China

Innovative and contributing underground spaces

- Fuxin Parking Lot of Shenzhen Rail Transit Line 14, China
- Lefdal Mine Data Center The Norwegian Solution – where scale and flexibility meet resiliency, Norway

Young tunneler of the year

- Chiranjib Sarkar, India
- Gianluca Comin, Italy
- Keith Bannerman, Australia
- Michael Mains, Canada
- Nick Hatzibousios, Australia
- Zhuanzhuan Zhang, China. ■

2022 Moles award winners named

Alfonso "Al" Daloisio Jr. and Frederick P. "Fred" Salvucci have been selected for Outstanding Achievement Awards by The Moles, a national heavy-construction industry professional organization. The awards will be presented at The Moles' Annual Award Dinner at the New York Hilton Midtown on Jan. 19, 2022. Daloisio will accept The Moles Member Award and Salvucci will receive the Moles Non-Member Award.

Al Daloisio has worked in every facet of heavy construction including field supervision, cost estimating and project management, and is currently the chief executive officer at Railroad Construction Company (RCC). Under his leadership, RCC has grown from a relatively small, $2 million company mainly focusing on railway installations, into the multidisciplinary major construction firm of today, with an annual revenue of nearly $200 million. Daloisio also owns and manages several companies specializing in building construction, electrical contracting, steel fabrication, and specialized equipment manufacturing. RCC has performed numerous major contracts for public agencies such as the Port Authority of NY and NJ; NJ Transit; NYC Transit; LIRR; SEPTA and the NJ Department of Transportation, among others. He has served on numerous Moles committees.

The Moles 2022 Non-Member Awardee for Outstanding Achievement in Construction is **Fred Salvucci**. A native of Massachusetts, Salvucci received his bachelor's and master's degree in civil engineering from the Massachusetts Institute of Technology (MIT) and attended the University of Naples as a Fulbright Scholar.

Salvucci is a true quintessential industry leader, instrumental in facilitating numerous infrastructure mega projects which enhanced the Boston skyline over the past 40 years. Through his personal efforts, he has enabled billions of dollars in economic development to take place in the greater Boston area while also making it easier and safer for commuters to travel throughout the downtown area. During his tenure as Massachusetts Secretary of Transportation, he devoted particular emphasis to the expansion of the MBTA transit system, the development of the Central Artery/Tunnel Project (Big Dig), all while implementing strategies consistent with the Clean Air Act. He is often referred to as, "The Man Behind the Big Dig." ■

Make an Exciting Career Move with the UCA Career Center

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A Division of SME

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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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Anna Merkulova, the Group of Companies “Mosproekt-3” CEO: We ensure infrastructure breakthrough

The rate of Moscow rapid transportation system expansion is one of the fastest in the world. Its' length has already reached 780 km.

Commuter rail system has been partly integrated into the city's metro network, thus increasing development potential of the metropolitan area.

Tunnelling and Underground Construction has discussed the solutions that provide consistently rapid pace of designing and construction with the Group of Companies “Mosproekt-3” CEO and a personal member of ITA in Russia Anna Merkulova.

The Group of Companies' engineers are involved in implementation of crucial segments of this megaproject.

- What changes has been introduced to the transportation system of the Russian capital in the last several years?

- We've managed to make an outright transportation breakthrough. It has taken us 10 years to perform, and the development program continues.

The off-street rail transportation network remains the centerpiece of the Moscow transportation framework, and in this field the attention has been predictably focused on the metro. 7 million passengers use it daily.

Novatorskaya station, BCL

The metro network expansion by its' sheer scale is unparalleled in the history of the Moscow underground. It required concentration of vast technical and engineering resources. The success of the project and consistently high pace of the Moscow metropolitan area urbanization has incentivized the city's government to develop commuter rail system that practically assumes the function of ground-level metro lines.

To implement large-scale transportation projects, within our Group of Companies we've formed a team of top tier specialists that provides solutions for the most challenging tasks.

- What stages of the program has already been implemented?

- Firstly, the outreach of the metro network has been expanded to cover remote areas. To achieve this goal 7 already existing radial lines has been extended, receiving about 20 new stations, and the construction of 5 new lines has been commenced.

Nevertheless low flexibility of passenger traffic patterns remained obvious. Pronounced commuting effect inherent to Moscow was amplified by the lack of lateral connections between radial lines. To change lines passengers had to use stations in the city center.

To mitigate this effect the Moscow government has launched two projects that create alternative routes.

The first one is the Moscow Central Circle, or MCC. It has been implemented more promptly thanks to the existing freight rail infrastructure that had been modernized and adapted for passenger transportation.

The network of transport hubs developed by the engineers of the Group of Companies “Mosproekt-3” helped to seamlessly entwine the new line into the city landscape and connect it to other transportation systems. Unified ticket system and metro-like train operating mode made it possible to fully integrate the line with the Moscow underground. Nowadays MCC caries more than 120 million passengers a year.

The second project is the “classic” underground Big Circle Line, or BCL, that will become the longest metro circle in the world. More than 70 km long, it'll have 31 stations.

Two sections of the line designed by engineers the Group of Companies “Mosproekt-3” are to become operational this year. With the launch of these sections passengers will have access to 2/3 of the line. Once complete, we expect BCL to take up to 30% of passenger traffic from radial lines.

- What solutions make it possible to implement these large-scale projects within such a short time frame?

- Implementation of such an ambitious program has become a real challenge for the Russian construction industry and has required involvement of all the specialists in the country as well as engagement of foreign experts.

We've increased the pace of implementation by switching to construction of close-to-surface stations that allowed more extensive use of TBMs.

As of today Moscow metro builders employ more than 30 TBMs. 23 of them were simultaneously engaged in construction of BCL – a registered World Guinness Record.

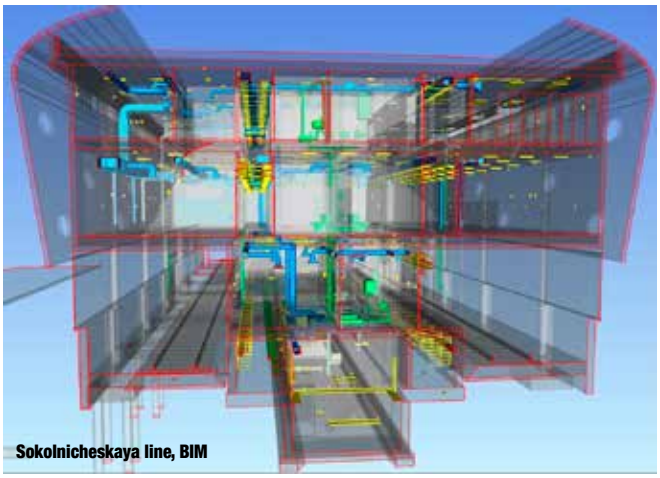
Engineers of the Group of Companies "Mosproekt-3" has also adjusted the Spanish technology of double-track tunnel boring with 10-meter TBMs to be used in complex geological conditions of the Russian capital.

More rapid construction of metro stations has become possible due to the use of standard designs. It allows continuous flow production of different elements of station structures.

At the same time it is important to preserve unique architectural identity of the stations that grants the Moscow metro its inimitable glamour. For that reason standard designs are used only for structural and planning layout while exterior is developed individually for each station, and our specialists constantly look for approaches that are new and unconventional for the Moscow metro. E.g. for south and south-east sections of BCL has been designed in parametricism – a style that give up on traditional geometric figures in favor of dynamic elements, which require complex mathematical formulas and 3D-modelling programs to calculate their forms.

- What advanced technologies do you use in designing process?

- Our team puts the emphasis on digitalization of designing process - primarily BIM-technologies and common data environment. Specialists of the Group of Companies "Mosproekt-3" are engaged in development of application methods and promotion of information modelling in the field of infrastructure construction. Russian customers and industry players have acknowledged the advantages of BIM: this approach enhances transparency and quality of projects, improve their cost efficiency and time frame.



Sokolnicheskaya line, BIM

Program interoperability is one of key focuses of our BIM-expertise development. We've decided on using open formats that give possibility to employ software from different manufacturers. Thus we expand capabilities of digital models and facilitate cooperation while working on large-scale projects with several contractors.

At the same time we consistently study and test new software that appear on the market, evaluating the possibility of its' implementation in our workflow.

- How long have you been using information modelling technologies?

- We were aware of BIM advantages early on and started to proactively implement these technologies while engaging in creation and introduction of industry standards even before the government has set course on digitalization of the field. As of today we have experience in designing huge infrastructure objects like part of a Moscow metro line completely within BIM environment – such expertise is unique for Russia. Tremendous amount of work done by our specialists helped us to secure the title of BIM-leader in Russia.

In the process of transferring to information modelling we've run into a problem of the lack of standard tools for tunnel design. Our specialists have found a solution by implementing visual programming technologies.

We've also optimized the workflow in BIM environment inside the Group of Companies. Design of various engineering systems is allocated to several departments. To increase cooperation efficiency we've codified our BIM frameworks that regulate the rules of exchange and administration of information about facilities under construction.

Moreover, a BIM-competency center has been formed within the Group of companies. It is entrusted with the task of expanding database and component library. In such a way engineers can use effectively the practices developed while working on previous BIM projects. All technical data is already included into component description. This facilitates calculations and compilation of data sheets.

BIM potential becomes completely evident while designing facilities to be constructed in densely built-up urban areas packed with utility lines. Accumulated knowledge and expertise helps engineers of the Group of Companies "Mosproekt-3" to blend new structures in the crowded metropolitan landscape with no impact on operation of existing infrastructure.

- What about the future of the Moscow metro development program?

- City's government has already announced ambitious plans aimed at development of the Moscow metropolitan area transportation network. Construction of two new metro lines (Rublevo-Arkhangelskaya and Biryulevskaya) will be launched in the near future.

Furthermore the process of commuting system integration into the rapid rail transportation network is still under way. Within the next several years the number of MCD lines will increase from 2 to 5, adding 240 km of tracks and 115 stations.

The success of the Moscow metro expansion program has prompted administrations of other cities to consider an array of transportation network development options. Such future projects include the creation of both "classic" underground and hybrid systems. The latter is now under development in Chelyabinsk, where the infrastructure left after an unfinished metro program is going to be merged with the tram network.

Meanwhile the underlying concept of MCC and MCD – adaptation of railroad network for metro-like passenger transportation – can be further adjusted for other Russian cities.

GROUP OF COMPANIES MOSPROEKT-3

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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 as well as 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 t on 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 as well as drill and blast 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. This 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.

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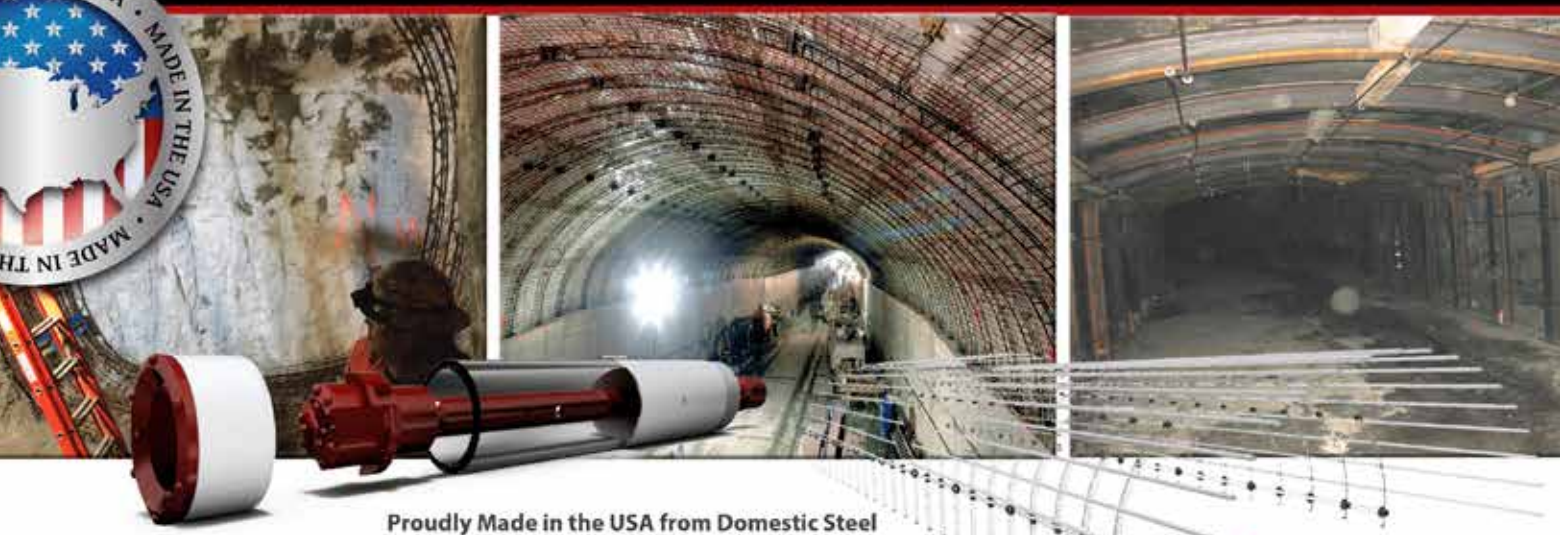

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JENNMAR continues to grow, but our focus will always be on the customer. We feel it is essential to develop a close working relationship with every customer so we can understand their unique challenges and ensure superior customer service. Our commitment to the customer is guided by three words: SAFETY, SERVICE, and INNOVATION. It's these words that form the foundation of our business. It's who we are.

JENNMAR Civil, a brand of JENNMAR has been working on some exciting projects over the past year. See photos and description below:

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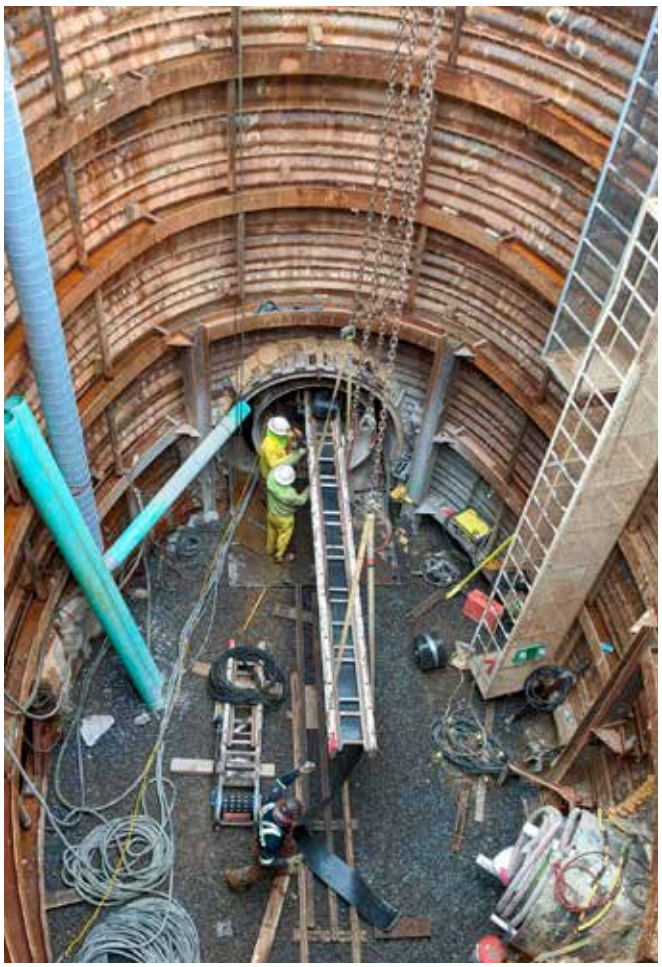
JENNMAR Civil and Specialty are excited to be a part of such an impressive job. Twelve miles of tunnel ribs and shaft rings. Great job everyone! #civilengineering #infrastructure #tunneling



JENNMAR Civil & Specialty Products are in GA with Garney/Bradshaw Construction for re-alignment of a gravity sewer line. This elliptical design is supported with JENNMAR shaft rings and ConTech liner plate. Great work! #civilengineering #infrastructure #manufacturing

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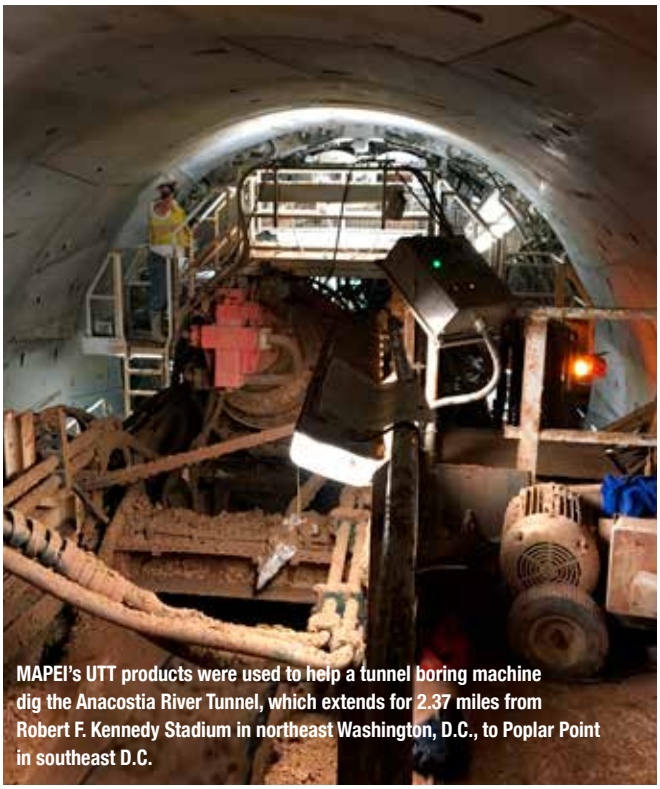
MAPEI Corporation

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 Cristina Onate, PhD, UTT Business Development Manager — Tunneling.



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.

The UTT group is a successful division of MAPEI Group, which has provided proven construction system solutions for more than 80 years. Established in 1937, MAPEI Group is a global corporation, based in Milan, Italy, and with 90 subsidiaries that include 83 plants in 36 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.

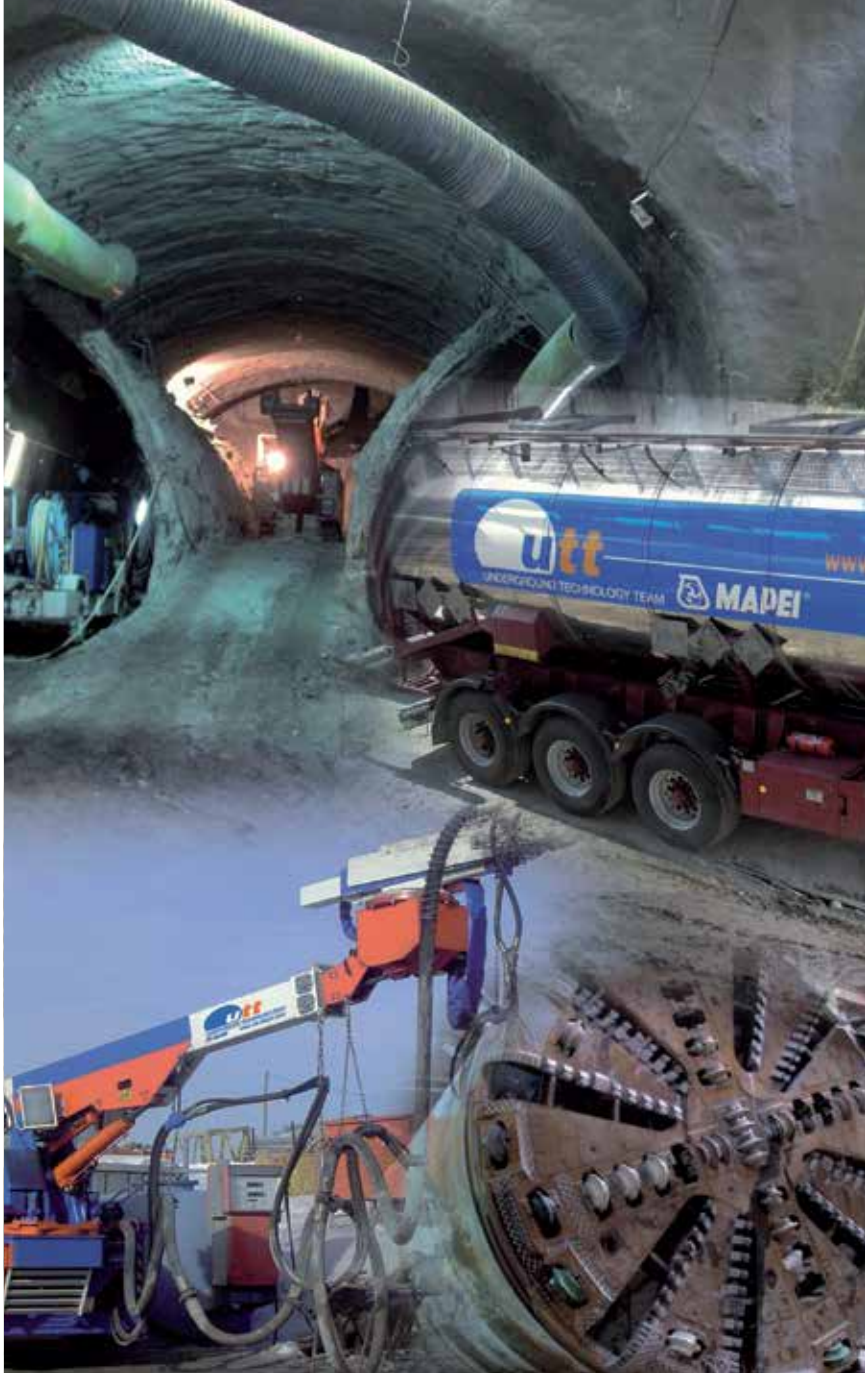
"The UTT group started in earnest in the U.S. in 2015," stated James Pinkley, Country Manager UTT – North America. "But the business has grown substantially since then." In the underground industry, speed is essential – not only of the products themselves, but also of the evolution of technology. MAPEI 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: Mechanized Tunneling; Injections for Heavy Civil and Mining Applications; Waterproofing & Water Membranes; Shotcrete Products; Renovation, maintenance and repair; and Coatings for underground construction. No matter the division or the product line, MAPEI is known for quality products and for providing system solutions. As Pinkley 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. MAPEI UTT services a project from the very beginning to the very end like no one else in the industry does," he said. "UTT also has the agility to adjust to the customers' needs when necessary per the demands of changing geological settings"

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

MAPEI®
ADHESIVES · SEALANTS · CHEMICAL PRODUCTS FOR BUILDING

Reliable Automatic Sprinkler Co., Inc.

Protecting the 'New M4' East Tunnel

About the Tunnel

The 'New M4' East (M4E) tunnel project is located in the inner west of Sydney, Australia. The M4E tunnel is a twin tube design of 3 lanes in both directions. Each tube is 5.5 km (3.4 miles) in length. Therefore, the project has approximately 11 km (6.8 miles) of tunnels in total. The tunnels are divided into 517 fire deluge zones along the entire length, including the covered entry & exit ramps. Each fire deluge zone is approximately 30 meters (98 ft) long. The tunnel is equipped with fibre optic detection that signals a central monitoring station. Each deluge zone is monitored by operators and manually activated.

When the specifications for the project were being developed, the design brief called for "an extended coverage nozzle that could effectively deliver 10 mm/min (0.25 gpm) density". At the time, no such product was commercially available. In response to this requirement, the Reliable® model TNL280 nozzle was developed.

About Deluge Systems

Deluge systems consist of water supply, a valve, a system of piping and nozzles that are open to atmosphere, and a means of detection and actuation. When the deluge valve is activated, water flows through all nozzles controlled by the valve. Unlike automatic sprinkler systems, where water flows only through individual sprinklers that have activated close to the heat source, deluge systems are designed to "surround and drown" an entire zone to prevent the spread of fire in hazardous environments.

About the TNL280 Nozzle

The Reliable TNL280 pendent nozzle has been specifically designed to provide an extended coverage nozzle suitable for use in vehicle tunnels. Key to the design of the nozzle is a very large K-factor (orifice size). The large nozzle coverage area typically results in lower installed costs by reducing the amount of material (pipe and hangers) and facilitates faster installation. By comparison, traditional tunnel nozzles — usually spaced at around 9 m^2 (97 ft^2)— are much more material and labour intensive.

Project Quick Facts:

- Consulting Engineer: Norman Disney Young (NDY)
- Site Engineer: Jessica Keogh
- Number of Deluge Systems: 417
- Tunnel height: 5.3m (17.4 ft)

Learn More:

Reliable Automatic Sprinkler Co., Inc. is a manufacturer and distributor of fire protection equipment. Reliable manufactures the highest quality and most innovative fire sprinklers, valves, and special systems on the market. Reliable also distributes a full line of best-in-class system components. All Reliable products are backed with premier customer service. Reliable's corporate headquarters is located in Elmsford, NY with manufacturing headquarters in Liberty, SC. Regional sales and distribution centers are located throughout the US and around the world.

For more information on Reliable® products, systems, and innovation, visit our website at www.reliablesprinkler.com/tunnels

Disruption is not an option

Reliable® Tunnel Deluge Systems protect your most critical infrastructure assets

Reliable deluge systems are the perfect solution for the challenges of tunnel environments:

- The Model DDV Diaphragm Deluge Valve is simple to maintain and rated for pressures up to 400 psi (27.6 bar). Available with a remote resetting pressure regulating option, the Model DDV features a compact footprint and can be installed in any orientation.
- The industry-leading low-pressure/high density TNL280 nozzle features a corrosion-resistant Electroless Nickel PTFE (ENT) finish and anti-reflective black paint topcoat.

TNL280

Over 100 Years of Reliable Experience

Reliable Automatic Sprinkler Co., Inc. has been a trusted source for high-risk fire protection solutions since 1920. Our manufacturing headquarters are in Liberty, South Carolina, USA, while our Sales and Technical Services teams span the globe.

Reliable®

Manufacturer and Distributor of Fire Protection Equipment

Contact our Technical Services team to identify the ideal solution to your specific need—no matter what the challenge.

reliablesprinkler.com/tunnels

Keller – The leading geotechnical specialty contractor

Facing challenging subsurface conditions is a familiar scenario for tunneling contractors, and as the leading geotechnical specialty contractor, Keller has provided solutions to these challenges for almost 100 years. Our solutions for tunneling include diaphragm walls, ground freezing, secant piles, dewatering, jet, permeation and compensation grouting, and instrumentation and monitoring.

By connecting global resources and expertise with local knowledge and focus, Keller develops innovative, practical, and cost-effective solutions to geotechnical challenges. Keller builds projects designed by others and offers full design-build services for any geotechnical construction application.

Sector challenges we can solve

- Stabilizing soil for tunneling operations
- Earth retention for break-in and break-out shafts
- Controlling settlement of structures overlying tunneling operations

Contact us today about your next tunneling project.

Keller
7550 Teague Rd #300
Hanover, MD 21076
Telephone: +410-551-8200
www.keller-na.com

Northgate Link Extension, Seattle, WA, ground freezing for groundwater control and support of excavation

DC Clean Rivers Project, Washington, DC: Division A - Blue Plains Tunnel, reinforced concrete slurry diaphragm wall shafts (pictured); and Division I Diversion Structure, jet grouting for underpinning, support of excavation, and groundwater control




PIONEERING UNDERGROUND TOGETHER

With the experience of more than 5,300 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 1,069 million euros in 2020. The independent family-run business employs around 5,000 people worldwide, including around 200 trainees. With around 70 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 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).

Herrenknecht Tunnelling Systems USA Inc.
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pr@herrenknecht.com
www.herrenknecht.com

HERRENKNECHT
Tunnelling Systems

DSI Underground

Reinforcing Progress - DSI Tunneling LLC.

Our future begins underground. From providing the commodities on which everyday life depends, to creating the spaces, transport conduits and communications networks that connect our world, mining and tunneling are vital to human progress. As ground support specialists, and a proactive partner to underground operations everywhere, we're the people that make it all possible.

We have been a leader in the underground support business in North America since 1920: celebrating 100 years of excellence. Our core product line ranges from steel ribs and liner plates to lattice girders, injection chemicals, anchors, bolts and pre-support systems. We design and develop technically sophisticated Tunneling Systems; offer technical planning with integrated customer support and produce in house to ensure the availability of our systems and our special equipment – anytime and anywhere.

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. Our customized products and systems are just in time delivered to service our customers.

Wherever you are in the world, whenever you need us, we'll be on the ground – and beneath it – to reinforce your operation and drive you deeper, further, faster.

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.

When you're tackling a seemingly insurmountable objective, facing tonnes of rock and earth, and need the skills and knowledge to achieve it, we're with you. We understand the complexities and considerations, the depths and dangers far below the ground – and we work with you to navigate them, taking you downward and forward, efficiently and intelligently, safely and sustainably. By helping you progress, we're helping our society progress. Which is why it all begins underground. Together, we can help you advance into the earth – and into the future. **DSI Tunneling LLC. Reinforcing progress.**

DSI UNDERGROUND

www.dsiunderground.com
502.473.1010

DSI
UNDERGROUND
A SANDVIK COMPANY

Reinforcing Progress

NEW – Injection Chemicals for Tunneling Applications!

Tunnels help maximise space and improve communications – all key to helping drive human progress. And we supply key solutions that reinforce progress underground. Our products keep workers safe. Our reliability helps engineers plan ahead. And our expertise keeps tunnels advancing efficiently to bring benefits to everyone. **We reinforce progress - for our customers, and for the world.**

DSI Tunneling LLC
502-473-1010

dsitunneling.com

Industry leaders. Delivering innovative solutions.

Parsons (NYSE: PSN) is a leading technology firm driving the future of critical infrastructure, defense, and intelligence. Our expertise in engineering, construction, technical, and management services allows us to provide innovative, alternative delivery methods to customers worldwide. We provide groundbreaking solutions to some of the largest, most complex tunnel and underground construction projects in the world. Our experts are dedicated to overcoming the toughest challenges to help our customers move safely under or through any obstacle.

From planning and design through construction management and operations, Parsons provides a complete range of services for underground utilities, water storage, wastewater, and transportation tunnels, as well as underground buildings. Whether your project involves soft ground, rock, or mixed-faced conditions, our dedicated staff of more than 110 tunnel professionals have the experience and skills to manage the risks and deliver safe, economical, and innovative solutions. We offer a host of cutting-edge tunneling techniques to minimize the risks associated with underground structures of all sizes and levels of complexity. Our 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/tunnel/

Southern Nevada Water Authority, Low Lake level Pumping Station, Las Vegas, NV.

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

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.
1550 Mike Fahey St.
Omaha, NE 68102
(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
DRIVEN.
For those who get the job done.
Apply for our job openings:
Kiewit is currently hiring:
Interns, Field Engineers, Project Engineers, Superintendents, Safety Managers and more
Want a career that can take you places? Look no further.
kiewitjobs.com

Master Builders Solutions

Master Builders Solutions continues to break new ground in addressing the needs of tunneling professionals. Our Underground Construction team brings a total solutions approach to your projects, providing an added resource to help meet your challenges underground. Our solution-based systems enhance the efficiency and performance of the TBM operations and offer performance-based ground support solutions, from novel soil conditioning technologies to innovative anchoring systems; no matter the tunneling method. Throughout the life of your project, our team of specialists work with all relevant stakeholders to help maximize your production rates and to ensure the most successful product and system selection.

The MasterRoc® product line offers a wide range of solutions for TBM excavation in soft ground and hard rock, with high-performance products including soil conditioners, polymers and anti-clay agents. Our full line of greases and sealants help to maximize efficiency for every excavation method and soil type.

Sprayed concrete, Rock Bolt Anchoring systems, Injection and water management systems are also widely considered, selected and used for ground support and enhancement in tunneling and Mining applications. Master Builders Solutions offers customers innovative product solutions and experienced technical resources to tailor cost-effective solutions to specific project needs. These solutions dramatically improve working environments, production and safety.

The Master Builders Solutions product line is designed to be a single source for all your underground construction needs. In addition to the wide range of products and systems, our globally connected team assists our customers in selecting the right systems and combinations, allowing for successful operations, coupled with the highest safety standards.

Master Builder Solutions, a world leader in reliable products specifically designed to address the requirements of tunneling projects worldwide… where production meets performance and safety. Utilizing our global expertise, we are steadfastly focused on the needs of tunneling professionals.

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

Dragados TBM Bertha
Photo credit-Catherine Bassetti Photography

MASTER® BUILDERS SOLUTIONS

SOLVING YOUR UNDERGROUND CHALLENGES

Our customers shape the future. By listening to their needs and challenges, we have developed a complete and comprehensive offering for the tunneling industry.

We continue to focus our R&D efforts on safe, sustainable, innovative solutions for tomorrow's challenges.

www.master-builders-solutions.com/en-us/products/mining-and-tunneling

Photo credit: Catherine Bassetti Photography

Miller Contracting

MILLER has the ability to sink shafts conventionaly from 16' diameter and larger to depths of 1,600' or greater. We utilize nontraditional mucking methods that give us an edge on both safety and productivity. We own two raise bore machines with the capacity to do shafts as small as 48" diameter with our Atlas Copco 73R and as large as 26' diameter with our Herrenknecht RBR400 and up to 2,400' deep. We offer steel lining or cast in place concrete lining. We also offer pilot hole guidance to ensure tight tolerances are attained on hole deviations for elevators, man and material hoist, or emergency escape hoist applications. A MILLER shaft is not just another hole in the ground, it is a finely crafted structure that the owner can use and be proud of! Please give us the opportunity to do one/another one for you!

At MILLER, we strive to bring the best value to our customer's projects With fair prices, superb service, and outstanding quality, all delivered by an honest hard-working team of professionals. We are committed to seeing that our values are a part of every project we do. We strive to practice the hightest levels of intergrity with all persons involved and praise God in every interaction.

Please contact us with all your shaft needs! email- Jake Welch jwelch@millercontracting.us or Matthew Miller matthew@millercontracting.us or call them at the office- 618.994.4616 -Jake ext. 115 or Matthew ext. 103

MILLER

SHAFT DIVISION

We at MILLER have a great team of highly trained men in our shaft division. We have the ability to sink shafts conventionally from 16' diameter and larger to depths of 1,600 ' or greater. We utilize nontraditional mucking methods that give us an edge on both safety and productivity. We own three raise bore machines with the capacity to do shafts as small as 48" diameter with our Atlas Copco 73R and as large as 26' diameter with both of our Herrenknecht RBR400s and up to 2,400' deep. We offer steel lining or cast in place concrete lining. We also offer pilot hole guidance to ensure tight tolerances are attained on holt deviations for elevators, man and material hoist, or emergency escape hoist applications. A MILLER shaft is not just another hole in the ground, it is a finely crafted structure that the owner can use and be proud of! Please give us the opportunity to do one/another one for you!

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Please contact us with your shaft needs!
Check us out on our website: millercontracting.us

The Robbins Company

Robbins, Revitalized

U.S. TBM Supplier is Focused Forward

Robbins continues as the world's foremost developer and manufacturer of advanced, underground construction machinery. Every single piece of equipment you receive from Robbins is crafted and engineered for maximum durability and premium performance, guaranteeing the successful completion of even the most challenging construction projects. Our team of dedicated experts is committed to getting your equipment delivered on time and to providing continuous support from TBM launch through to breakthrough.

A Glimpse into the New Era: Remote Machine Acceptance

Adaptability has been key for ongoing projects across the U.S. and Canada into 2021. Last year Robbins assembled a 7.95 m diameter Single Shield TBM at a facility in Mexico and conducted the company's first ever fully remote machine acceptance testing. The Robbins machine was disassembled and transported to the Ashbridges Bay Treatment Outfall in Ontario, Canada, where it is in the process of being launched alongside a continuous conveyor system. This tunnel will be bored through shale interbedded with limestone, siltstone and sandstone to replace a 70-year-old existing outfall.

The Largest Hard Rock TBM in the U.S. Changes Diameter

In Dallas, Texas the largest hard rock TBM ever to operate in the U.S. is undergoing a size conversion. The Main Beam TBM, which is partway through its bore on the Mill Creek Drainage Relief Tunnel, is being changed underground from its original 11.6 m diameter to a more streamlined 9.9 m. Designated essential by the City of Dallas, the tunnel's purpose is to provide 100-year flood protection for east and southeast Dallas; both areas affected by severe storms in the past. Launched in April 2020, the Robbins TBM and continuous conveyor system have excavated around 2,500 m of the 8 km long tunnel for Southland/Mole JV thus far.

From Disused Gold Mine to World Class Research Facility

There are more than just TBM tunnels in progress in the U.S. this year. A Robbins conveyor system is currently being readied for a Spring 2021 startup at the Long Baseline Neutrino Facility (LBNF), a project for Fermilab in Lead, South Dakota. Contractor Kiewit will use the conveyor to revamp a disused gold mine into a world-class neutrino research facility. Crews will be excavating two caverns by drill & blast and roadheader, both 1.5 km below the surface. A cable hoist will transport rock up the 1.5 km deep Ross Shaft to a rock crusher at the surface using much of the original but refurbished mining equipment. The crushed rock will then be transported via conveyors. The Robbins conveyor system is designed for the unique application and includes the longest overland conveyor Robbins has ever provided (550 m), which travels over a main road, city park, and near a residential area. The system includes sound dampening, dust filters, sound-proofed transport points, and monitoring systems, among other features.

For more about Robbins products and projects worldwide, visit our website: www.RobbinsTBM.com

A proud heritage of innovative thinking.

Moving forward, one tunnel at a time.

We're proud of the legacy that the Robbins name represents, but more importantly we're focused on the future of the underground industry and the success of our client partners today. Join us in realizing the next era of underground accomplishments.

Robbins
RELIABLE | RESPONSIVE

A GLOBAL TBM COMPANY / ROBBINSTBM.COM

Terratec

Incorporated in 1990, TERRATEC is a world renowned designer & manufacturer of Tunnel Boring Machines, encompassing all ground conditions and diameters – ranging from 0.60 to over 16 metres – as well as TBM back-up equipment, Raise Boring Machines and other custom-engineered products for the tunnelling and mining industries. TERRATEC's success is based on the experience and excellence of its global engineering team. TERRATEC is also fully managed by engineers enabling quick and efficient solutions that meet customer expectations.

TERRATEC products are well-known in the industry as Robust, Durable and Safe, basic principles that must prevail in the design of any equipment made to work in the extreme conditions encountered underground. As a provider of Total Tunnelling Solutions, TERRATEC's scope of work extends to custom engineering, as well as the operation and maintenance of tunnel boring equipment and the supply of ancillary equipment.

TERRATEC's capacity to provide a wide range of services means that it is not only an equipment supplier but a qualified and experienced partner in the execution of tunnelling works.

As a result, it is becoming more and more common for TERRATEC to supply a Total Tunnelling Solution package consisting of the TBM/s, other main equipment in the tunnel (Trains, Conveyors, Segment Moulds and Ventilation), spares and consumables for the equipment and a team of TERRATEC field personnel who can assist in the operation and maintenance of the supplied equipment throughout the duration of the project.

TERRATEC offers full range of equipment from pipe jacking machine to open TBM, soft ground to very hard rock machine. TERRATEC's continuing success on global projects is a result of tailor-made robust TBM design, prompt onsite assistance, readily available stock of TBM spares and highly-skilled specialised TBM support throughout tunnelling operations.

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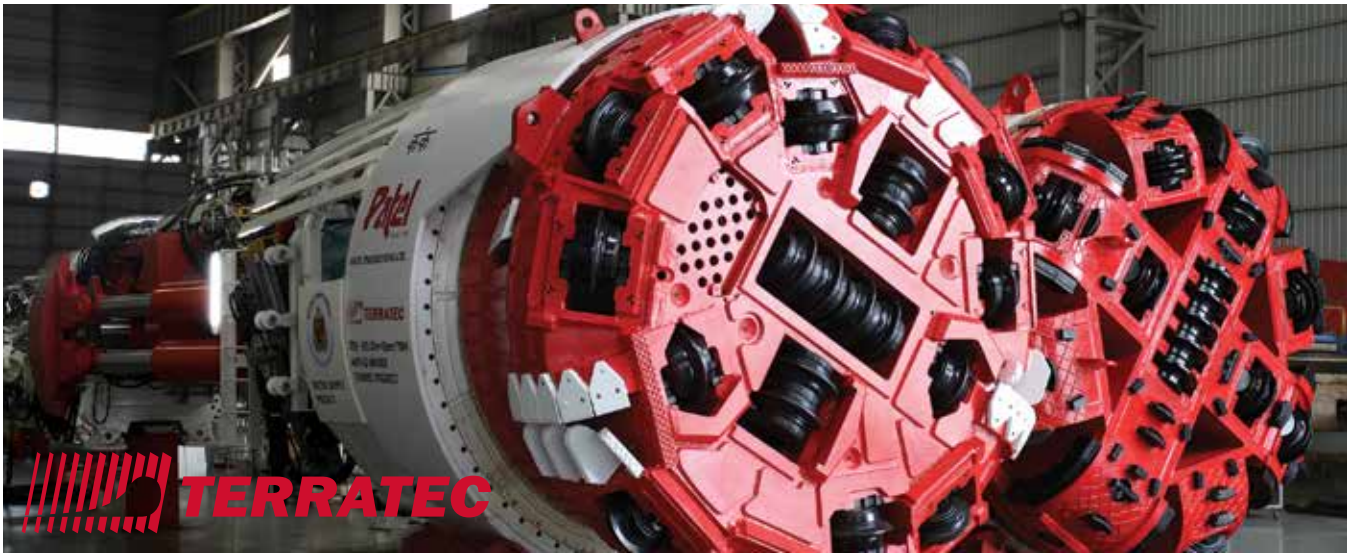
Company telephone number
+ 61 362233282



ALWAYS ADVANCING

www.terratec.co

MUMBAI'S WATER TUNNEL PROJECT

TERRATEC has recently delivered the second 3.2m diameter Open TBM for the Amar Mahal water transfer tunnel contracts in Mumbai, India.

In recent years, TERRATEC's order book has demonstrated significant growth & diversity globally including projects in Argentina, Turkey, Thailand and India which have been the result of robust custom-made TBM designs, a readily available stock of TBM spares and consumables, and a highly-skilled team offering specialised TBM support and prompt onsite assistance throughout tunnelling operations.

TUNNELLING SOLUTIONS | WATER

TERRATEC

David R. Klug & Associates, Inc.

Since 1996, David R. Klug & Associates, Inc. has provided international and national manufacturer's 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 Nittetsu ultrafine cement, GFRP rock bolts and soft-eyes, steel and synthetic fiber reinforcement, prefabricated welded wire fabric and rebar reinforcing panels, and specialty grout systems for various tunnel backfill grout requirements for highway, rail, subway, water and CSO tunnel construction applications.

David R. Klug & Associates, Inc.
1994 Lumber Ave.
Wheeling, WV 26003
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Fax: 304-905-0154
Cell: 304-281-4239
E-mail: jklug@drklug.com
Website: www.drklug.com

CDM Smith – A Leader in Tunnel Engineering

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
- Geotechnical engineering
- Geotechnical data & baseline reports
- Lining & structural engineering
- Numerical analysis
- Ground improvement & ground freezing design
- Deep excavations & ground support design
- Groundwater modelling & control
- Soil and rock testing

To support our clients, we offer comprehensive consulting, engineering, and construction support services.

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
- Environment
- Water/wastewater
- Mining

Award-Winning Projects

MEED Project Award (2020), International Project of the Year, Ismaïlia Tunnels under Suez Canal

ENR Global Best Projects (2017), Best Water/Wastewater, Abu Hamour Surface and Groundwater Drainage Tunnel

ACEC Engineering Excellence Award (2018), New York Harbor Water Siphon

Contacts:

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Mahmood Khwaja, PE | KhwajaM@cdmsmith.com | 617-452-6391

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

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

Reusable, Reliable Wireless Underground Communications

Innovative Wireless Technologies (IWT) believes that being underground shouldn't mean being out-of-touch. IWT networks are designed specifically for underground environment, unlike surface technologies that often do not work well below the surface.

IWT networks are highly-reliable, scalable, and offer a wide variety of integrated products and solutions. From crystal-clear voice communication and real-time tracking, to multi-gas monitoring and data analytics, an IWT network is an expandable, single network that is easy to use, and less costly to maintain.

Self-configured nodes form a network of repeaters to relay voice and data from one device to the next - from the deepest working areas, all the way to the surface. Wireless transmission between nodes means no cables to run (or break) resulting in high reliability and low installation and maintenance costs.

Regardless of tunnel contruction material, height, or length, an IWT network has you covered with multiple infrastructure solutions including fixed-location line powered devices, or rapidly deployable battery units. Additionally, IWT solutions are completely recoverable after project completion and re-deployable at your next jobsite.

Have a short-term inspection or project?
IWT offers flexible rental options for portable communications and networks.

Start the conversation today at iwttunneling.com

IWT

Defining the Future Underground.

The underground future built on three pillars, which highlight our expertise and focus:

1. **Securing a safe and sustainable future** – means building the safest places underground while minimising the impact to the environment and is committed to exceeding industry standards.

2. **Innovating for Performance** – means delivering productivity with leading-edge solutions and technology.

3. **Partnering for the Future** – means that our whole team is committed to our customers' goals, and we build capacity for agile cooperation.

We work in close collaboration with our customers. The process expertise amassed over thousands of mine and tunnel projects all over (and under) the globe translates into experience and expertise about what should and should not be done to achieve the optimum results. We utilise our process expertise into concrete actions and financial results for our customers.

Normet has a broad underground offering:

- Equipment for concrete spraying and transport, explosives charging, scaling, lifting, installation works, and logistics.
- Construction chemicals for sprayed concrete, admixtures for all types concrete, injection systems for rock improvement and water control, reinforcement systems for high deformation conditions, spray applied waterproofing systems and needed chemicals for Tunnel Boring Machine (TBM) technology covering hard rock, Earth Pressure Balance (EPB), open face and slurry type machines,
- High quality and innovative rock reinforcement products that reduce the risk and consequences of accidents and facilitate high productivity in challenging rock conditions.
- Services for underground mining and tunnelling, including for example spare parts, rental equipment, equipment refurbishment, performance and field services.

Normet has delivered over 13,000 built-for-purpose underground machines which are serviced and supported with a broad service portfolio.

Normet currently employs over 1400 business professionals with a passion for doing "big" things for its customers and for the industries which the company serves.

Normet is a Finnish company operating globally with over 50 locations in 33 countries worldwide. This breadth allows rapid response and reliability to all customers whenever and wherever in the world they may be. Company revenue in 2020 was over 300 M€.

Innovative Onsite Concrete Production Equipment for Rent

OUR SERVICES, EQUIPMENT & PARTNERSHIP

GALLOVICH CONSULTING LLC, with over 20 years of professional experience in American Concrete Industry and the support of a concrete machinery manufacturer, Fiori Group SpA, a worldwide leader known for its history and industry leadership of over 70 years, brings to the market the most innovative onsite concrete production and transportation solutions with our Simple Rent or Rent-to-Purchase program.

Our fleet is exclusively made by FIORI GROUP SpA, always keeping equipment new or with few hours, providing maximum performance experience to customers.

Fiori Group SpA has its headquarters in Finale Emilia (MO) Italy, that designs, develops and manufactures off-road Concrete Batching Vehicles and Dumpers for the construction industry. The company's product portfolio is rounded off by the Group's capabilities in finding the most effective solution for any customer in making and transporting concrete on-site with great flexibility, minimizing energy costs and reducing environmental impact.

Let us help you to set up your concrete production and transportation equipment for your next tunneling project.

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P: +1 (786) 762-4068
M: +1 (240) 893-6580
8333 NW 53rd Street
Suite 450
Doral, FL 33166

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CERTIFIED CONCRETE PRODUCTION AND TRANSPORTATION. ANYTIME, ANYWHERE.

FIORI Concrete Batching Vehicle series (CBV) produces Certified Concrete anywhere, anytime, for all job sites and for all kinds of applications. These four-wheel drive vehicles are true batching plants equipped with highly-advanced yet simple to operate controls and mixing systems which facilitate production of Certified Concrete of any mix design. FIORI Site Dumpers are the perfect solution of material transportation in all job sites and particularly in Underground projects using the drive seat swiveling feature, four wheel drive and four wheel steering.
BRAND NEW EQUIPMENT AND RENTALS AVAILABLE FOR YOUR PROJECT.

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CERTIFIED FIORI RENTAL

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Premier Pipe Systems Manufacturer for Over 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/A-606) 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.

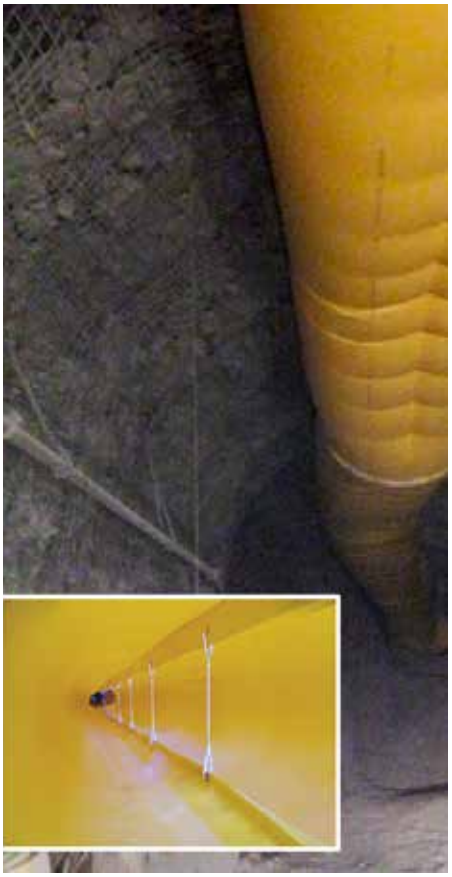
Quotations are immediately available on inquiry.

Naylor Pipe Company
1230 East 92nd Street
Chicago, IL 60619 USA
Tel: 1-773-721-9400 Fax: 1-773-721-9494
Email: sales@naylorpipe.com
www.naylorpipe.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.**



Brokk 200 Packs the Power of a 3-ton Machine Into a 2-ton Package

Brokk Inc. has been the world's leading manufacturer of remote-controlled demolition machines and attachments for 45 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. The 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., 17321 TYE Street SE, Suite B, 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®

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

Howden

Howden is the de facto choice for your ventilation needs. Whether you are building a new tunnel or mine or maintaining an old one, Howden is equipped with 160 years of OEM expertise. Our unblemished safety record places us above the competition while supporting the brands, people, know-how, and products to make your project pain-free.

The Howden range of fans, blowers, compressors and steam turbines, together with premier legacy brands such as Joy Fans, Westinghouse, TLT-Babcock, and Buffalo Forge, are highly reliable and efficient solutions for the tunnel and mining markets.

The Howden portfolio of solutions is enhanced with a Data Driven Advantage. Howden Uptime offers a unique and innovative digital solution; increasing the availability and reliability of critical assets, enabling optimization, and delivering cost-effective solutions and energy savings. Our Ventsim DESIGN software empowers you to design optimal ventilation.

The Howden service team is skilled in your applications and experts in ventilation. Our Long Term Service Agreements provide routine maintenance and OEM spare parts for the lifetime of your equipment. Our Remote Assistance offers a direct link to Howden product experts, enabling real-time communication to deliver a faster resolution even when travel is not possible. Howden combines our technology and worldwide engineering expertise to design and deliver solutions and services that optimize and enable your vital processes, creating a more sustainable world.

Howden's safe, simple and straightforward project management is backed by the OEM knowledge, technical expertise, and field experience you trust.

Contact us today at: www.howden.com

Dr. Sauer & Partners

Dr. Sauer & Partners is an independent consultancy specialized in providing the full range of design and construction management services for underground tunnelling and infrastructure projects. The company has nearly 40 years' experience delivering innovative, cost-effective designs, providing solutions for some of the world's most challenging tunnelling projects for metro, highway, water, rail and mining, and in any type of geology.

Services delivered include initial consultation and feasibility studies, final design, temporary works, supervision and construction management, tunnel inspection and condition surveys, rehabilitation, waterproofing and water control, geotechnical engineering, and mining support services. Dr. Sauer & Partners' approach is to work collaboratively and integrate fully with all disciplines (design and construction) on a project to achieve a robust and innovative solution.

Current and recent projects include: Hampton Roads Bridge Tunnel Expansion (USA), Chesapeake Bay Bridge Tunnel (USA), Effluent Outfall Tunnel Los Angeles (USA), Westside Purple Line Extension Los Angeles (USA), Eglinton West Extension Toronto (Canada), Bank Station Capacity Upgrade (UK), Metro M2 Tel Aviv (Israel).

www.dr-sauer.com

PROVIDING DESIGN SOLUTIONS FOR TUNNELS AND SHAFTS

Mueser Rutledge Consulting Engineers (MRCE) is a leading engineering firm focused on the below-ground disciplines of geotechnical engineering and structural foundation design for all structures, with a specialization in providing design solutions for tunnels and shafts. Founded in 1910, MRCE brings over 100 years of expertise to a wide array of tunnel projects in both soft ground and rock for railroads, highways, subways, pedestrians, utilidors, CSOs, interceptors, as well as water and wastewater treatment.

Current tunneling projects include the Narragansett Bay Commission's Pawtucket Tunnel, a 1.5 mile long CSO tunnel, designing ground freezing as temporary SOE to facilitate construction of two deep, large diameter shafts that will connect to the New York City Water Tunnel No. 3 and the East Bound Re-Route Construction for the LIRR East Side Access project. Among recent projects are the MD 355 Crossing in Bethesda for WMATA's NIH Medical Center station; the CSX Virginia Avenue Tunnel, VDOT Midtown Tunnel, DC Water's Blue Plains and First Street Tunnels; PSE&G Crossing #2 - Southern Reinforcement Project in Newark NJ; Toronto Subway Yonge-Eglinton Station, and New York City's NYCT Canarsie Tunnel, NYCT 2nd Avenue Subway, and the DEP Catskills and Delaware Aqueduct Rondout-West Branch Tunnel and Brooklyn to Staten Island Harbor Siphon Tunnel.

Mueser Rutledge Consulting Engineers PLLC
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New York, NY 10122 USA
Telephone: 917-339-9300
Fax: 917-339-9400
Email: farland@mrce.com
www.mrce.com

Trinity Products

Trinity Products' weldless interlocking system, Tri-Loc, offers contractors the ability to install casing much faster by eliminating field welding. The machined Male and Female teeth of each pipe joint means that once engaged, do not separate, making it ideal for trenchless Pipe-Jacking installations. Trinity Products manufactures two variations of Tri-Loc steel casing; a 3-Tooth Design used in Auger Boring, and a 4-tooth Design for Micro-tunneling. For Auger boring, the 3-Tooth design allows for a reduction in the required jacking forces to fully set or engage the interlocking joints.

Using a press-fit connection steel pipe eliminates the timely and costly process of welding each joint of steel casing before advancing more pipe down hole. A joint that may usually takes hours to weld, is connected in minutes.

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.

STRATA BRINGS THE BORAID® LINE TO TUNNELERS

Traylor Bros. Inc. have selected Strata Worldwide as their exclusive distribution partner in bringing the Boraid® line of TBM products directly to market. The Boraid line of soil conditioners, polymers and shield sealant will now be available to tunnel builders everywhere, beginning in North America.

"We are very happy to represent Traylor Bros. and act as their market channel partner in the distribution of these technologies," said Mike Berube, President and CEO of Strata Worldwide. "This is a very unique and novel line of products that will be the perfect addition to our Geotech offerings."

The Boraid line is a collection of specifically designed ground conditioning agents for sands, silts and clays in tunnel boring excavations, along with a proprietary tail shield sealant for TBMs.

Bert's Drillin' Juice is a concentrate designed specifically for conditioning sands and silts where additional lubrication at the cutting face and muck stability during handling is desired. Designed for use with Earth Pressure Balance (EPB) Tunnel Boring Machines, BDJ reduces wear on tools, screw conveyors, and cutterheads and provides better control at the face.

Soilax® - AC is a concentrate that is used for conditioning cohesive clays. It converts the clays into perfect EPB muck, reducing downtime due to cleaning and accelerates disposal speed.

Soilax® - S is a concentrate designed specifically for conditioning sands and silts, reducing wear of tools, cutterhead, and screw conveyors, and providing better pressure control at the face.

Brush Butter is a driving grade tail sealant for TBMs formulated to provide protection of the wire brushes and tightness of the tail seal. It effectively seals against water, muck, and backfill grout from penetrating through the tail seal brushes of TBMs.

Dick McLane and Josh Jonasen, Project Directors for Traylor, have been instrumental in the development of these technologies over the last 10 years. "The products are developed by TBM experts for TBM experts," states Dick McLane. "They are American made and have shown over various, diverse projects, to perform at a high level. The user should expect better advance rates, reduced torque, less cutter wear, and reduced downtime."

The Boraid line is produced in North America which assists in shortening the domestic supply chain, decreases freight costs, and provides lead time advantages to contractors.

Consultations are immediately available for existing and upcoming tunneling projects and Mike Rispin, VP Strata Tunneling, says that with this new partnerships Strata now offers solutions on even more fronts, which further enhances the company's value as a partner to tunnel constructors.

Visit our website for more information or contact us at
info@strataworldwide.com
www.strataworldwide.com/tunneling

Mike Rispin
Vice President, Tunneling
Tel: +1 385 234 1474
mike.rispin@strataworldwide.com

STRATA
WORLDWIDE

Michels Construction, Inc.

Michels Construction, Inc.'s foundations capabilities serve the deep foundation, ground improvement and earth retention requirements of the energy, heavy highway and building trade industries.

As one of North America's largest infrastructure contractors, Michels Construction's design-build capabilities ensure cost effective, engineered solutions for even the most complex deep foundations projects. Look to us for a variety of foundations work including Secant Drop Shafts, Temporary ERS, Augercast Piles, Micropiles, and more. Our in-house professional engineers can design temporary and permanent solutions that are cost effective in any soil condition.

We are conditioned to operating on challenging sites, including urban, high-traffic, low-headroom and off of barges. Our specialized equipment can meet any subsurface and site access conditions.

Safe access is a critical aspect of many underground construction projects. Michels Construction builds and designs shafts to the specific size and depth you need to supply crews, material and equipment to your work area.

Contact us today at 920.583.3132 or visit www.Michels.us.

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Infrastructure. Delivered.

Whether building new or maintaining existing, we enhance North America's infrastructure. It takes strength, adaptability, and the alignment of your goals and ours.

Challenging projects require the dedication and skill of true pioneers.

That's what we deliver.

MICHELS®
CONSTRUCTION, INC.

An Energy & Infrastructure Contractor

www.Michels.us

Gall Zeidler Consultants

Gall Zeidler Consultants is an international engineering consultancy specialized in solutions for tunnel and underground schemes. For over 20 years, we use our wide range of expertise in transportation, infrastructure, water conveyance, and mining projects to help our clients overcome difficult ground conditions and to provide a superior product from its first conceptual phases to its turn-key completion.

Our tunnel and geotechnical engineering services cover all stages of a project:

- Conceptual to Final Design
- Mine Access Tunnels & Shafts
- Program & Construction Management
- Construction Site Support
- Tunnel Inspection & Rehabilitation
- Independent Design Verification Services
- Building Information Modeling (BIM)

With our diverse team of experts and young professionals, we are represented in all major global markets with offices in North America, South America, Europe and Asia.

GZ Gall Zeidler Consultants

ELEVATED THINKING, UNDERGROUND.

We provide award-winning tunnel consultancy and design services for underground schemes around the globe. By taking challenges as a motivation, we are a leader in our field and have successfully completed 300 miles of tunnels worldwide.

GZ Gall Zeidler Consultants
Geotechnics | Tunnel Design | Engineering

Washington DC · London · New York · San Francisco · Toronto
Salzburg · Santiago de Chile · New Delhi · Singapore

www.gzconsultants.com

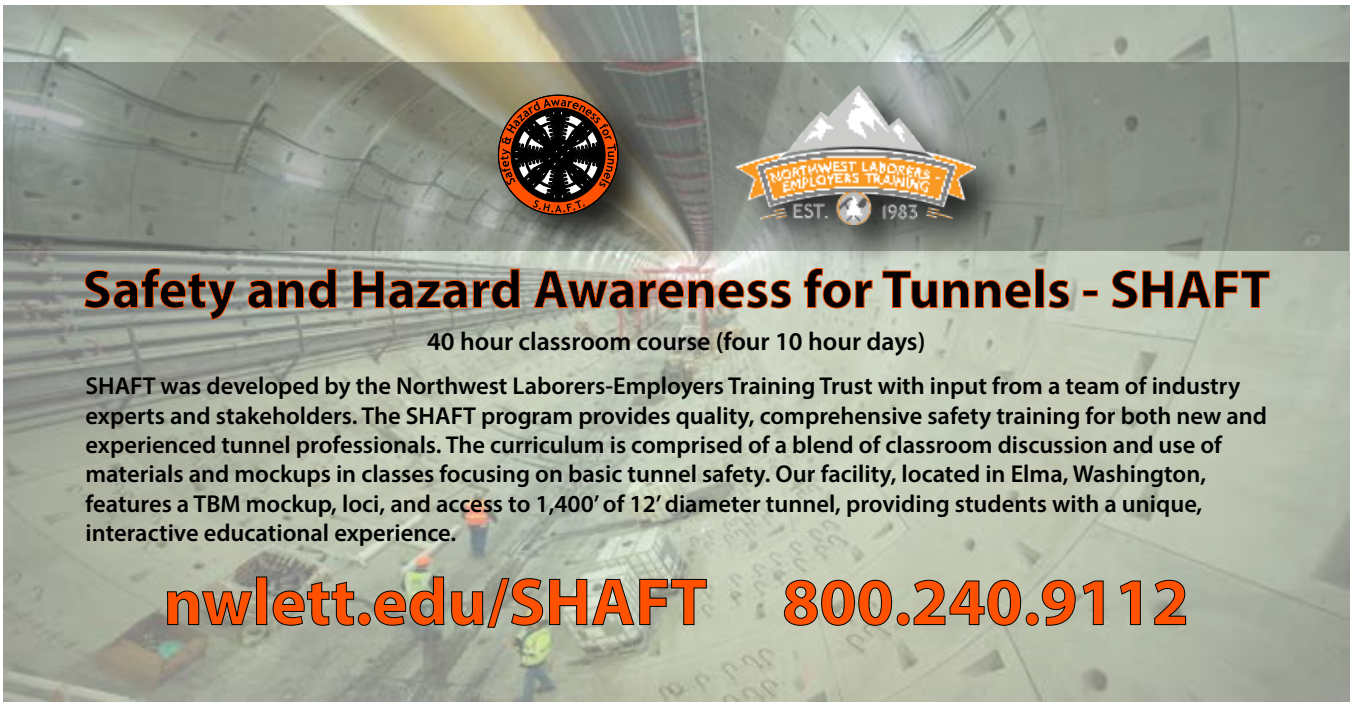
Northwest Laborers-Employers Training Trust – Safety and Hazard Awareness for Tunnels (SHAFT) program

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



McMillen Jacobs Associates

McMillen Jacobs Associates is a multi-disciplined firm, with self-performing design-build capability. We are experts in tunneling and water resources and deploy this expertise to serve water, dams, energy, wastewater, transportation, aquaculture, federal, private, and regulatory clients using a wide range of delivery methods. For 75 years we have worked closely with our clients at every stage of a project, assisting them with planning, permitting, design, project management, construction, and start-up. Our 21 offices in North America and Australasia and more than 400 staff serve clients locally and worldwide.

McMillen Jacobs Associates
Telephone: 800.842.3794
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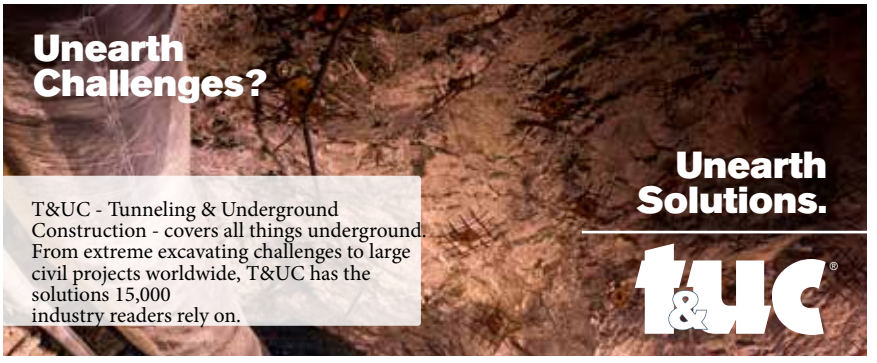
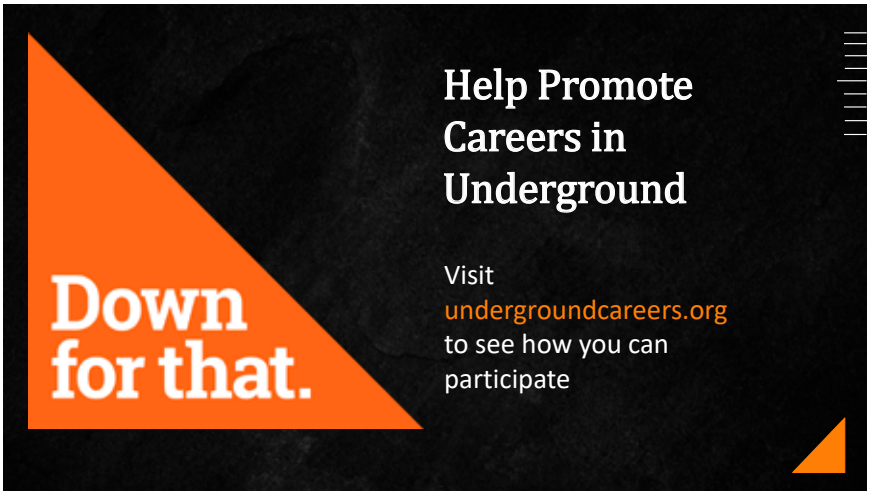
McMILLEN JACOBS ASSOCIATES

Design with Vision, Build with Integrity
www.mcmjac.com





Design with Vision

Build with Integrity

UNDERGROUND ENGINEERING

McMillen Jacobs Associates brings decades of highly technical expertise in engineering, environmental, and construction services to any transportation, water, wastewater, hydropower, and heavy civil project.

McMILLEN JACOBS ASSOCIATES

mcmjac.com

T&UC Tunnel Demand Forecast

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	2023	Under design
2nd Ave. Phase 3-4	NYC-MTA	New York	NY	Subway	89,600	20	2024-29	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
Cross Harbor Freight Tunnel	NYC Reg. Develop. Authority	New York	NY	Rail	25,000	30	2025	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
Silver Line Extension	Boston Transit Authority	Boston	MA	Subway	8,400	22	2024	Under design
Narragansett Bay CSO Phase III - Conveyance Tunnel	Narragansett Bay Commission	Providence	RI	CSO	8,800	10	2024	Under design
Amtrak B&P Tunnel	Amtrak	Baltimore	MD	Rail	40,000	32	2023	Awaiting funding
Ellicott City North Tunnel	Howard County	Ellicott City	MD	CSO	5,800	15	2022	Under design
Potomac River CSO Tunnel	DC Water and Sewer Authority	Washington	DC	CSO	24,000	18	2022	RFQ 1Q 2022
Superconducting Maglev Project - Northeast Corridor	TNEM/BWRR	Washington	DC	Rail	146,520	43	2023	Under design
Alum Creek Relief Tunnel Phase 1 Phase 2	City of Columbus	Columbus	OH	Sewer	30,000 21,000	18 14	2022 2023	Under design Under design
Southerly Storage Tunnel	NEORSD	Cleveland	OH	CSO	18,000	23	2024	Under design
Big Creek Storage	NEORSD	Cleveland	OH	CSO	22.450	18	2026	Under design
Northside Interceptor Tunnel	City of Akron	Akron	OH	CSO	6,850	24	2024	Under design
Enbridge Line 5 Tunnel	Enbridge	Traverse City	MI	Oil	23,760	12	2020	delayed
Minneapolis Central City Parallel Tunnel	City of Minneapolis	Minneapolis	MN	CSO	4,200	10-19	2021	Final planning
ALCOSAN CSO Ohio River Allegheny River Monongahela River	Allegheny Co. Sanitary Authority	Pittsburgh	PA	CSO	10,000 41,700 53,900	14 14 14	2023 2027 2030	Under design Under design Under design

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
Stormwater Control Program	Harris Co. Flood Control District	Houston	TX	CSO	52,800	25-40	2021	Under design
Project Connect Subway Program	City of Austin	Austin	TX	Subway	8,500	20	2023	Under design
Section 19 Long Tunnel Crossing	City of Dallas	Dallas	TX	CSO	12,310	10	2021	Bid date Sept.
D2 Subway - 2nd Light Rail Alignment	Dallas Area Rapid Transit	Dallas	TX	Highway	3,000	22	2020	Under design
Mill Creek Trunk Improvements	City of Nashville	Nashville	TN	CSO	13,800	10	2023	Under design
I-70 Floyd Hill Highway Tunnel	Colorado Dept. of Transportation	Denver	CO	Highway	15,840	60x25	2022	Under design
West Seattle to Ballard Extension	Sound Transit	Seattle	WA	Transit	10,500	18	2024	Under design
LA Metro Speulvada Pass Corridor	Los Angeles MTA	Los Angeles	CA	High/Trans.	55,500	60	2024	LOI received
Folsom Area Storm Water Improvement	SFPUC	San Francisco	CA	CSO	4,000	12	2022	Under design
BART Silicon Valley Phase 2 Tunnel	Santa Clara Valley Transit Authority	San Jose	CA	Subway	26,400	56	2021	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
Yonge St. Extension	Toronto Transit	Toronto	ON	Subway	15,000	18	2022	Under design
Massey Tunnel	City of Toronto	Toronto	ON	CSO	20,000	18	2022	Under design
Inner Harbour West	City of Toronto	Toronto	ON	CSO	18,400	19	2022	Under design
Scarborough Rapid Transit Extension	Toronto Transit Commission	Toronto	ON	Subway	25,000	18	2018	Strabag low bidder
Elington Crosstown West Extension	Toronto Transit Commission	Toronto	ON	Subway	40,000	18	2020	West End Contractors JV awarded
Ontario Line North Extension	Toronto Transit Commission	Toronto	ON	Subway	29,500	20	2022	Under design
Ontario Line South Extension	Toronto Transit Commission	Toronto	ON	Subway	29,500	20	2021	Shortlist announced
Blue Line Extension	Societe de transport de Montreal	Montreal	QC	Subway	19,000	20	2021	Under design
Green Line LRT	City of Calgary	Calgary	AB	Transit	26,250	20	2021	RFQ submitted
Nose Hill Project	City of Calgary	Calgary	AB	CSO	10,800	10	2020	Under design
Annacis Water Supply	City of Vancouver	Vancouver	BC	Water	7,500	15	2021	RFQ requested
Millennium Line Broadway Extenstion	Metro Vancouver	Vancouver	BC	Subway	18,700	18	2020	Acciona/Ghella JV awarded
Eagle Mt. Pipeline	Fortic BC Woodfibre	Vancouver	BC	Oil	29,500	13	2021	Awaiting final award
Stanley Park Water Supply Tunnel	City of Vancouver	Vancouver	BC	Water	5,000	15	2021	Under design

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