t&UC®
Tunneling & Underground Construction
The Official Publication of UCA of SME
www.TUCmagazine.com
Volume 16 NO. 1 March 2022

Tunnel rehabilitation
Technical advances
Cutting Edge recap

All New
Business Profiles
Inside!

Special Editorial Supplement from the publisher of Mining engineering

METRO LOS ANGELES, USA

SUCCESS STORY IN CALIFORNIA WITH 10 TBMS

120 million passengers are travelling through Los Angeles every year. In the past 15 years a total of 10 EPB Shields have been built for more than 35 km of new metro lines. Herrenknecht guarantees the local support with their office in Sumner, WA.

› herrenknecht.com/MetroLA

Client:
- Los Angeles Metropolitan Transportation Authority

Customer:
- Purple Line Section 3 – Frontier-Kemper Constructors, Inc. / Tutor Perini JV
- Purple Line Section 2 – Frontier-Kemper Constructors, Inc.
- Purple Line Section 1 – Skanska / Traylor / J.F. Shea JV
- Regional Connector Transit Corridor - Regional Connector Constructors (Skanska / Traylor JV)
- Crenshaw/LAX Transit Corridor – Walsh / Shea Corridor Constructors
- Gold Line Eastside Extension – Traylor Bros., Inc.

PIONEERING UNDERGROUND TOGETHER

HERRENKNECHT
Tunnelling Systems

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In this issue the rehabilitation of the Tuscarora Tunnel is examined in detail. The current $110 million repair effort seeks to modernize the tunnels, improve safety and extend the structure's design life, see page 12. In Dallas, TX, the tunnel boring machine named Big Tex is boring the Dallas Mill Creek Drainage Relief Tunnel, an 8.4 km (5 mile) tunnel that will provide 100-year flood protection, page 16.

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tucmagazine.com

AN OFFICIAL PUBLICATION OF UCA OF SME | WWW.SMENET.ORG | VOLUME 15 NO. 4 | DECEMBER 2021

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Special editorial section from the publisher of Mining Engineering

Mining engineering

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Bellevue, Washington
Role: Design Services

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Vision

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Who needs to know about tunnels and underground infrastructure?

The short answer is: Everyone. The benefits that tunnels and underground infrastructure bring to people the world over are indisputable. Those of us in the industry know that our solutions in terms of performance, environmental standards and economics are the right ones in a long-term context and that they deliver huge value, whether transportation, water, sewer or other applications. The industry is growing globally at a compound annual growth rate of around 10 percent for a reason … the world needs tunnels and tunnels are a good investment.

This is what the UCA calls stakeholder awareness, one of our three key strategic objectives. And, while the public-at-large is a stakeholder, as referenced in the first paragraph, is it realistic to target our UCA efforts to that group? Probably not. We need instead to focus on the decision-makers who make infrastructural investments – owner organizations, legislators – and get the message to them to help ensure that they have all the facts at their disposal when they make their decisions for or against underground investment. This is a strategic "must do" for our association, and we are focusing a variety of efforts in this regard.

Moussa Wone, of DC Water, one of our executive committee members, has recently taken up the leadership of the Owners' Forum. The intent here is to give focus to the folks who commission the building of, and own and operate tunnels. This focus now extends beyond one meeting a year at a conference and, despite challenging time schedules, moves forward on a variety of fronts. We look to grow participation on this team. Owners: Moussa wants you.

I hope that you took notice in the Dec. 2021 issue of *T&UC* that we have now published a "Tunnel Project Watch List," which highlights 20 active projects and 20 projects needing to be built, to draw attention to what our industry is doing and what, in the near future, our society needs us to do. This UCA program now slots under the auspices of the Owners' Forum, with the intent that the list will be reviewed and published annually. It is a tool to reference and be used with stakeholders.

We have begun discussions around an "educate the owner/legislator" initiative. This is envisaged to be something akin to the "teach the professors" program I referenced in my last column. It is a way to get the right tools and information onto the hands of those who can make a difference. It's understood that it is sometimes difficult for owners to get to our conferences and access content and contacts. So, if we can't get the owners to the conference perhaps we can still get the information from the conference to them. We're looking to build a package of information that can be sent to owners, to give them facts and figures about tunnels, so that they can have a fully formed picture when it comes time to decide. Down the road, we also hope to identify a "task force" of individuals who could travel to owners and be a resource during that period when options are being weighed.

On the subject of legislators, I'd like to share with you a recent anecdote. Dave Klug, of Klug & Associates, a former UCA Chair himself, had a serendipitous meeting at a charity event he sponsors. At dinner, he sat beside a senior staffer of Sen. Joe Manchin (D-WV). She showed great interest in his involvement in underground infrastructure work in the United States. This led to a request for a follow-up visit which he and Jon Klug, a current UCA Executive

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New rating clears way for Hudson Tunnel

The U.S. Federal Transit Administration (FTA) upgraded the long-awaited, planned $10 billion Hudson Tunnels project's rating to medium-high, thus making it eligible to receive federal funding.

The project was given lower ratings during the Trump administration which clashed with the states of New York and New Jersey over the financial commitment of each entity.

Under an understanding reached during the administration of former President Barack Obama, the states had agreed to split half the cost of the tunnel, using federal loans to be paid back over decades, with federal grants accounting for the other half.

Under former President Donald Trump, the FTA said states weren't allowed to use federal loans as part of their funding match to get the federal grants. That policy was rescinded by the administration of current President Joe Bide, the *Associated Press* reported.

Funding for the tunnel will come out of money earmarked for rail projects in the recently passed $1 trillion infrastructure bill.

In a statement, the Gateway Development Commission, which is overseeing the project, said, "Along with the more than $6 billion commitment from New York and New Jersey, and the $1.4 billion that Amtrak has pledged, today's action moves us a big step closer to a true Federal-local partnership that finally brings 21st-century rail infrastructure to the heart of the nation's economy."

The existing tunnel beneath the Hudson River is more than 110 years old and prone to problems and delays due to crumbling walls and aging signals and wiring. Saltwater intrusion from Superstorm Sandy in 2012 accelerated the tunnel's deterioration and forced Amtrak, which owns the tunnel, to embark on costly repairs to keep it functioning reliably.

Hundreds of trains and hundreds of thousands of passengers per day pass through the tunnel during normal times, and delays can ripple up and down the East Coast between Boston and Washington. Once primary construction begins, the new tunnel could take as long as seven years to complete.

Under the Gateway project, the new tunnel would be built parallel to the existing tunnel. Once completed, the existing tunnel would be taken out of service for a complete overhaul, estimated to take as long as two years.

Among other large-scale rail improvements in the region are the replacement of a century-old rail bridge in New Jersey that has been a regular source of delays; tunnels connecting the Long Island Rail Road to Grand Central Terminal, scheduled to open this year; and the transformation and eventual expansion of the aging and unsightly Penn Station in midtown Manhattan.

"As a major component of the Gateway Program, the Hudson Tunnel Project will improve commuter safety, help address the myriad of delays that impact the entire Northeast Corridor, and increase our nation's economic competitiveness," said Sen. Corey Booker. "For years, I have worked with colleagues on both sides of the aisle to ensure this vital infrastructure project gets the federal investment it deserves and am glad to see this announcement from the FTA which will allow construction to commence and create jobs for our state's residents." ■

Los Angeles rail line receives approval

Transportation officials in Los Angeles, CA approved an $8.5 billion, 31-km (19.3-mile) light rail line project that will include 3.7 km (2.3 miles) of underground tunneling. The line will serve largely working-class Latino communities in southeast Los Angeles County, and the officials agreed to look for ways to speed up the project slated for completion in 2043.

The *Los Angeles Times* reported that the line runs from Artesia northwest to Union Station, cutting through the cities of Cerritos, Bellflower, Paramount, Downey, South Gate, Cudahy, Bell, Huntington Park and Vernon. It would provide key connections to other lines, helping build out a rail system decades in the making.

The costs of the project is $8.5 billion and is more than double the original estimate. The Metropolitan Transportation Authority decided to construct the project in two segments.

Local leaders have complained about the long wait for rail service.

The rail line was part of Los Angeles Mayor Eric Garcetti's plan to build 28 transit projects by the 2028 Olympics.

The first 23.8-km (14.8-mile) phase runs from Artesia along a former Pacific Electric right of way to Slauson Avenue and Long Beach Boulevard, where it would connect with the A (formerly Blue) line. Groundbreaking for the $4.9-billion phase is slated for next year and completion about 10 years later.

The second phase heads north 7.2 km (4.5 miles) from the Slauson depot to Union Station and is set to be completed by 2043. About half of the line is planned to run underground through Little Tokyo, where Metro construction disrupted businesses for years and tunneling is driving up costs.

The Metro board unanimously approved a plan that will look at cheaper alternatives to tunneling that could accelerate construction for the second phase. In an hours-long public comment period, dozens of elected officials representing the communities along the rail line pleaded with the board to speed up

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Aecon awarded contract for Annacis project

Aecon Group Inc. announced that Traylor-Aecon General Partnership, a consortium comprised of Aecon (40 percent) and Traylor Bros Inc. (60 percent) has been awarded a $288 million contract by Metro Vancouver (Greater Vancouver Water District) for the Annacis Water Supply Tunnel, Fraser River Crossing project in British Columbia. Aecon's share of the contract will be added to its construction segment backlog in the first quarter of 2022.

The scope of work includes the construction of two deep vertical shafts, one on each side of the Fraser River, connected by a 2,350-m (7,710-ft) tunnel between New Westminster and Surrey, as well as the installation of a watermain, valve chambers and surface piping. Construction is expected to commence in the first quarter of 2022, with anticipated completion in the second quarter of 2027.

"This complex, multi-year project further strengthens our diverse backlog in Western Canada and demonstrates our position as the partner-of-choice in the civil construction market for tunnelling and water infrastructure projects," said Jean-Louis Servranckx, president and chief executive officer, Aecon Group Inc. "This project will ensure the sustainable, reliable supply of clean drinking water for growing communities. As we continue to execute the Second Narrows Water Supply Tunnel project with Traylor, we are pleased to strengthen our partnership and further our relationship with Metro Vancouver."

The tunnel will be one of five new water supply tunnel crossings in the region built to withstand a major earthquake. Once complete, the new tunnel will be connected to the region's drinking water system and will help ensure the continued, reliable delivery of clean, safe drinking water in a growing region. ■

LA rail line

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the timeline.

The rail line was a cornerstone of Measure M, a $120-billion half-cent sales tax approved by voters in 2016, which gained widespread support among elected officials in the region. Along with Measure R, approved in 2008, the tax fueled a rail construction boom.

Metro plans to tap $3.1 billion in federal funds and an additional $850 million in state funds for the first leg of the rail line.■

THE CITY OF
COLUMBUS
ANDREW J. GINTHER, MAYOR

DEPARTMENT OF
PUBLIC UTILITIES

LEGAL NOTICE

Capital Improvements Project No. 650033-100002
BIG WALNUT SANITARY TRUNK EXTENSION, PHASE 2

SCOPE: The project consists of the construction of approximately 12,350 linear feet of 72-inch diameter sanitary sewer (fiberglass reinforced polymer mortar) via an open face tunnel boring machine through shale rock, full face conditions. Construction also includes two (2) shafts to be constructed using secant piles; two (2) intermediate shafts and two (2) hydraulic drop structures to be constructed by drilling. The project will include ancillary work at the shaft sites as shown on the detailed drawings, as specified in the contract specifications, and the City of Columbus Construction and Material Specifications as set forth in this Invitation For Bid (IFB).

BID OPENING: Bids will only be received electronically by the Department of Public Utilities of the City of Columbus, Ohio, via Bid Express (www.bidexpress.com). No public bid openings will be held pursuant to Columbus City Code Chapter 3219.18.

PROCUREMENT OF DOCUMENTS: Bidding Documents, including the Invitation for Bid, Drawings, and Technical Specifications will be available as separate documents at Bid Express (www.bidexpress.com) in March 2022.

CLASSIFICATION: This project has been selected for financial assistance from the Ohio EPA's Water Pollution Control Loan Fund (WPCLF) Program. For this reason, Federal Davis-Bacon Wage Rates and Requirements will apply. A ten percent (10%) proposal guarantee is required for this bid, and a one hundred percent (100%) performance and payment bond will be required for the making of a contract.

PREQUALIFICATION REQUIREMENTS: Pursuant to Columbus City Code Section 329.20(c), the bidder must demonstrate that it has satisfied the City's construction pre-qualification requirements. Contact the Pre-Qualification Office at (614) 645-0359 or http:/www.columbus.gov/prequalification.aspx if you are unsure about your construction pre-qualification status.

For additional information concerning this bid, including procedures for obtaining a copy of the bidding documents and how to submit a proposal, you must go to the City of Columbus Vendor Services web page (http://vendors.columbus.gov/sites/public), and view this bid number in the "Open Requests for Quotations" listing.

Two TBMs arrive at London's HS2 project

The first two Earth pressure balance tunnel boring machines (TBM) arrived on site for the HS2 London Tunnel program. The Herrenknecht TBMs were delivered to HS2's Main Work's Civils Contractor, Skanska Costain STRABAG joint venture (SCS JV).

The start of tunneling works is expected to begin in 2022.

The two machines will be the first of six TBMs that will bore 21 km (13 miles) of twin bored tunnels underneath London where HS2 services will run. They will join eight other machines that will operate on Phase One of the HS2 project between London and the West Midlands, which will dig 103 km (64 miles) of tunnels in total.

Getting the huge pieces of the TBM to site required a huge amount of logistical coordination, with support from the police and National Highways. The largest components of the machines were transported by road from Essex ports on vehicles that could support the extra wide loads," HS2 reported.

"The HS2 team at West Ruislip have been preparing the site for over two years to ensure it is ready to launch the first two London TBMs in 2022. This will be an exciting step as we begin our four-year program of tunneling under London, showcasing the best of British engineering, and building Britain's newest low carbon transport network."

The two machines have been designed specifically to bore predominantly through Lambeth group (a set of geological rock strata), chalk and London clay, and are automated to install 4,220 tunnel segment rings each, to create each 8 km (5 mile) tunnel.

Around 15 people at a time will operate on each TBM working in shifts, keeping the machines working around the clock for two years, only stopping at Christmas and Easter. A team of approximately 40 people are working to assemble the TBMs, preparing for the launch in 2022.

"Delivering these huge TBMs to West Ruislip was an enormous logistical challenge involving 260 deliveries, including 110 abnormal loads," said James Richardson, Managing Director of Skanska Costain STRABAG joint venture. "Our team worked tirelessly to deliver these items efficiently, whilst minimizing disruption to our neighbors. All eyes will be on West Ruislip in 2022 as we start to build the London tunnels, reaching depths of 30 m (90 ft) below ground."

As the date for tunneling to begin draws closer, HS2 will be seeking to name each TBM and has already begun that process, working with local schools in Hillingdon where the TBMs will be launched. In early 2022, a shortlisted set of names will be put to a public vote, to help chose the names for HS2's fourth and fifth TBM, after Florence, Cecilia and Dorothy who have already started their journeys underground. ■

Crossover TBM holes through in Chile

A Robbins 4.6 m (15.1 ft) diameter crossover tunnel boring machine (TBM) holed through in the Andes Mountains of Chile in the last quarter of 2021. The XRE TBM bored a 3.3 km (2.1 mi) long tunnel for Chile's Los Condores Hydroelectric Power Project (HEPP) and project owner Enel.

A dedicated team guided the machine to breakthrough in conditions including tuff, sandstone, breccia and conglomerate with sections of high-pressure water inflows. Ground cover reached up to nearly 450 m (1,500 ft) above the tunnel with rock strengths maxing out at 60 MPa UCS.

"Robbins Field Service was an important part of the success of the excavation, evaluating continuous improvements in the machine and correcting faults," said Ricardo Riveros Puratic, project engineer for Enel.

For Riveros Puratic, crossover machines make sense despite the challenging conditions: "Toward the end, [the TBM] exceeded expectations. Crossover TBMs are suitable for Andean geology of sedimentary and volcanic type, where there is a great range of rock strengths and hydrogeological conditions." Maximum advance rates topped out at 605.8 m (1,988 ft) in one month and 212.8 m (698.2 ft) in one week.

The crossover machine featured a heavy duty, centrally mounted screw conveyor for the duration of the drive. The TBM remained in a hard rock configuration with muck chute installed, along with paddles, bucket lips, scrapers and disc cutters on the cutterhead. However, "75 percent of the excavation was performed using the main drive gearboxes in high torque configuration (EPB or low speed mode). We never physically changed the cutterhead or screw conveyor to EPB mode," said Omar Alvarez, Robbins field service site manager at Los Condores.

High-pressure groundwater inflows were the key challenge of the project. "When we started the excavation, we used dewatering hoses to reduce the water into the cutterhead during the excavation," said Alvarez. Water pressures rose whenever the TBM stopped, however. "During the segment ring installation, we stopped the water from draining through the rear shield drilling ports and we closed the screw conveyor rear gate. We reached 7+ bar in the cutterhead earth sensors."

"We bored in places with 5,500+ l (1,500 gal) /min, making back-fill grout injection behind the concrete

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Chair's Column: Growing the workforce

(continued from page 4)

Committe member, undertook, during which they presented, two copies of the History of Tunneling in the U.S. (provided by the UCA) one for the home office and one for the federal office in DC. Now, this was a personal effort which resulted in an industry connection being created with a legislator. Wouldn't it be wonderful if this could be replicated with every legislator? Granted, that is an ambitious vision. However, if we are systematic about it, perhaps it is something that we can build toward.

So, the owners' forum is now discussing an initiative that, at least for the time being, we are calling "50 State Reps." The idea is to identify at least one individual in a jurisdiction who can become a go-to underground construction resource in-state. At the start, states with vigorous tunneling activity will be a priority … and we can build from there. From a starting point, we can progress from passive to assertive. The more we can get the right information and expertise about underground construction into the hands and minds of the decision-makers, the better off the future state (no pun intended … well, maybe a little) can be.

This spring, we will resume our Legislative Fly-In program in conjunction with ASCE. Ten UCA members will attend either in person or virtually for this opportunity which has been conducted very successfully in the past. Hopefully you saw the call for volunteers and, if you were interested and motivated, you got on the slate.

Other discussions are gestating with respect to how the UCA may make an impact in the arena of government and public affairs. Our country's decision-makers deserve to know as much as they can about tunnels and underground construction and their beneficial impacts to society, so they can make the right long-term decisions which impact a legacy upon their jurisdictions, whether federal, state or municipal. Please stay tuned, and …

Tunnel on!

Michael Rispin,
UCA Chair

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Get the most out of your Underground Construction Association (UCA) membership by volunteering. While volunteering helps UCA, it also benefits you as a volunteer:

- Get to know other UCA members as you build your professional network.
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- Give back to the underground construction community through UCA's programs and services.

Learn about UCA committees, volunteer opportunities and submit a volunteer interest form at: **smenet.org/uca/volunteer-portal**

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George A. Fox Conference moves to Spring date

The George A Fox Conference, has been rescheduled for May 10, 2022.

The conference with a 21-year tradition in the tunneling and underground construction industry, was scheduled to return to New York City on Jan. 19, however the rapid spread of COVID-19 due to the Omicron variant forced the change in plans. For those who have already registered, your registration will be transferred to May 10. If you have scheduling conflicts with the new date, simply contact SME customer service at 303-948-4200, or by email at cs@smenet.org.

For those who attend the conference in May, they can expect the same high-quality programming. The one-day conference will include project updates, strategies for overcoming challenges and discussions about critical industry issues including workforce challenges and diversity and inclusion. It is also an opportunity for attendees to reconnect with colleagues.

Robert Palermo from GZA is the chair of the 2022 conference. He and the Fox Conference committee has established a fantastic technical agenda that includes a keynote presentation from Nuria Fernandez, Administrator from the U.S. Federal Transit Administration (FTA). Fernandez was confirmed by the U.S. Senate as the 15th Administrator of FTA. She was previously Deputy Administrator and senior FTA official. With more than 35 years of experience, Fernandez made a name for herself as an inspiring leader in the transportation industry. She came to FTA after serving as general manager and CEO of the Santa Clara Valley Transportation Authority (VTA).

Among the highlights of her tenure at VTA was the completion of the first Bay Area Rapid Transit (BART) heavy rail service into Silicon Valley, a 10-mile, $3 billion line that opened to passenger service in June 2020. She also received federal approval in 2018 to extend the heavy rail service for another 10 km (6 miles).

Fernandez is also responsible for the creation of VTA's Innovation Center, an incubator to encourage collaboration, test the latest technology, and imagine new ways to keep the valley moving forward by leveraging the expertise of Silicon Valley's high-tech corporations and universities.

"We are very excited for her to speak at the conference," said Palermo. "We feel this is a good way to develop a stronger relationship with the FTA and our members so that both sides and better understand each other. I think both sides, government and industry, will be able to learn a lot from each other."

The conference will also include the always popular industry update in which projects around the world are discussed as well as two very interesting historical presentations. Angus Gillespie, professor at Rutgers University will speak about the Holland and Lincoln Tunnels and how they were built to cross under the Hudson River and Ed Plotkin will give a history of the conference and a tribute to George Fox. George A. Fox, a leading figure in the construction of Third Water Tunnel in New York. Fox was a civil-engineer who devoted his career to the design and management of major construction projects, including roads, bridges and tunnels. His largest, undertaken by his company in the mid-1970's, was the construction of a 60-mile water tunnel hundreds of feet beneath the city. A brief history about Fox can be found here (https://www.georgefoxconference.org/index.cfm/why-attend/overview/)

And a full schedule of events can be found here (https://www.georgefoxconference.org/index.cfm/conference/agenda/schedule/)

The in-person conference will be held at the Hilton New York and will adhere to all local and state COVID protocols including proof of vaccination and wearing a mask when in a public setting. ■

Coming Events

George A. Fox Conference
May 10
New York Hilton Midtown,
New York, NY

NAT2022
NORTH AMERICAN TUNNELING CONFERENCE
June 19-22, 2022
Philadelphia, PA

More information: Meetings Department, SME, phone 800-763-3132, 303-948-4200, fax 303-979-4361, email sme@smenet.org

Sydney Airport Metro tunneling contract awarded

Sydney Metro has awarded a $A1.8 billion contract to CPB Contractors and Ghella Joint Venture to excavate 9.8 km (6.1 miles) of dual-bore tunnel as part of the Western Sydney Airport project.

The driverless 23-km (14.2 mile) metro line will link St Marys to the center of the new Aerotropolis via the new Western Sydney International (Nancy-Bird Walton) Airport, with six stations to be built along the alignment.

The contract is split in two sections: the 4.3-km (2.6-mile) northern tunnels run from St Marys to Orchard Hills; and the 5.5-km (3.4-mile) southern section of tunnels runs between the Airport Business Park and the Aerotropolis Station.

The Station Boxes and Tunnelling contract includes: 9.8 km (6.1 miles) of twin rail tunnels in two sections. The 4.3-km (2.6-miles) northern tunnels run from St Marys to Orchard Hills and the 5.5-km (3.4-mile) southern section of tunnels runs between the Airport Business Park and the Aerotropolis Station as well as excavation and civil works for new stations at St Marys, Orchard Hills, Western Sydney International (Nancy-Bird Walton) Airport, and Aerotropolis;. Four hard rock tunnel boring machines (TBM) will build one of the two temporary precast concrete factories for the project on the Western Sydney International site. The project will include more than 67,000 concrete segments to line the twin tunnels and two TBM launch sites at Orchard Hills and Western Sydney International and two TBM retrieval sites at St Marys and Aerotropolis Station.

The first of four TBMs will be in the ground by early 2023 under the terms of the contract. Tunneling is scheduled for completion by late 2024 when fit out will commence. ■

Robbins: Los Condores project

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segments a challenge. We decided not to use the grout injection through the tail shield ports, but instead injected grout directly through the concrete segment with hoses. This approach was more flexible and reduced the need for reinjections," said Alvarez.

Once brought online, the Los Condores HEPP, located in the mountainous southern Maule region, will have an annual generating capacity of 150 MW. ■

Rehabilitation of the Tuscarora Tunnel

Repairs are underway at Pennsylvania Turnpike's Tuscarora Mountain Tunnels between the Fort Littleton interchange (Exit 180) and the Willow Hill interchange (Exit 189).

The construction of the eastbound tunnel began in the 1800s for railroad use, but it was never finished. The area was converted to roadway use as part of the original Pennsylvania turnpike construction started in 1940. The westbound tunnel, completed in 1968, increased the flow of traffic along the Pennsylvania Turnpike.

Typical deterioration has resulted in both tunnels experiencing water intrusion. Due to its advanced age and the construction technology available at the time, the eastbound tunnel has more significant systemic leakage throughout the structure than the westbound. The westbound tunnel has less systemic leakage, but locations of significant water leakage are still present, particularly at construction joints.

The current $110 million repair effort seeks to modernize the tunnels, improve safety and extend the structure's design life. Once nicknamed "Lake Tuscarora" because of the degree of water infiltration, the tunnels will be repaired by multiple methods addressing the different leak regimes.

The westbound tunnel will have drainage installed at each construction joint and all water-bearing cracks will be repaired. An umbrella system to convey water into the tunnels' existing drainage systems will be used in the eastbound tunnel.

This article focuses on the eastbound tunnel repairs as they represent the majority of the repair effort.

Design summary

Installation of the umbrella system in the eastbound tunnel will extend the lifetime of the tunnel by 100 years while also significantly reducing the amount of maintenance required. Given the systemic nature of the water infiltration in the tunnel, the repair of each leak individually would lead to chasing leaks throughout the structure. Therefore, a more systemwide solution was chosen.

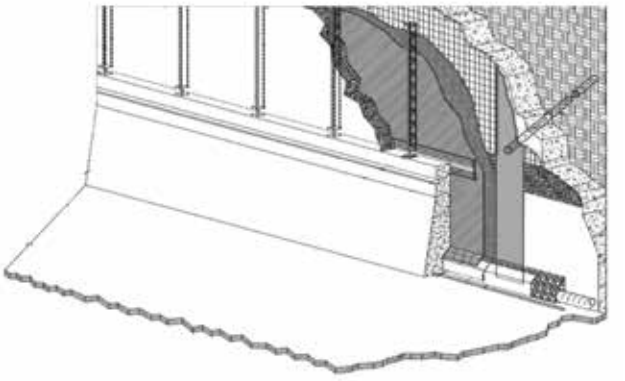
In this method, water is captured by a waterproofing membrane and conveyed to the structure's existing drainage system. This eliminates maintenance costs that would occur if more work would be needed to plug new leaks. With this design, only occasional standard maintenance is needed to ensure the drainpipes are flowing properly.

Thomas Martin, Thomas Leckrone and James Stump

Thomas Martin, member UCA, is tunnel engineer, GZ Consultants, Thomas Leckrone is bridge department manager, Gannett Fleming, and James Stump is assistant chief engineer, design, Pennsylvania Turnpike, email office@gzconsultants.com.

FIG. 1

Typical drainage system isometric view.



The Pennsylvania Turnpike Commission (PTC) tasked Gannett Fleming and subcontractor Gall Zeidler Consultants with developing a design for long-term remediation, with the goal of relieving PTC from excess maintenance costs and extending the life of the tunnel structures.

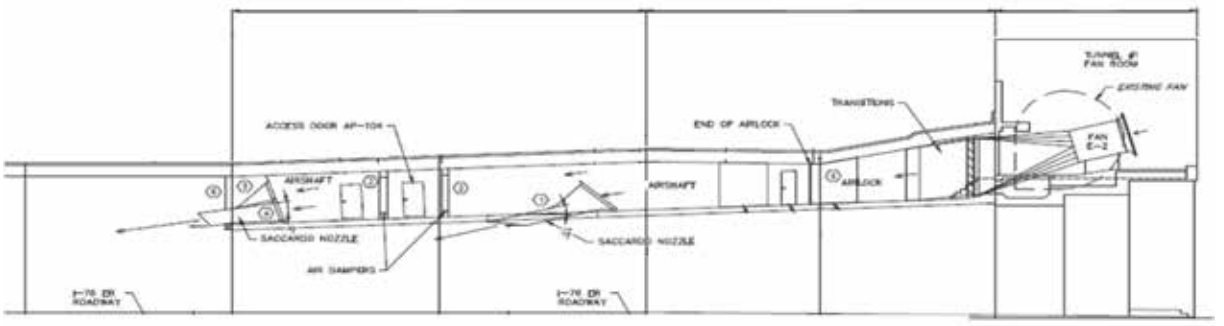
Therefore, the Tuscarora Tunnel rehabilitation design was developed with the idea that a tunnel with systemic, structure-wide leakage could not be successfully rehabilitated by treating individual leaks. Rather, the structure should be treated wholly by understanding the leakage regime, geology, hydrogeology and maintenance history.

After reviewing these factors, an umbrella system was chosen as the best option to accomplish the goals for the eastbound tunnel. The umbrella system consists of installing a polyvinyl chloride (PVC) waterproofing system on the walls and ceiling of the tunnel. The waterproofing system includes a PVC waterproofing membrane with remediation hoses and PVC water barriers. This system is more resilient than a PVC membrane alone, as it isolates any potential leaks, increasing the ease and effectiveness of a repair. In the event of leakage, the water barriers prevent the PTC from having to chase leaks.

The membrane is welded to a drainage angle installed at the roadway surface, allowing the water to flow through a newly installed porous concrete block

FIG. 2

Tunnel 1 East portal section B-B.



into a slotted drainage pipe. This pipe then follows the existing slope of the roadway and is eventually routed to the existing tunnel drainage. New concrete barriers and a self-supporting reinforced shotcrete liner will protect the membrane.

The installation of the umbrella system requires the removal of the tunnel plenum ceiling. Since the existing ventilation design, which requires a plenum the length of the tunnel, would no longer be possible, an alternate design was developed using a Saccardo nozzle, which is a system that introduces a strong jet of air flow into a tunnel from an existing fan room.

To implement this system, the ceiling remained in place for a short portion at each end of the tunnel. Fans and ductwork were designed that would direct the air as needed to create the desired effect. This design decision allowed for the work to progress on the umbrella system.

Given the intricate nature of parts of the design, significant detail was put into the design documents. An embedded channel was designed to support tunnel lighting directly from the lattice girders prior to the shotcrete gaining full strength, and to eliminate the need for hundreds of anchors.

Mounting eyelets were precisely shown on the lattice girder geometry details for easy mounting of the embedded channels. The construction sequencing challenges were also addressed, with membrane protection details developed for lapping lengths that had to be exposed for months given the construction schedule.

Tunnel specific details were also developed for the sectioning, terminations and transitions in the portal sections.

Construction sequencing

Unlike metropolitan tunnels, the Turnpike's tunnels have traffic peaks on the weekends, and thus construction is limited to weekdays only. Due to the nature of the repairs in the eastbound tunnel, the entire tunnel needed to be closed to ensure safe and efficient working conditions. As a result, traffic in both directions was reduced to one-lane in the westbound tunnel during weekdays. Based on the challenges posed by the eastbound tunnel needing to be open every weekend, it was critical that construction sequencing be well thought out to avoid delays and lessen any impacts to scheduling.

The preliminary step was to demolish the existing tunnel ceiling and sidewall barriers. After the barriers had been demolished, the new drainage system was installed at the base of the walls. Waterproofing was installed over the new drainage system and up to a height of approximately 2.4 m (8 ft). New barriers were then constructed over the waterproofing, measuring

FIG. 3

Eastbound tunnel rehabilitation: Membrane and lattice girder installation.

FIG. 4

New barrier and shotcrete liner over drainage system.

1.5 m (5 ft) high. Metal flashing was installed over the final 1 m (3 ft) to protect the waterproofing, which was not covered by the new barriers. The new barriers were installed on each side of the tunnel prior to moving on to the next phase of construction.

Once the new barriers were in place, the waterproofing membrane was installed radially from barrier to barrier in 9 m (30 ft) panel sections. Following the membrane installation, lattice girders were installed along with the welded wire mesh. Embedded lighting channels were also installed on the lattice girders to allow for easy light installation without installing anchors. A 20 cm (8 in.) shotcrete liner was then installed in 10 cm (4 in.) lifts. This process is currently being completed panel by panel for all 180 panels in the eastbound Tuscarora tunnel.

While it was originally assumed that this phase of work would occur with panels being completed consecutively, that was not ultimately the case. To lessen the impact of waterproofing reinforcement installation and shotcrete operations on each other, the contractor had its crews working at spaced out locations along the tunnel.

Innovations and challenges

Innovations in sequencing: Originally, only limited sections (lapping length of under 0.6 m (2ft) of the waterproofing membrane were to be exposed leading into the weekend of the tunnel opening. However, it was determined that this requirement would make construction difficult, especially on the proposed schedule. The PTC permitted the contractor to leave exposed waterproofing in the eastbound tunnel to ease schedule concerns.

FIG. 5

Shotcrete liner installation over welded-wire mesh in tunnel.

Before shotcrete and the lattice girders are installed, the membrane is carefully inspected for damage. If there is damage that has occurred to the membrane, the area is repaired prior to the work continuing.

In addition to opening every weekend, there had to be contingencies for the tunnel to open as soon as possible for weather or traffic emergencies. If an accident or blockage occurs in the primary transit tunnel, the contractor must be ready to quickly move out of the worksite to allow traffic to flow through the tunnel.

This means that all equipment and supplies must be mobile and ready to clear out of the tunnel within defined time periods set in the contract. Additionally, a minimum shotcrete liner strength is specified prior to opening the tunnel to traffic. It is a cardinal project

goal from the PTC that there is as little inconvenience to drivers as possible.

Optimizing shotcrete means and methods: When construction began, the contractor proposed several alternates to the shotcrete liner installation shown in the design drawings. The design drawing prescribed two 10 cm (4 in.) lifts in both the vertical and overhead applications. The contractor requested that instead of spraying shotcrete through one layer of mesh in 10 cm (4 in.) lifts on the walls, they spray through two layers of mesh in 20-cm (8-in.) lifts on the walls.

After a proof of concept during the construction mock-up phase of the work, it was determined that the contractor could safely spray through two layers of mesh in a 20-cm (8-in.) lift on the walls of the tunnel. With this improvement, additional float was allowed during the weekly construction schedule. This in turn allowed for work to proceed more efficiently without compromising worker safety.

Embedded channels: One major challenge faced during the design phase was how to install lights without having anchors in the new shotcrete liner. A solution was devised to use lattice girders with eyelets to which embedded channels could be affixed. These channels were installed after the first shotcrete lift was sprayed.

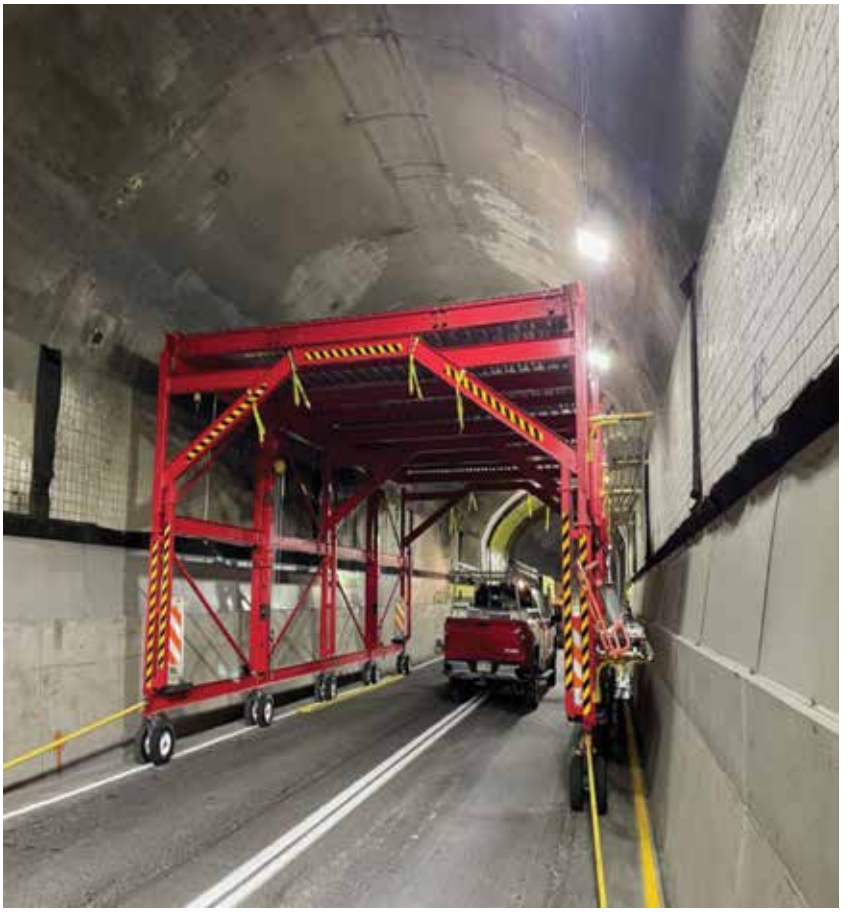
Since the tunnel lights have two points of attachment, two embedded channels had to be installed in parallel wherever lights were planned for installation. The contractor developed an innovative solution whereby the embedded channels were preconnected in parallel with curved steel supports. This allowed for two embedded channels to be connected to the lattice girders as one unit, resulting in easier installation of the embedded channels.

Waterproofing installation means and methods: When the project first began, the waterproofing membrane installation was set by manlifts that raised the membrane into place. This process was tedious as only two manlifts could be operating in one panel at the same time. Additional coordination was required for vehicles or personnel to safely pass under the manlifts while they were in operation.

Custom scaffolding was ordered to allow an entire panel to be scaffolded while vehicles and personnel could pass underneath. This helped to alleviate worksite congestion and make construction more efficient. The scaffolding was determined to be much safer to use than the manlifts in the tunnel, as the scaffoldings' fixed structure reduces potential hazards inherent with high variable lifts.

FIG. 6

Mobile custom scaffolding used to install waterproofing membrane.



Conclusion

The PTC set out to bring the Tuscarora Tunnels to current design standards and address the leak infiltration problems that had plagued the structures for years. The design team reviewed the existing conditions, evaluated possible remediation options and after consultation with PTC, chose the remediation option that most completely remedied the tunnels going forward.

Collaboration with the contractor before and during construction has allowed this design to come to life more efficiently, meeting an ambitious design schedule and goals while maintaining quality workmanship. With the state-of-the-art umbrella system, the lifespan of the Turnpike tunnels will be extended, and anyone transiting the tunnels will take notice of the effort that has been put into improving these structures. ■

Utilizing the TBM, Big Tex for the Dallas Mill Creek drainage relief tunnel

The Dallas Mill Creek Drainage Relief Tunnel is an 8.4 km (5 mile) tunnel that will provide 100-year flood protection for impacted neighborhoods in the east Dallas area. "Big Tex" is a main beam gripper tunnel boring machine (TBM) capable of changing diameters in mid-tunnel to excavate 2.83 km (9,290 ft) of 11.45 m (37.58 ft) diameter tunnel and 5.21 km (17,095 LF) of 9.93 m (32.58 ft) diameter tunnel. Construction began in April 2018 and is anticipated to be completed in 2024. This article will discuss the challenges and lessons learned during assembly, reassembly, start-up and mining with Big Tex.

FIG. 1

Dallas Mill Creek drainage tunnel alignment.

History and background

The city of Dallas has a long history of severe flooding over the years that has resulted in property damage, injuries and even deaths. Efforts to mitigate the flooding included a series of levees built by the U.S. Army Corps of Engineers in the early 1900s along the Trinity River that evolved into what is today the Dallas floodway.

A 1995 flooding event, caused by a series of heavy rainstorms throughout the Dallas metro area, overwhelmed the storm drains and box culverts installed in the 1930s and 1940s and flooded streets in some areas with up to 3 m (10 feet) of water. This devastating event resulted in the deaths of 15 people, injuries to more than 100 people, and severe damage to hundreds of homes and businesses, including flooding the emergency room of a major hospital in Dallas, Baylor University Medical Center.

Paul J. Smith, J. Milton Brooks, Quan D. Tran and Eudomar A. Silva

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Subsequent severe storm events in 2006 and 2007 accelerated the level of planning and design for flood relief using stormwater diversion and conveyance to the Trinity River. The city looked at the drainage areas most impacted by severe flooding and selected the Mill Creek, Peaks Branch, East Peaks Branch, and State Thomas drainage areas for stormwater flood mitigation.

The city and design engineer assigned to the project collaborated to develop and evaluate separate conceptual designs for three of the four drainage areas, but construction costs, environmental impacts, the inconvenience of expected large cut and cover trench construction, various detours and multiple road closures resulted in combining the three separate drainage designs and the State Thomas drainage area into a deep drainage tunnel discharging into White Rock Creek.

After completion of a detailed boring program, the final design resulted in the 8.4 km (5 miles) long Dallas Mill Creek Drainage Relief Tunnel as shown (Fig. 1).

The project

After more than 10 years of planning and design, the Dallas Mill Creek Drainage Relief Tunnel project was finally let out for bid in September 2015 followed by bid openings in December 2015. However, the decision was made to reject all bids due to bid irregularities, revise the plans, revise the bidding process and rebid the project. The city also replaced the construction management firm. The city, design engineer and new construction management firm revised the bid

documents and advertised the project in July 2017. The city successfully awarded the Dallas Mill Creek Drainage Relief Tunnel Project to Southland Mole JV (SMJV) in February 2018 and awarded notice to proceed in March 2018.

Outfall shaft site

The outfall shaft is the design discharge point of the Dallas Mill Creek Drainage Tunnel and will be the main working shaft during construction of the tunnel. The outfall shaft site is located at the end of Barber Avenue on property purchased by the City of Dallas (Fig. 2).

Large diameter tunnel and shaft projects typically require large work sites because of the lay down areas required for specialty equipment and to enable room for operations facilities as well as tunnel muck stockpiles and muck handling areas.

To secure the land required for the project, the city purchased as many properties located along Barber Avenue as possible, but not all residents accepted purchase offers. In anticipation of multiple truck loads 12-hours a day on Barber Avenue, the city and design engineer added Barber Avenue street improvements, including utilities and new pavement to the contract.

Challenging muck limitations and handling

SMJV realized the limited size and location of the outfall shaft site would impact TBM production because of muck storage limitations and muck handling and hauling restrictions from 7 a.m. to 7 p.m. due to noise ordinances on city streets.

SMJV proposed changing the location of the muck shaft operation from Site O to a location across Scyene Road (state route 352) approximately 594 m (1,950 ft) up station from the outfall shaft. SMJV negotiated a land use agreement with the property owner of the muck shaft site that resulted in a win-win situation for the city's residential neighborhood along Barber Avenue and Dixon Avenue, and for SMJV, as it would allow SMJV to mine and haul tunnel muck

FIG. 2

Outfall shaft site.

FIGS. 3

Robbins 11.5 m TBM "Big Tex" assembled on the surface.

TABLE 1

Tunnel muck handling, 24 hour and 12 hour.

Item	TBM tunnel reach (metric)		TBM tunnel reach (U.S)	
	Reach	Reach 2	Reach 1	Reach 2
Station	010+71	100+90	010+71	100+90
Station	100+90	271+85	100+90	271+85
Length (L)	2,750	5,212	9,019	17,095
Diameter (L)	11.46	9.93	37.58	32.58
Area (L^2)	103	78	41	31
Volume (L^3/L)	103	78	41	31
Avg. Prod (L/day)	24	24	80	80
Volume (L^3/day) 60% swell	4,024	3,025	5,259	3,953
Truck loads (L^3) 24 hr	268	202	263	198
Volume (L^3/12 hr) 60% swell	2,012	1,512	2,630	1,977
Truck loads (L^3) 12 hr	134	101	131	99

FIG. 4

TBM trailing gantry assembly on rail and slab.

24-hours per day.

The proposed change would eliminate heavy truck traffic on residential streets and allowed for hauling muck 24-hours a day, six days a week on a state highway (Table 1).

The Dallas Mill Creek Drainage Relief Tunnel was designed with two different cross-sections to handle peak flows of 424.7 m^3/sec (15,000 cu ft/sec) through the upper reach and 566.3 m^3/sec (20,000 cu ft/sec) through the lower reach.

FIG. 5

Lowering rear main beam section with grippers and gripper carrier.

The upper reach is a 9.1 m (30 ft) finished dimeter circular tunnel 5,212 m (17,095 ft) long and the lower reach is a 9.1 m × 10.8 m (30 ft × 35.5 ft) finished horseshoe tunnel 2,750 m (9,019 ft) long.

It was thought that the contractor would excavate the complete tunnel with a TBM from the outfall shaft to the Woodall Rodgers intake shaft and then complete the horseshoe tunnel bottom excavation by roadheader or excavator. The horseshoe tunnel liner would require additional concrete forms and multiple diameter placements that would result in increased costs and increased schedule.

TBM assembly and TBM launch

The Robbins Co. (TRC) and SMJV elected to assemble the TBM onsite using TRC's patented onsite first-time assembly delivery method.

- Deliver TBM components and assemble the TBM onsite (Fig. 3).
- Commission, startup and test various systems. Provide "factory" test reports.
- Reassemble the TBM in the starter tunnel, complete final testing and provide final factory test reports.

SMJV installed a reinforced concrete slab system to assist TRC with the TBM onsite assembly and trailing gear on. The 1,133 t (1,115 st) TBM (cutterhead, cutterhead support, main bearing, mainframe, finger shields, grippers, gripper carrier, gripper feet, etc.) was assembled on a 0.61 m (2 ft) thick 31 MPa (4,500 psi) concrete slab with a double mat of reinforcement.

The four trailing gantries were fully assembled on a 0.3 m (1 ft) thick concrete slab with a single mat of reinforcement and rolled onto an 85 lb. rail that simulated the 2.9 m (9.5 ft) gauge leapfrog rail system for the gantries to roll on during excavation. (Fig. 4).

The various components and pieces of the TBM, including all of the parts for the four gantries, the vertical conveyor system and the continuous horizontal conveyor system began arriving onsite in February 2019.

Delayed delivery of major TBM parts, including the mainframe, grippers, main bearing and cutterhead support, drive motors and cutterhead resulted in significant slippage of the project

FIG. 6

Starter tunnel with curved pocket and gripper walls.

schedule and resequencing of the TBM assembly by TRC and SMJV.

To accelerate the disassembly and reassembly in the starter tunnel, TRC and SMJV used a 653-t (720-st) Manitowoc MLC650 super-lift crane to make eight heavy-lift picks of the TBM and gantries (Fig. 5).

The four TBM heavy picks included the cutterhead at 190.5 t (187.5 st), the cutterhead support with main bearing at 389 t (375 st), the front main beam section at 127 t (125 st) and the rear main beam section with grippers and gripper carrier at 228.6 t (225 st).

The four gantry heavy lifts included each gantry assembled and fully dressed weighing in at an average of 91 t (90 st). Prior to lifting the gantries, all utilities including electric, hydraulics, communications, ventilation ducts, etc. were disconnected. All eight heavy lifts were sequentially lowered down the excavated 14 m (46 ft) diameter outfall shaft and assembled in the 76.2 m (250 ft) long × 12.2 m (40 ft) horseshoe starter tunnel.

The reassembled TBM was moved to the face of the starter tunnel on a curved invert cast in the working slab (Fig. 6) followed by rolling the four gantries on the leapfrog rail system (Fig. 7). The TBM was launched from STA 10+71± after final testing was complete, and the TBM was certified as ready to go and the muck conveyance system was installed.

The muck conveyance system is comprised of seven belt conveyors, an advancing tail piece, and a double-stacked horizontal belt storage unit on its surface.

1. TBM conveyor.
2. Transfer crossover conveyor.
3. Gantry transfer conveyor.
4. Horizontal continuous conveyor.
5. Vertical conveyor.
6. Surface transfer conveyor.
7. Radial stacker conveyor.

SMJV, with TRC on board, advanced the TBM for the first 305 m (1,000 ft) to confirm and verify the capabilities of the TBM per the contract. SMJV continued advancing the TBM and was scheduled to relocate the mucking operation (vertical conveyor and radial stacker conveyor) from the outfall shaft to the muck shaft after reaching STA 30+50±.

In an effort to mitigate project schedule slippage, SMJV and TRC elected to relocate the mucking operation concurrently during the scheduled TBM cutterhead diameter conversion in late December 2020, however SMJV and TRC reversed their decision and kept the mucking operation at the outfall shaft.

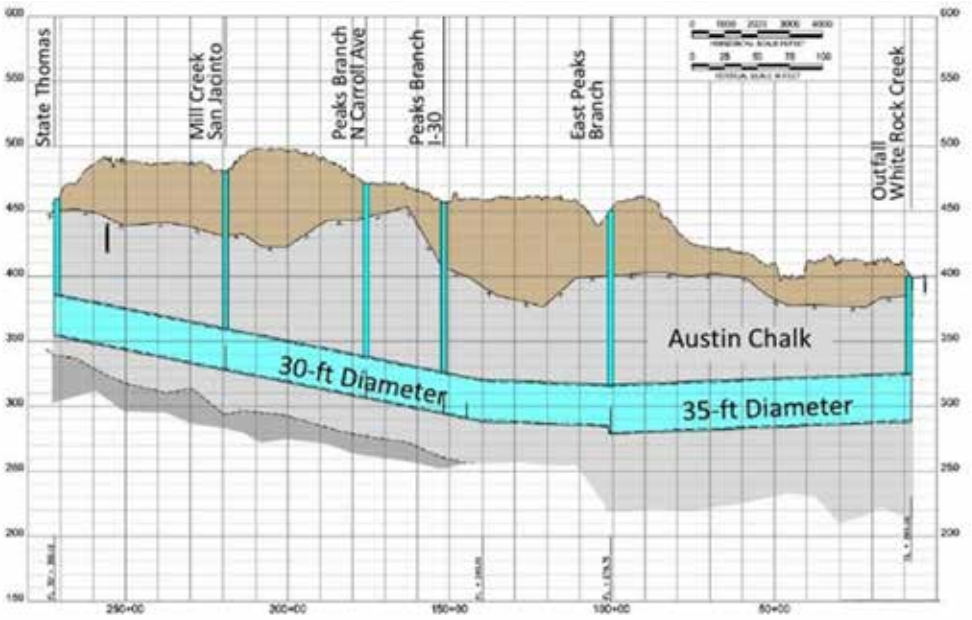
The tunnel is being excavated through Austin Chalk, a geological formation in the Gulf Coast region of the United States made up of weak limestone with an average unconfined compressive strength of 24.8 MPa

FIG. 7

Last gantry in starter tunnel on leapfrog rail.

FIG. 8

Dallas Mill Creek drainage tunnel geotechnical profile.



(3,597 psi) at depths of 33.5 m to 51.7 m (110 ft to 170 ft) below the surface (Fig. 8).

SMJV is using an average TBM production rate of 24.4 m/day (80 ft/day) for the project schedule that is based on previous tunnel projects in the Dallas area that occurred within the same geology. however SMJV has not been able to achive that production rate. The excavation will generate 1.15 million m³ (1.5 million cy) of tunnel muck. In an effort to maintain the scheduled advance rate of 24.4 m/day (80 ft/day) and not get muck bound, an average of 230 trailer dump loads per day of muck must be removed from the outfall shaft site.

SMJV has experienced up to 400 trailer dump loads

FIG. 9

Plan and section of cutterhead diameter conversion at lateral A.

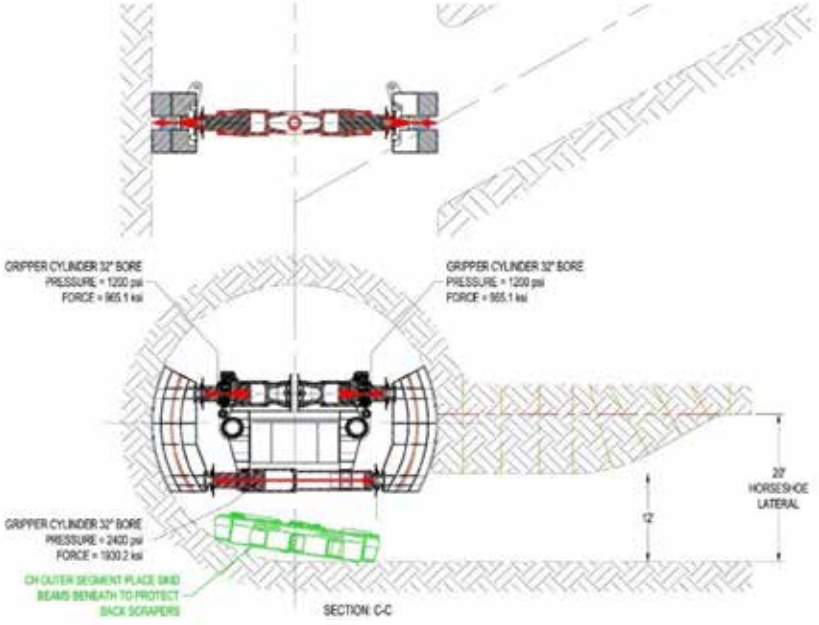
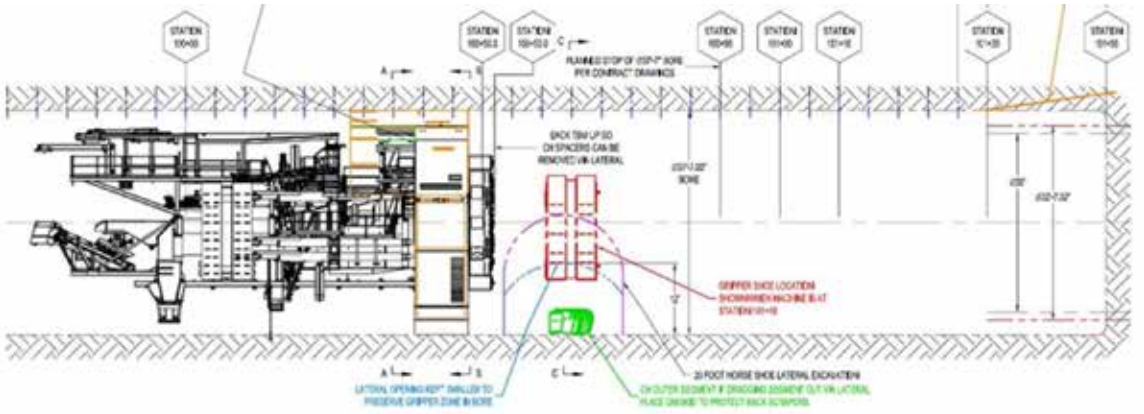


FIG. 10

Section profile of cutterhead diameter conversion at lateral A.



per day. The relocated muck shaft site would have enough surface area available to stockpile up to three days of excavated tunnel muck.

TBM cutterhead diameter conversion in mid-tunnel

To mitigate the extra work, time and cost of the lower reach 9.1 m × 10.8 m (30 ft × 35.5 ft) finished horseshoe tunnel, SMJV proposed to change the 2,749 m (9,017 ft) lower reach from the horseshoe tunnel to a 10.7 m (35 ft) finished diameter circular tunnel by using a Robbins hard-rock gripper TBM designed to reduce cutterhead diameters from 11.5 m to 9.9 m (37.6 ft to 32.6 ft) in the tunnel underground at STA 101+55±, the beginning of the lower reach.

The larger diameter cutterhead uses 67 432 mm (17 in.) disk cutters and the reduced diameter cutterhead will use 59 432 mm (17 in.) disk cutters. The end of the lower reach location includes the East Peaks branch intake structure, shaft A, lateral A, lateral P and shaft P.

SMJV and TRC set out to complete the TBM diameter conversion from the larger diameter to the smaller diameter through a sequence developed by SMJV and TRC that included mining to a specific station and sequentially removing (unbolting) the 0.76 m (2.5 ft) cutterhead extensions and the outer cutterhead quadrants while backing the TBM up approximately 31.4 m± (103 ft) to the lateral A transition area at STA 100+52±.

SMJV continued the diameter conversion by cutting (plasma torching) the 0.76 m (2.5 ft) extension outer wraps off the grippers, cutterhead support side

FIG. 11

Cutterhead diameter conversion area.

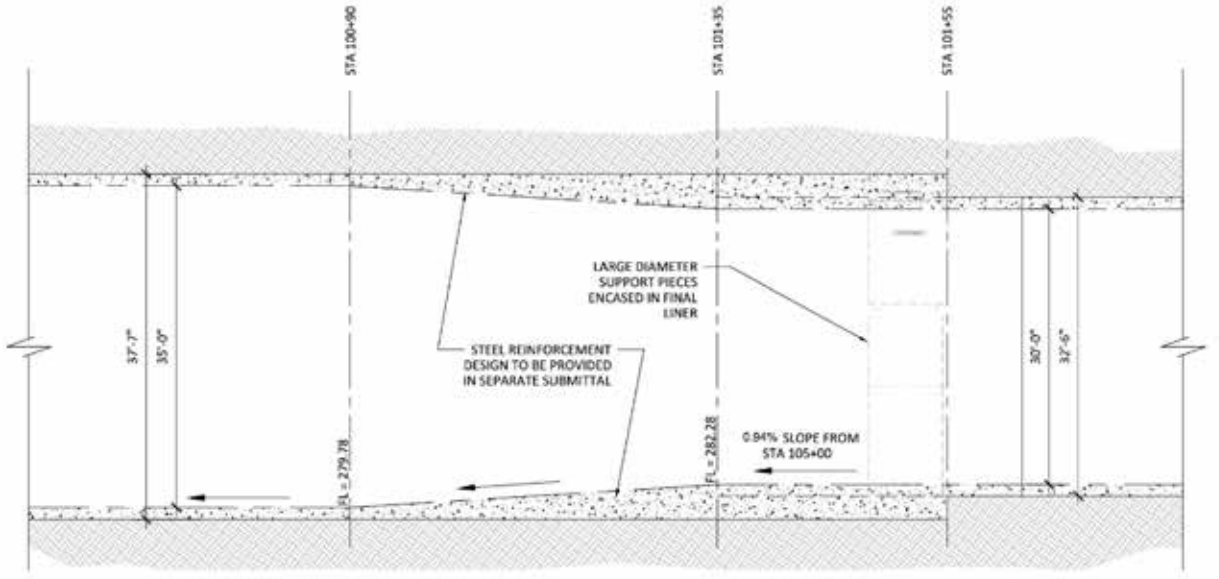


FIG. 12

Dallas Mill Creek Drainage Tunnel mega hard rock TBM "Big Tex"

stabilizers, the three roof finger shields and the rear support (gripper feet).

The 0.76 m (2.5 ft) cutterhead extensions, outer cutterhead quadrants and cut pieces were removed through the 3.7 m (12 ft) horseshoe tunnel extension of lateral A and excavated after the right gripper passed lateral A (Figs. 9 and 10).

The cutterhead extensions, outer cutterhead quadrants and cut pieces were removed through the 91 m (300 ft) long 6.1 m (20 ft) diameter lateral A and out the 6.1 m (20 ft) diameter shaft A. The cutterhead quadrant buckets required additional machine work to meet the smaller diameter.

The TBM was moved forward as the outer cutterhead quadrants were rebolted sequentially to the center section and the leapfrog rail and trailing gantries blocked up to line up with the new diameter. The gripper outer wraps and cutterhead support side stabilizer outer wraps were cut and pinned to the tunnel wall in the 11.5 m (37.6 ft) tunnel prior to the main beam with grippers sliding by.

SMJV resumed mining with the 9.9 m (32.6 ft) diameter TBM on a 1 percent grade to STA 105+00± where the TBM was back on contract grade (Fig. 11).

Shafts, intake structures and dewatering pump station

The drainage tunnel, with a capacity of 605,666 m³ (160 million gal), has six shafts that vary from 3.8 m to 12.2 m (12.5 ft to 40 ft) in diameter and are 33.5 m to 57 m (110 ft to 187 ft) in depth. There are five intake structures that intersect five existing storm box culverts and will convey stormwater to the tunnel via vortex drop shafts and laterals.

The horseshoe laterals vary from 15.8 m to 149.4 m (52 ft to 490 ft) in length and 3.66 m to 6.1 m (12 ft to 20 ft) in height. There is a dewatering pump station in shaft P at the East Peaks branch intake designed to dewater the tunnel for maintenance and inspection.

The pump station has three submersible pumps with a design capacity of 113.6 m³/min (30,000 gal/min) located in shaft P, the deepest part of the drainage tunnel at 57 m (187 ft) deep.

The pump station is designed to dewater the inverted siphon conveyance tunnel within three to five days during dry periods.

Conclusion

The Dallas Mill Creek Drainage Tunnel will be the largest hard rock gripper TBM tunnel under construction in the Western hemisphere, and possibly the world. There were valuable lessons learned on this project by everyone involved during site mobilization, shaft construction, large diameter TBM assembly, launching the TBM, excavating the Dallas Mill Creek Drainage Tunnel with "Big Tex" (Fig. 12), and preparing for the unique cutterhead diameter conversion in mid-tunnel.

The expected and unexpected challenges encountered during the start-up and production mining of the Dallas Mill Creek Drainage Tunnel were solved by collaboration and communication between the experienced individuals involved with the Dallas Mill Creek Drainage Tunnel team.

The proposed relocation of the muck shaft to accommodate hauling 24-hours per day on a state highway, eliminating the large horseshoe tunnel construction with a round tunnel construction, and the innovative changing TBM cutterhead diameters in mid-tunnel should result in a more efficient excavation operation and should save time on the construction schedule.

The city, construction management team and SMJV were able to work through issues while maintaining an open line of communication that helped keep the project moving forward during difficult times. Many thanks to everyone directly and indirectly involved in this challenging world class project. ■

Advances in tunneling technology discussed at Cutting Edge Conference in Dallas, TX

by Nancy Profera, Associate Editor

The SME and UCA (Underground Construction Association) "Cutting Edge" conference hosted its largest attendance yet with 285 in-person participants meeting in Dallas, TX Nov. 15–17. Attendees came from the United States, Europe, Israel and Canada and included engineers, contractors, project managers and college students. Elisa Comis from McMillen Jacobs Associates chaired the three-day event.

Priscilla Nelson, professor and head of mining engineering at the Colorado School of Mines in Golden, CO was the opening speaker and delivered a keynote address discussing crumbling infrastructure in tunnels, waterways, sewage and drainage systems in the United States and world and ideas on how to address resilience and the underground. Nelson has worked as a program director and senior advisor at the National Science Foundation, as a professor at the University of Texas at Austin, and was formerly provost at the New Jersey Institute of Technology. She is internationally known for her expertise in geological and rock engineering.

A tour of the Mill Creek Tunnel project followed the Cutting Edge Conference. Photo courtesy of Southland Holdings.

Her talk focused on the fact that cities throughout the world are growing in population and that growth is anticipated to continue in the coming years. "Our future is one of population and urban growth worldwide," said Nelson. "It'll be interesting to see how people want to live, considering the long-term effects of the pandemic."

Nelson encouraged the audience to think about the often vast, public and private infrastructure systems that are frequently created independently from one another and in silos in many cities. She explained that many have been created in an uncoordinated manner and need to be considered by engineers in more of a "systems of systems" approach. The complexities and interdependence of waterways, sewage, drainage, electricity and transportation modes need to be looked at more holistically, she said.

"We have to inform the public, professionals and politicians, and provide truths, examples and answers," said Nelson. She cited natural disasters and the recovery time it took for each including Hurricane Sandy in 2012, Hurricane Katrina in New Orleans in 2005, and the earthquake in Kobe, Japan, in 1995, lessons learned and the necessity of studying what went wrong and how to anticipate for these types of events in the future.

Crumbling infrastructure

There is growing demand for equity in any proposed infrastructure rebuild efforts of cities. Repairing and replacing water mains, gas pipelines and sewers in places like New York City, where much of the systems are 60 to 100 years old, requires consideration of what neighborhoods are most affected and where the work should be prioritized. According to Nelson, the Federal Emergency Management Agency (FEMA) does not have these potential breakdowns on its list of possible emergencies, though they should be added.

Scott Elmer from the Harris County Flood Control District presented "Going Deep to Reduce Harris County's Future Flood Risks," as he represented the city of Dallas' flood control project, equating the length of it to the driving distance between New York and Los Angeles. Elmer said that historically, people did not think tunnels could be built in this area because of weak soil, yet there are lots of water and waste tunnels in downtown Dallas.

Hurricane Harvey, a devastating Category 4 hurricane that made landfall in Texas and Louisiana in August, 2017, impacted all of Harris County. Tens of thousands of homes were flooded and this generated political support for a bond package that was approved by voters. "Tunnels are one of the ways we're looking at this differently. We were told to be innovative, and so now we are asking, 'Can tunnels be built in Harris County?'" said Elmer, adding, "If so, can they move enough water to make a difference?"

The team has created 2D models of the entire county, establishing critical mass areas with consideration of social

equity. They believe the answer is "yes" to the feasibility of the work and have moved on to phase two of the study. "We're not quite sure where we're going to build these tunnels—we'll need all of you engineers and contractors in the future. We've got some good projects coming up," Elmer said to the crowd.

The team considered water quality and sedimentation issues and collected data to look at the watershed and history of flooding in the area over the last 100 years. They also considered how the land was being used.

John Kinnear from Jacobs in Toronto, Canada presented on the London Thames Tideway Tunnel Project. The project involves sewage upgrades necessary because "every time it rains in London, the system goes over and into the river," said Kinnear. He explained that in London, the river generally drains to the east, and that the Thames water management project is run by a private utility, which is a common practice in England, and in this case, amounts to managing systems worth £4.2 billion pounds (equivalent to $6 billion U.S.).

Jacobs has developed a reference design for the project and the work is being done as design/build contracts. The Thames is made up of clay to the west and above the river is mixed sand and gravel.

Milton Brooks with the City of Dallas and Paul Smith, Black & Veatch, discussed "Changing TBM Excavation Diameter Mid-Tunnel in Dallas." When Dallas was founded in the 1920s it was a much smaller city, and as it began to develop, it spread east and north. Brooks shared that deep, underground tunnels have never been built in this city, but the need has become apparent as there is "$4 billion worth of property to protect in Dallas."

The city is trying to build an alternative outfall for the current drainage system to reduce possible flooding, moving from a 9.1 to 10.7 m (30 to 35 ft) section. The soil in the build area is made up of soft limestone, is 8 km (5 miles) long, and currently has seven shafts. Completely paid for by the city of Dallas (no federal or state funds), the project is estimated to cost $210 to $285 million.

On Wednesday of the conference attendees who had preregistered visited the Mill Creek drainage relief tunnel project site and learned about its design change from a horseshoe to round tunnel design.

Brad Grothen from Robbins presented "The Future is Noncircular: TBM Solutions for Flat Inverts," and discussed recent advancements in nonround tunnel designs. These include noncircular tunneling and mechanized excavation for soft ground and soft rock. He shared lessons learned from the company's work at the Fresnio Mines in Mexico, where the geology is hard rock.

"Grouting and Greasing in Frozen Ground" was presented by Sean Grant of Traylor Bros. He is a registered civil engineer working in Los Angeles and shared about the company's recent work experience on a tunnel in Vancouver, Canada. The project was challenging and involved highly variable geology with abrasive ground and rock.

Werner Burger from Herrenknecht discussed TBM technologies of the future. Burger, a mechanical engineer, said the company is focused on optimizing existing technologies, including those in operator assist systems for slurry and hard rock machines.

Also in attendance and presenting were Mark Stephani of HNTB on the topic of resilience through design, Angel Del Amo of Aldea Services on building tunnels that cross fault lines in Los Angeles, and Mark Funkhauser of McMillen Jacobs Associates on geotechnical considerations and the alignment selection for the lower Olentangy Tunnel in Columbus, OH.

Mike Rispin of Strata Worldwide led a panel discussion on research and development "from idea to implementation." There was discussion of the typical length of time it takes to complete projects; whether owner, contractor and designer all need to be in alignment for innovation to take place (the consensus was not necessarily); and how to work cheaper and faster. Alternative design and build delivery methods, how to measure innovation and its effects, the increasing cost of projects, inflation, supply chain and labor shortages were all reviewed.

Around the discussion of innovation, Bill Edgerton, SME president, said "we innovate to do things we haven't done before."

During the UCA Young Members session, Sean McDonald from Jay Dee discussed next generation technology and climate change. Katherine Westerlund from Mott MacDonald led a carbon portal and building information and modeling (BIM) integration talk, and Rachelle McDowell from Atkinson discussed working through the pandemic on the courthouse commons tunnel in downtown San Diego, California.

Federico Bonaiuti from Lane Construction in Italy presented "3D modeling for Tunnels: A Tool for Inspecting and Foreseeing Construction Activities from Planning to Execution." McDonald discussed the "Down for That" website and young member development initiatives.

In the afternoon, Sanja Zlatanic and Brandi Crawford of HNTB gave an update on the DART D2 subway project in Dallas using 3D animation to show the progress. The project has brought 150,000 jobs to the area.

Nick Chen from Jacobs discussed the Amtrak East River tunnel reconstruction project. During Superstorm Sandy, four of these train tunnels were flooded. Chen said the reconstruction project involves a "total organ transplant, to use an analogy of the body," because the tunnel is over 100 years old. One of the tunnels in the project is underwater, and issues like egress from the train to inside parts of the tunnel in case of fire or emergency must be considered. Fire, life safety, ventilation, drainage and building redundancy into the construction methodology are all aspects to be addressed. Chen said that the project schedule is a fast, 16 months and there's been "lots of knowledge gained and lessons learned." ■

UCA scholarships open March 1

The UCA is committed to the future of the tunneling and underground construction industries by supporting the next generation of professionals to enter the field. One of the ways in which this goal is accomplished is through the scholarships that are awarded during the summer events. This year, the UCA will host the North American Tunneling Conference June 19–22 in Philadelphia, PA, where three scholarship opportunities are available.

The application process opens on March 1, 2022 and will close on May 1, 2022.

UCA Young Members Scholarship

UCA Young Members Scholarship for the North American Tunneling Conference (NAT) provides selected students with an opportunity to attend conferences where they can experience the challenges, opportunities and rewards of a career in the field of tunneling and underground construction. Each recipient will receive:

- NAT conference registration.
- One-year student membership to UCA.
- An invitation to the UCAYM networking event.
- Round-trip airfare to the conference.
- Hotel accommodations at the conference hotel.
- Orientation at the conference.
- Conference proceedings.
- Valuable opportunities to network with industry experts and potential employers
- A $1,000 stipend for miscellaneous cash needs.

UCA and RETC Attendance Scholarship

The UCA and Rapid Excavation and Tunneling Conference (RETC) Attendance Scholarship provides students with an opportunity to attend this conference. Applicants must be full-time freshman, sophomore, junior, senior or graduate students with a designated major in an applicable field of engineering (civil, mechanical, mining, electrical, geological) or construction management. Applicants must have a demonstrated interest in the underground industry. Up to 12 recipients can be selected. Each recipient will receive:

- NAT conference registration.
- Round-trip airfare to the conference.
- Hotel accommodations at the conference hotel.
- Conference proceedings.
- Social function tickets.
- A $200 stipend for miscellaneous cash needs.

Recipients are responsible for their own ground transportation and for other expenses including meals, other than at social functions.

RETC Executive Committee Scholarship

RETC annually awards one or more scholarships to college students who want to develop their skills in the tunneling industry. The total amount of the award, approximately $5,000, is apportioned to one or more students at the discretion of the RETC Executive Committee. Each recipient will receive:

- NAT conference registration.
- Round-trip airfare to the conference.
- Hotel accommodations at the conference hotel.
- Conference proceedings.
- Social function tickets.
- A $200 stipend for miscellaneous cash needs.

The goals of the award are to increase exposure to career opportunities and to provide educational and networking opportunities to future underground industry professionals.

Visit https://www.smenet.org/uca-of-sme/membership/scholarships for more information on these awards, including criteria and deadlines for application and instructions on how to apply. ■

WTC moved to September in Copenhagen

The World Tunnel Congress (WTC) that was to be held in Copenhagen from April 22–28 has been moved to Sept. 2–8, 2022 because on ongoing complications associated with the COVID-19 pandemic.

The WTC2022 Organizing Committee and the International Tunnelling Association (ITA) announced the conference will remain at Bella Center in Copenhagen.

In a statement, WTC and ITA said the decision was made in a context of a global health crisis and awareness of the difficulty for many industry professionals at this time to commit to participate in the WTC2022 in April.

"The expectation is, as it was also the case in 2021, that by September the COVID-19 virus will be less virulent and therefore will allow the entire tunnel and underground profession to finally meet and see each other again in good conditions.

"The organizing committee and the 150 exhibitors will look forward to meeting you all, and we will ensure that the conference will follow any health regulations that may be in force by next September in Denmark, if any," the statement read.

All ITA activities will also take place between Sept. 2 and 8 such as the general assembly and meetings of the working groups and committees.

The WTC2022 will take place in a hybrid mode (physical and digital). More information is available at https://wtc2022.dk/ ■

Axel Nitschke

Tunnelling professionals globally are mourning the premature passing of U.S.-based Dr. Axel Nitschke, who died on Dec. 26, 2021. Nitschke was a much-valued contributor to *Tunnels and Tunnelling International* (*T&T*).

Born in Germany in 1968, Nitschke relocated with his family in 2008 to the United States where he continued his distinguished tunnelling career in earnest. By the time his career tragically ended, he had worked with some of the biggest names in consultancy, leading tunnelling projects in the United States, Canada, South America and Europe.

Throughout his career, Nitschke wrote numerous technical papers, some of which have become standards in the tunnel industry. In the last technical paper he wrote for *Tunnels &Tunnelling* (November 2020) he proposed a labelling and classification system designed to provide an effective and easy way to specify FRC for tunnel linings.

Nitschke graduated in 1993 with a master's degree in civil engineering from Ruhr University, Bochum, Germany and immediately embarked on a Ph.D. there, his thesis focusing on the loadbearing capacity of steel fiber-reinforced concrete in tunnelling. This he successfully completed in 1998. During his time at the university, he was also employed as an assistant professor and chair of construction technology, tunnelling and construction management.

There followed a highly successful career in tunnel design and consultancy in both Germany and subsequently the United States, spanning well-known firms such as IMM, BeMo Tunnelling, Wayss & Freytag, Gall Zeidler, Shannon & Wilson and WSP.

While at Gall Zeidler in Washington, Nitschke was senior tunnel engineer and then vice-president; later at Shannon & Wilson, also in Washington, he was vice president, director of operations for underground services. From October 2015 to January 2021, at the American Shotcrete Association (ASA), he was chair of the underground committee, rising to vice president of the executive committee. His time at ASA overlapped with some of his other employments.

Axel Nitschke

Nitschke's final role was as vice president and tunnel practice leader (NATM) at global engineering consultancy WSP in Washington, where he had started working in June 2017.

He is survived by his wife, Anke and their four children. ■

Grouting short course returns in August

The 2022 Grouting and Ground Improvement short course at the Colorado School of Mines will take place Aug. 1–4, 2022 at the campus in Golden, CO.

The four-day course covers engineering, equipment, materials and methods for grouting and ground modification used in civil and geotechnical engineering, underground construction, tunneling and mining.

The course combines classroom instruction with hands-on labs and demonstrations, providing participants with the opportunity to see grouting and ground improvement field equipment in action including compaction, cellular, chemical and permeation grouting equipment.

The course is intended for industry professionals including owners, planners, designers, contractors, consultants and suppliers involved in the design, planning and construction of civil and geotechnical engineering, underground, tunneling and mining projects.

The Colorado School of Mines will award 2.4 continuing education credits up successful completion of the course.

The course instructors are Dr. Reza Hedayat of the Colorado School of Mines and Ray Henn of RW Henn, LLC. Bill Warfield is the coordinator for field day demonstrations.

Registration will open March 1. Space is limited and early-bird and group discounts are available through June 20.

For more information visit www.learn.mines.edu/ggi/. ■

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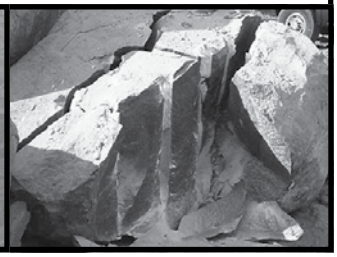

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HNTB'S TUNNEL VENTILATION AND FIRE LIFE SAFETY TEAM DEMONSTRATES GROWTH

Practice boasts one of the industry's largest and most experienced team of experts, focusing on technical excellence, innovation and quality delivery.

HNTB continues to expand its tunnel ventilation and fire life safety (FLS) practice and team, completing numerous high-profile projects in recent years and becoming a preferred provider of fire and life safety engineering services in North America through sustained growth and a focus on technical excellence, innovation and quality delivery. The team has also spearheaded recent industry efforts to improve infrastructure safety for transit clients across the U.S., promoting the increased resiliency of systems in response to the pandemic, as well as readiness to face possible similar events in the future.

"HNTB is committed to ensuring the infrastructure we design and support is safe, reliable, sustainable and efficient for our clients," said Bernd Hagenah, Ph.D., principal engineer for tunnel ventilation and fire life safety at HNTB. "By growing our technical expert resources on the ventilation and fire life safety team, we demonstrate our commitment to improving safety of road, rail and facility systems and rolling stock including protecting lives in the event of an emergency (for both 'cold incidents'/accidents during operation, or a fire event). National and international experiences of our enhanced team draw the lessons learned from major global projects; the team implements state-of-the-art approach to efficiently resolve most complex issues."

Over the past five years, the company has added professionals from around the world to its ventilation and fire life safety team, including leading experts in engineering, ventilation, fire protection, and rail aerodynamics. The company offers a full and wide range of services, from concept designs, cost benefit analysis for different options, and risk analysis to state-of-the-art modeling processes and simulations; fire protection strategy and evaluation; air quality analysis and environmental impact studies; climate and pressure control; specification of mechanical and fire protection equipment for tender processes; evacuation concepts and modelling; inspection, rehabilitation and restoration; preparation, execution and evaluation of tenders, site supervision, testing and commissioning, and optimization under operation. We provide valuable support to our clients during the whole lifecycle of transportation infrastructure with a holistic approach.

"Ultimately, HNTB's ventilation and fire life safety team ensures that future generations will have safer infrastructure, designed to have a robust and reliable service with minimal operating and maintenance cost and long life span," said Sean Cassady, HNTB Fellow and principal engineer, who was engineer of record for design of ventilation and fire life safety systems on SR-99 Alaskan Way Tunnel — the world's second-largest double deck highway tunnel, nearly two miles long, beneath downtown Seattle, which replaced the earthquake-damaged Alaskan Way Viaduct in 2019. "There are a number of examples where team collaboration is key," noted Cassady, "to overcoming challenges in conceptualizing efficient ventilation, fire detection and suppression systems that would effectively mitigate carbon emissions. Teamwork had brought a major value toward application of cutting-edge technology to control possible fire scenarios and evacuate smoke while allowing people to exit safely."

The ventilation and fire life safety team also has provided infrastructure planning and design for transit agencies such as Sound Transit (Seattle), Bay Area Rapid Transit (San Francisco), St. Louis Metro, Dallas Area Rapid Transit, Massachusetts Bay Transportation Authority (Boston), Los Angeles County Metropolitan Transportation Authority, and New York City Transit Authority, and enabled HNTB's continued expansion into other markets.

"Our national tunnel practice is known nationally and internationally to include the world's leading experts and thought leaders in tunnel ventilation, fire life safety and aerodynamics," said Sanja Zlatanic, PE, HNTB chair national tunnel practice, senior vice president and HNTB Fellow. "Our expertise brings value to every mobility solution including both highway and rail tunnels and stations, as well as to wide range of multi-modal transportation hubs including airports. As tunnel methodology continues to evolve and grow in importance in the U.S. due to increased population migration to cities and a need to minimize surface disturbance and construction impacts on communities, tunnel solutions are becoming broader to include larger tunnel diameters and house transit stations within. Our team had proven that the engineering solutions to resulting complex ventilation and safety solutions need to evolve as well to include RAMS (reliability, availability, maintenance and safety), as a sustainable approach more and more agencies require, as well as consideration of tunnel climate issues for ensuring long-term service life of majority of system components. The team's knowledge and experience in this realm is unique and would bring value to the projects and clients across the nation."

Novatorskaya station, BCL

HNTB's Tunnel Ventilation and FLS Technical Leaders

Bernd Hagenah, National Tunnel Practice Consultant

Bernd Hagenah has more than 23 years of experience in tunnel ventilation, climate, aerodynamics and safety and has worked on numerous major international infrastructure projects, including iconic rail tunnel projects such as the Gotthard Base Tunnel, Brenner Base Tunnel, Vienna Metro, Melbourne Metro, Brisbane Metro, highway tunnels in Europe and the French Nuclear Waste Depository (CIGEO). He is a recognized leader in the design of tunnel safety, electromechanical equipment including ventilation systems for underground transit systems, and high-speed rail aerodynamics.

Sean Cassady, Principal Engineer

Sean Cassady has more than 24 years of experience developing creative solutions for tunnel ventilation and FLS systems for enclosed facilities including road/rail tunnels and stations. His specific skill set developing ventilation, fire hazard and energy analysis with numerical modeling and other engineering analysis methods, integrated with practical experience, has been employed in facilities such as the 1.7-mile, 57.5-foot diameter, SR99 stacked highway tunnel in Seattle. Many projects that Sean has worked on such as San Francisco's Muni 3rd Ave Extension and BART San Jose Extension have maximized safety and efficiency based on design approach that emphasizes robust simplicity.

Petr Pospisil, Principal Engineer

Petr Pospisil has worked in the field of tunnel safety and ventilation since 1997, contributing to more than 150 major infrastructure projects worldwide, including the Gotthard Road Tunnel, the Seelisberg Highway Tunnel, Klosters Bypass Tunnel (adjacent to the Sunniberg Bridge), high-speed rail tunnels between Tel Aviv and Jerusalem in Israel, as well as some of the world's longest rail tunnels, the 55km long Brenner Base Tunnel and the 57.5km long Mt. Cenis tunnel on the Lyon-Turin rail line. He has led standards development teams and research projects, and published various books on tunnel ventilation, and risk and safety, focusing on a holistic approach.

Jesse Harder, Senior Supervising Engineer

Jesse Harder has 21 years of experience in the planning, design and commissioning of tunnel ventilation and fixed fire-fighting systems. He has served in key roles supporting both new tunnel construction and tunnel retrofit projects including the Marmaray Tunnel, BART San Francisco International Airport Extension, BART Transbay Tube, Caltrans Caldecott Tunnel, Sound Transit North Link and East Link Extensions, and the Midtown Tunnel. He has a proven record of design leadership and technical expertise in the areas of fire hazard analysis, emergency egress, tunnel safety, maintenance and operations.

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ANTRAQUIP CORPORATION – your reliable, innovative partner

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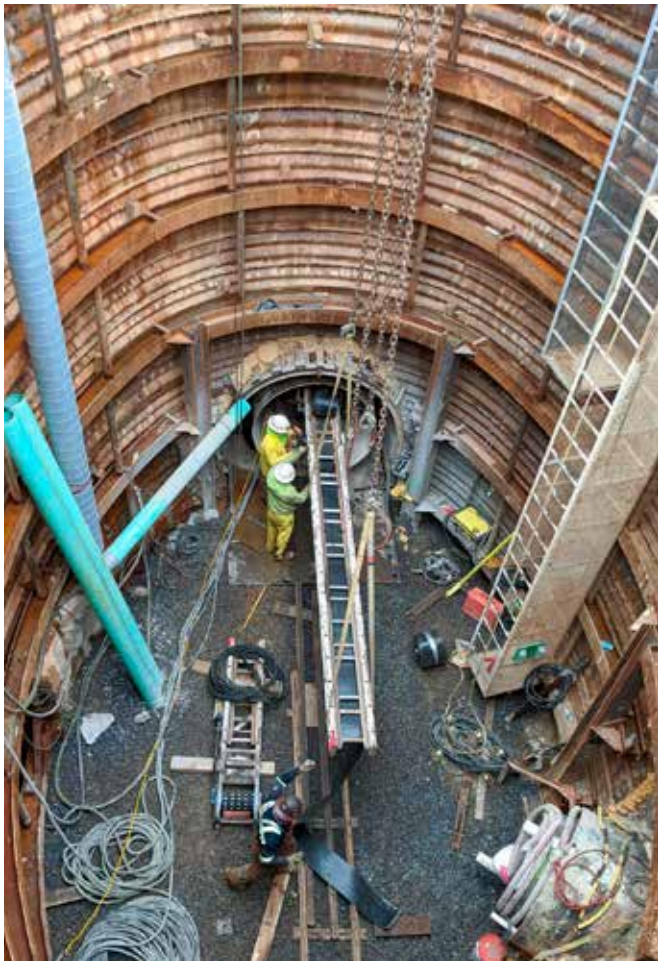

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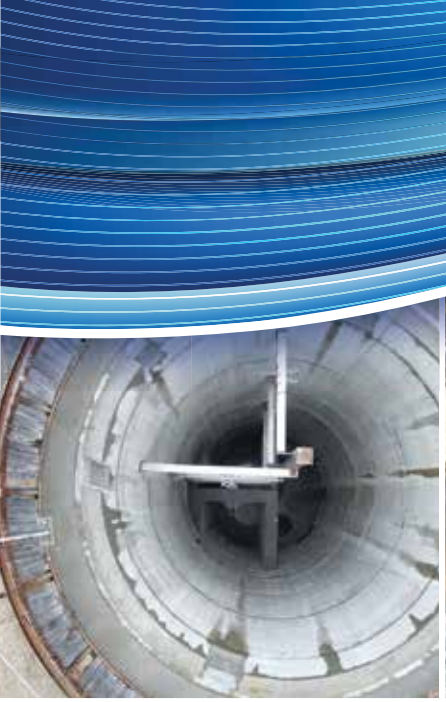

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For more information on our portfolio of diverse and complementary brands visit us at www.jennmar.com.

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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.

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.

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 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, with decades of experience in the underground marketplace.

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.

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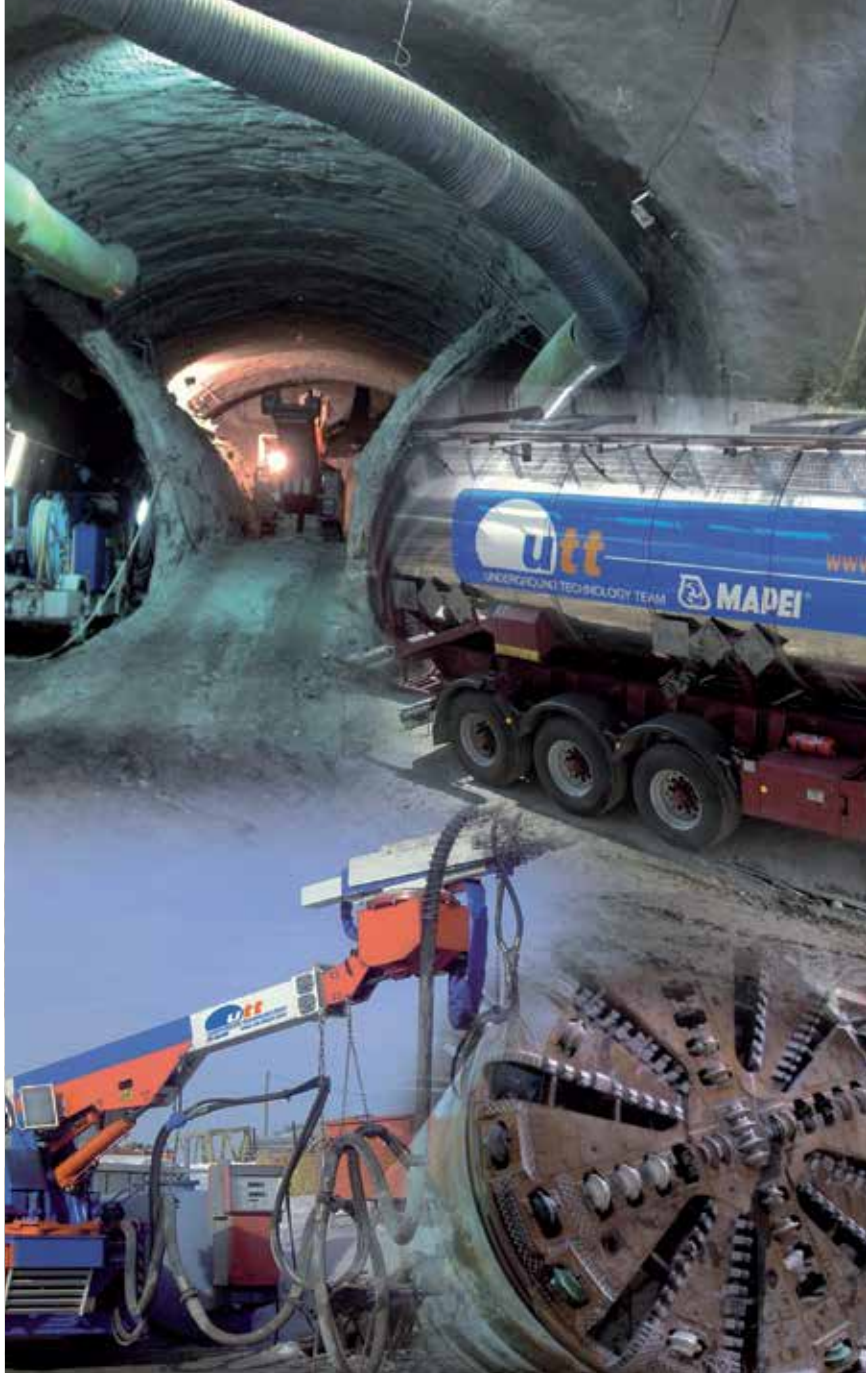

Our commitment is the detail that makes the difference.

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

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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

Colorado School of Mines' Earth Mechanics Institute

EXPERIENCE MINES

Colorado School of Mines is a public university focused on science and engineering, dedicated to pioneering research that addresses and offers innovative solutions to the great challenges society faces today—particularly as they relate to the Earth, energy and the environment—and committed to educating students who will do the same. The following is a selected list of tests performed by EMI.

STANDARD TESTS:

- Uniaxial Compressive Strength (UCS)
- Indirect (Brazilian) Tensile Strength
- Cerchar Abrasivity Index (CAI)
- Punch Penetration Test
- Acoustic Velocities and Dynamic Elastic Constants
- Point Load Test
- Thin-Section Petrographic Analysis
- Schmidt Hammer Hardness
- Shore Scleroscope Hardness
- Taber Abrasion
- Abrasive Mineral Content and Mohs Hardness
- Static Elastic Constant
- Triaxial Compressive Strength
- Direct Shear Test
- Moisture Content
- Permeability
- Porosity
- Rock Quality Designation (RQD)
- Slake Durability Index

SPECIALIZED TESTING

- Linear Cutting Testing
- Cutterhead and Bit Performance Evaluation
- Full-Scale Cutterhead Performance Testing with Laboratory TBM
- Bearing Life Evaluations
- SINTEF Rock Boreability/ Drillability Testing
- Soil Abrasion Testing for EPB Tunneling
- Miniature Linear Cutting Testing
- Bit Analysis using Full-Scale Top Hammer Percussive Drill
- Sieve Analysis

Additional information about technical papers, upcoming short courses, details on current and past projects and descriptions of research and work capabilities is available online at **emi.mines.edu.**

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EARTH MECHANICS INSTITUTE

The Earth Mechanics Institute was established at the Colorado School of Mines in 1974 to enhance education and research in the field of excavation technology. Over the past 40 years, EMI has developed suites of tests and modeling procedures for performance prediction, project costing analysis, mechanical excavation tool design and machine concepts.

EXCAVATION ENGINEERING & EARTH MECHANICS INSTITUTE

Contact us to discuss your unique needs:
1312 Maple St. Golden, CO 80401
+1 303 273 3123
emi@mines.edu




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.
1613 132nd Avenue East, Suite 200
98390 Sumner, WA
USA
Phone +1 (253) 447-2300
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 ii all possible.

We have been a leader in the underground support business in North America since 1920 for over 100 years of excellence. Our core product line ranges from steel ribs and liner plates to 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 minimize downtime and maximize productivity and performance. We have the people and the products for every challenge, and a supply chain you can rely on to deliver. Working along side you, we help you progress towards your objectives - quickly, reliably, cost-effectively.

When you're tackling a seemingly insurmountable objective, facing tons 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 sustainable. 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.

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www.dsiunderground.com
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You want to advance your operations efficiently. To improve safety. To minimize downtime and maximize 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.

DSI Tunneling LLC
Phone 502 473 1010

dsitunneling.com

Derrick Corporation

Founded by H. William Derrick Jr. in 1951, Derrick® Corporation was created to solve some of the most challenging mechanical separation needs of the Mining Industry. At the heart of our present-day offering resides the Integrated Vibratory motor. Our pioneering spirit pulses through the organization and inspires development of our leading-edge solutions.

Over the years, we have experienced exponential growth, expanding from our Mining roots to Oil & Gas Drilling, Civil Construction, Industrial and other challenging markets worldwide. We have an extensive network of thousands of cohesive individuals located across the globe.

SERVING THE CIVIL INDUSTRIES

Derrick has offered premium slurry separation and desanding equipment to the worldwide Microtunneling, Diameter Tunneling, Slurry Wall/Foundation Drilling, Horizontal Directional Drilling, Hydrovac Mud Processing, Water Well Drilling, Dredging and other Civil Construction Industries for over 30 years.

Throughout this time, Derrick has remained dedicated to complete in-house manufacturing of every piece of solids/liquid separation equipment. Each unit is created and assembled at Derrick's Buffalo, New York headquarters facility.

EQUIPMENT THAT MAKES THE DIFFERENCE

Drilling or tunneling performance is directly related to the overall cleaning ability of the separation equipment. Drilled solids remaining in the slurry have numerous adverse effects on the overall operation, significantly reducing its profitability. Consequently, selecting the proper separation equipment for your fleet is just as critical as the drill or tunnel boring machine. Derrick answers this critical need with innovative, high performance solids control equipment proven time and time again to increase the rate of advance while reducing:

- Non-production time
- Hauling and disposal of solids-laden drilling fluid
- Cost of drilling fluid and chemicals
- Water usage and hauling
- Wear on downstream pumps, plumbing, and other equipment
- Environmental impact

Visit us at **www.Derrick.com** to discover more.

DERRICK®

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Email: Info@derrick.com
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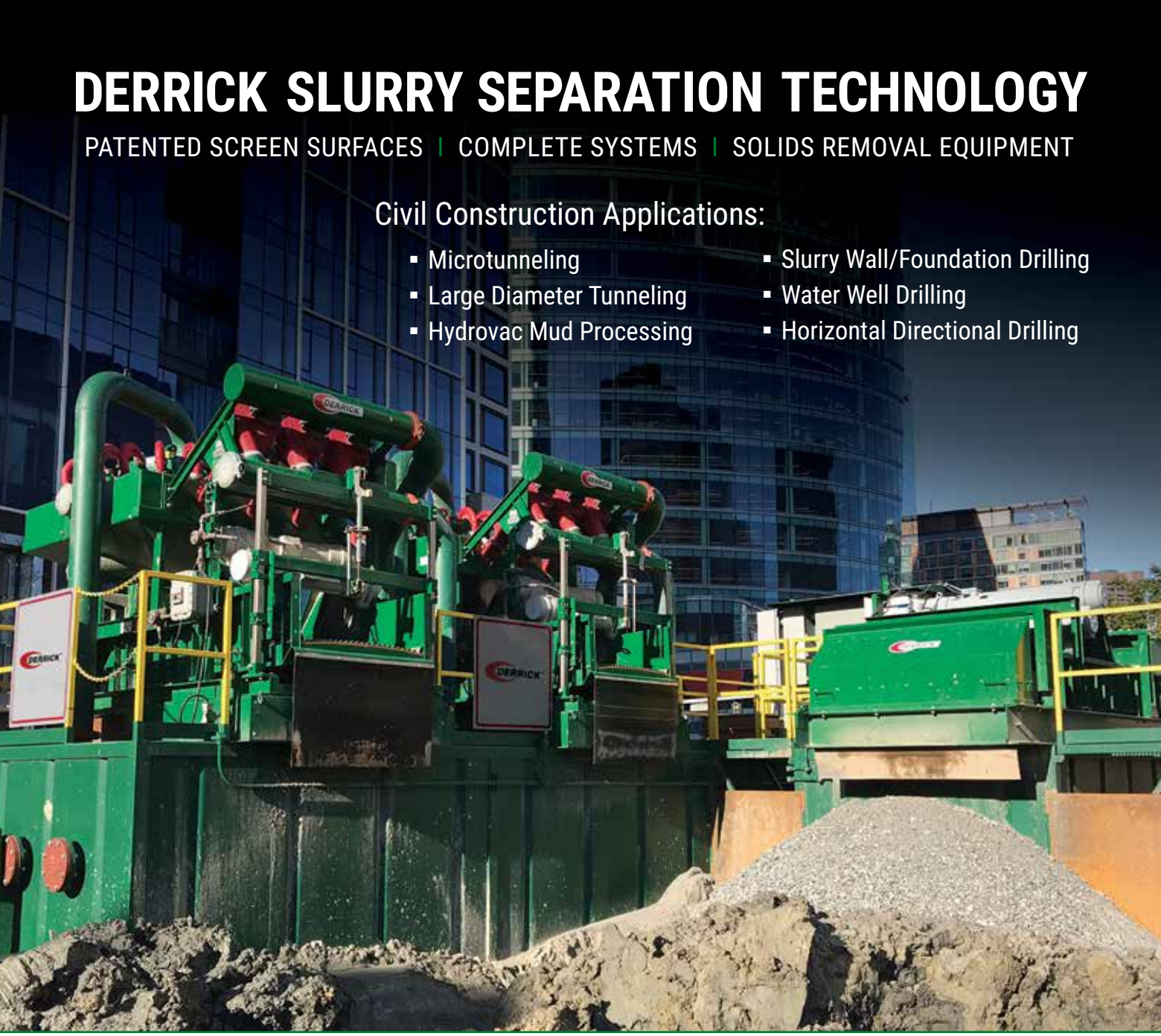
DERRICK SLURRY SEPARATION TECHNOLOGY

PATENTED SCREEN SURFACES | COMPLETE SYSTEMS | SOLIDS REMOVAL EQUIPMENT

Civil Construction Applications:

- Microtunneling
- Large Diameter Tunneling
- Hydrovac Mud Processing
- Slurry Wall/Foundation Drilling
- Water Well Drilling
- Horizontal Directional Drilling



Leading-Edge Slurry Separation Solutions

Backed by over 70 years of cost-effective solutions, Derrick has manufactured innovative technologies for numerous civil construction applications for over three decades. Derrick's separation technology offers unmatched solids removal performance. Our civil construction solutions are currently used worldwide by companies that require high-efficiency separation and slurry dewatering in environmentally sensitive and urban environments.

Site Video
In camera mode, hover phone over QR code to watch full video.
(No app required)

Derrick Corporation
15630 Export Plaza Drive
Houston, Texas 77032
Toll Free: (866) DERRICK
www.Derrick.com

Exclusive Distributor

Clean Slurry Technology, Inc.
4101 Union Ave
Bakersfield, California 93305
Toll Free: (877) 365-8396
www.CleanSlurry.com

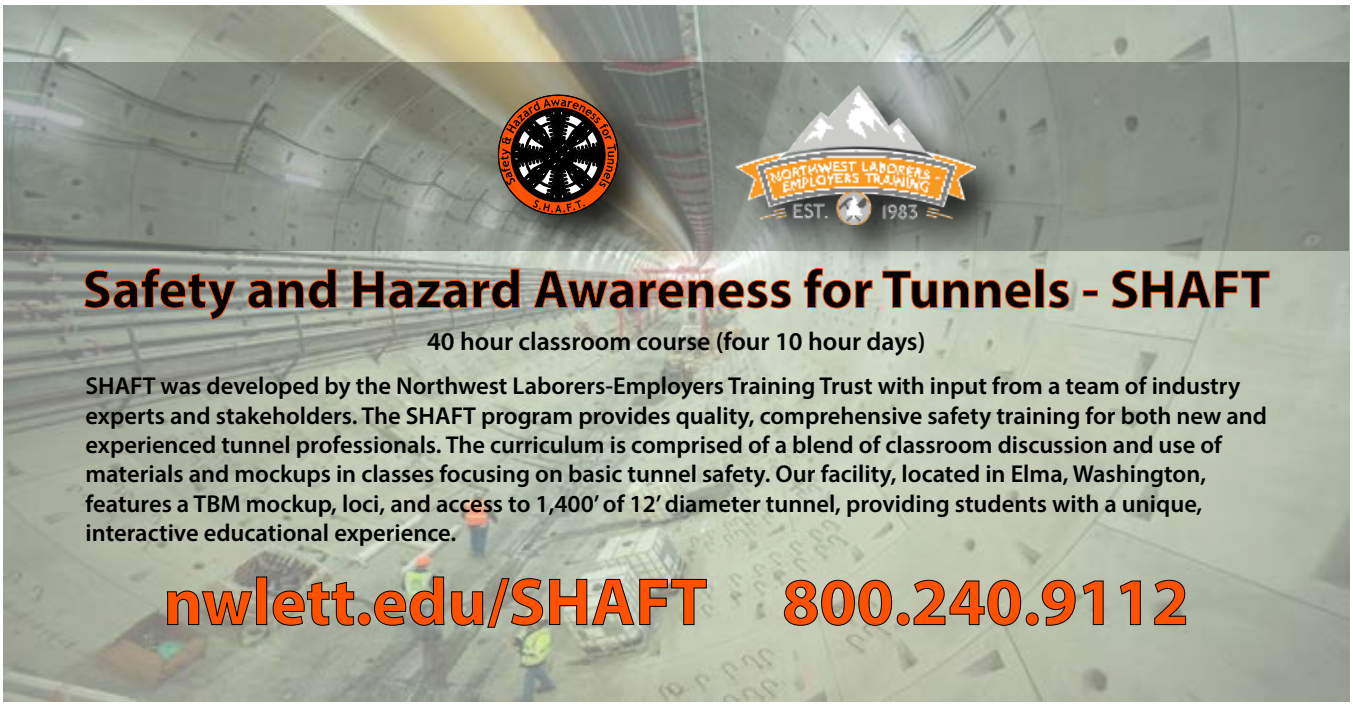
Northwest Laborers-Employers Training Trust – Safety and Hazard Awareness for Tunnels (SHAFT) program

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



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
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TUNNELING SPECIALISTS | bradshawcc.com 410.970.8300

By combining superior craftsmanship with innovative tunnel engineering and construction technology, Bradshaw Construction Corporation successfully provides cost effective tunneling solutions to the utility and transportation industries.

PROVIDING INNOVATIVE SOLUTIONS FOR TUNNELING PROJECTS

MICROTUNNELING | TBM TUNNELING | HAND TUNNELING | SHAFT WORK

BRADSHAW CONSTRUCTION CORPORATION

Kiewit

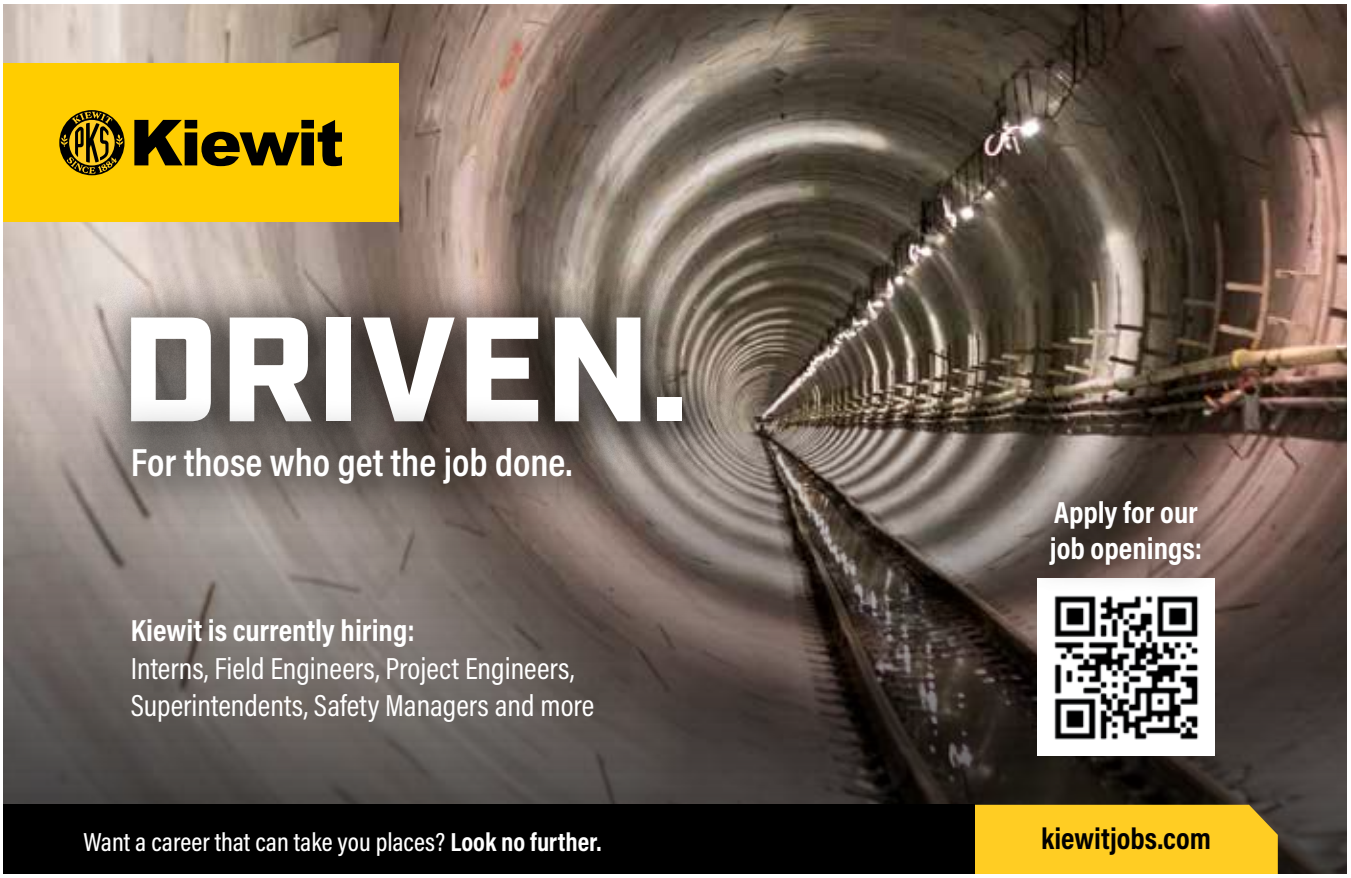
As a construction, mining, and engineering leader, Kiewit is a FORTUNE 500 company consistently ranking in the ENR's Top 10 Contractors. Kiewit is owned by active employees, creating a level of motivation that keeps the company on top. Kiewit, through its operating companies, brings a wealth of diverse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

Kiewit has built some of the most complex tunneling and underground projects for more than 60 years. We self-perform soft ground and hard rock TBM tunneling, along with conventional tunneling techniques such as SEM and Drill and Blast, and trenchless technologies such as MTBM and HDD. As one of North America's largest and most respected construction and engineering organizations, Kiewit's underground capabilities offer clients unique advantages to navigating complex, challenging projects from engineering and design, through construction.

We're hiring. Go to kiewitjobs.com to learn more.

Kiewit

Kiewit Infrastructure Co.
1550 Mike Fahey St.
Omaha, NE 68102
(402) 346-8535



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:

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

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.

MASTER® BUILDERS SOLUTIONS

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

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A brand of MBCC GROUP

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

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.
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E-mail: jklug@drklug.com
Website: www.drklug.com

DAVID R. KLUG & ASSOCIATES, INC.

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Jonathan D. Klug - Vice President

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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

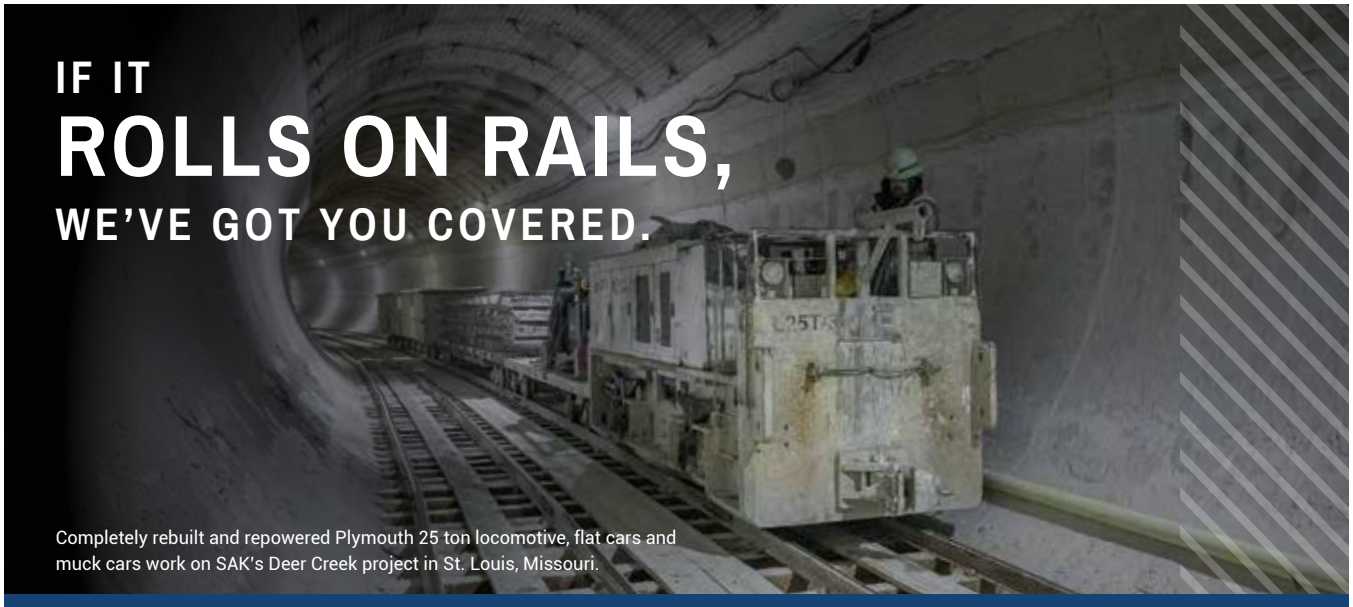
"Rolling for more than 35 years"

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



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- METALLIANCE MSVs
  (NORTH AMERICAN, GERMAN DEALER)

Normet - 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, remanufacturing and upgrades, performance and field services.

Normet has delivered over 14,000 built-for-purpose underground machines which are serviced and supported with a broad service portfolio.

Normet currently employs over 1600 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

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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.

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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.

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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.

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

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.

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.

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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).

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Stäubli provides a universal solution for automatic charging of electric mining equipment with its innovative **QCC** (**Quick Charging Connection**). For high power charging systems designed to stand up to the harshest environments, the Automated Connection Device (ACD) makes it possible to **transfer high levels of power (1MW+)** which ensures fast recharging of energy storage devices such as Li-Ion batteries and super capacitors.

The **high efficiency** and **reliability** of the QCC means less maintenance with decreased down time. The ability to quickly charge with the QCC allows manufactures to offer smaller onboard battery packs so that machinery can better serve its intended purpose – to transport the weight of ore, not the weight of extra batteries.

To find out more about the QCC solution, scan the QR code or call us at
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Stäubli Electrical Connectors meet the highest standards in even the most demanding and competitive industries, where absolute performance, safety, durability, reliability and efficiency are crucial.
High performance, long-term reliability and highest mating cycles for the connection of all types of industrial applications. We calculate our solutions for maximum reliability in the harshest environments.
With its innovative connector for high power charging systems the QCC by Stäubli provides a universal solution for automatic charging of various kinds of electric vehicles (Mining equipment, AGVs, buses, trucks, etc.). The automated connection device (a so-called ACD) makes it possible to transfer high levels of power, which ensures fast recharging of energy storage devices such as Li-Ion batteries and super capacitors. The QCC offers high efficiency and low maintenance requirements. The amount of stored energy required is reduced due to quick recharging stops, which enables the vehicle to better serve its purpose – transport of the weight of goods, not the weight of batteries.

Working closely with our customers, both conceptually and geographically, we assist with the most uniquely demanding tasks of our longstanding partnerships. Our customers' requests or project requirements are processed quickly, creatively and competently. These collaborations motivate us to move forward and constantly improve our products and services. Innovation is the driving force, which supports us to start trends and set standards.

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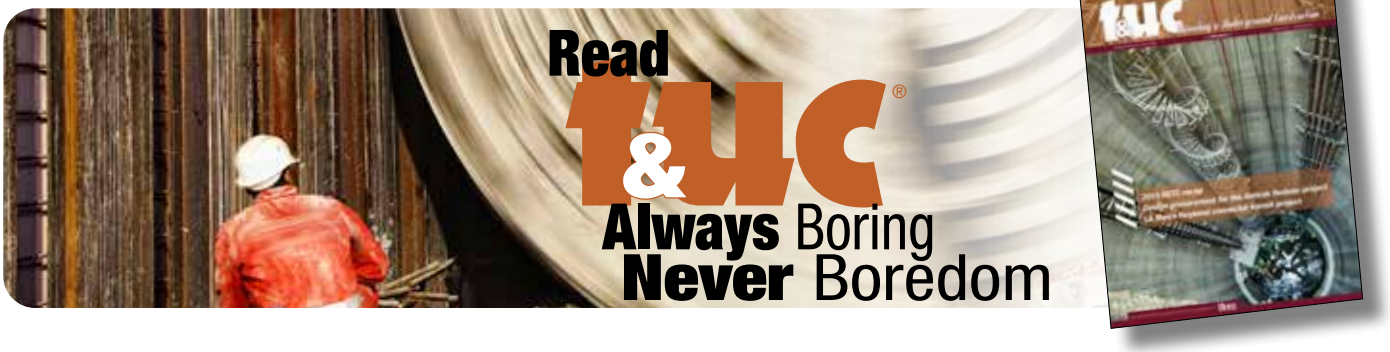
Brookville

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.



BORAID® GROUND CONDITIONERS FOR TBM EXCAVATIONS

Traylor Bros., Inc is a heavy civil construction company with decades of extensive experience throughout North America. They specialize in TBM tunneling, the sequential excavation method (SEM), and drill and shoot excavation.

Originally established in 1946 in Evansville, Indiana, Traylor Bros. experts employ state-of-the-art technology to deliver projects in every type of ground. TBM tunneling methods include mixed shield/slurry, earth pressure balance and hard rock tunnel boring.

In earth pressure balance (EPB) applications, special soil additives are typically used to assist with and optimize the TBM mining. These ground conditioners create more stable, cohesive conditions, which in turn improve the speed and efficiency of production and help to protect the TBM and its components from excessive wear and tear.

The team of skilled engineers at Traylor Bros. crafted these conditioning agents and polymers to meet specific customer needs and solve specific problems. Over the years, they have successfully formulated a collection of Boraid® ground conditioning agents.

Soilax®-S – A concentrate for sands and silts.

Soilax®-AC – An "anti-clay" concentrate that converts clay into perfect EPB muck.

Soilax®-P – A water-absorbent polymer that is used in sandy, high-water content ground to help to improve muck consistency.

Bert's Drillin' Juice – Specially formulated concentrate for sands and silts that was developed in response to difficulties experienced in specific conditions.

"We use a combination of technological knowledge and applied experience in developing the soil additives, and continually adapt and modify them to work in differing conditions. They are not solutions formulated in labs, but rather tested, used and proven in the field on real projects," stated Chris Hebert, Vice President and Underground Division Manager for Traylor Bros.

Realizing the effectiveness and evident advantages offered by Boraid® products, other contractors began requesting the solutions as stand-alone products for their own projects. Market demand eventually drove Traylor Bros. to explore their options in marketing and selling their products directly to end users.

In 2021, Traylor Bros. selected Strata Worldwide to exclusively represent the Boraid® line and the companies jointly announced their new partnership agreement in November. Consultation and proposals are immediately available for existing and upcoming projects.

"We are very excited to be working with Traylor Bros. to bring the Boraid® line directly to market," states Mike Rispin, VP of Tunneling for Strata Worldwide. "For Strata, it is not only about offering the products and technologies, but also about bringing expertise to help solve problems."

For more information please contact Mike Rispin at: 385-234-1474 or email us at: info@strataworldwide.com.

www.strataworldwide.com/tunneling

BORAID

STRATA WORLDWIDE

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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.

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Kelley Engineered Equipment

Kelley Engineered Equipment (KEE) celebrates their 15th anniversary of supplying custom equipment and professional engineering services to the tunneling and underground construction industry. KEE provides innovative, efficient designs optimized for safety and productivity. A growing team of 40+ professionals and a Seattle office staffed by TBM experts, the Kelley team has professionals with decades of underground experience, PE Licenses in 10 states and more on the way. KEE accepts your challenges and provides solutions with unmatched quality and customer support.

Contact KEE for: Tunneling Equipment, below-the-hook lifting systems, gantries, pipe carriers, mucking systems, trailing gear, custom tunneling shields, custom hydraulic attachments, conveyors, lift cars, equipment modifications, heavy load handling, custom cranes, personnel access systems and bespoke engineered solutions.

KEE is proud to represent Terratec TBMs in the USA and Canada along with Roxard Industries' TBM Cutters and Soft Ground Tools in North and South America.

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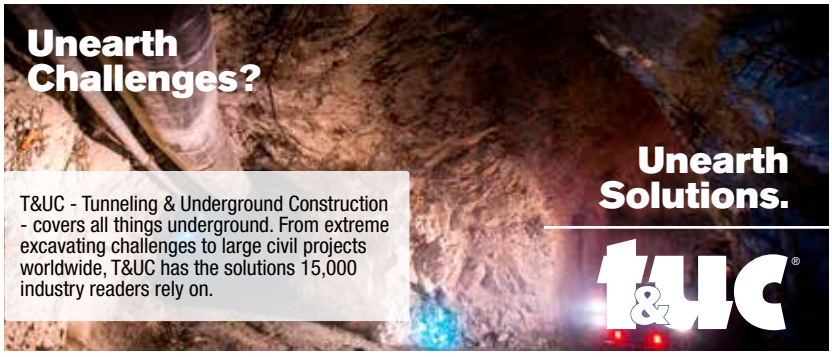

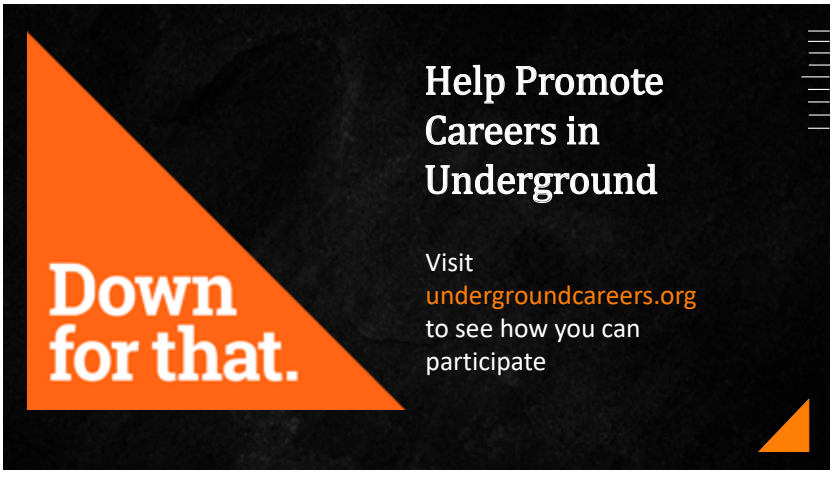

OneTunnel.org

OneTunnel.org is the definitive, global, online digital research library for the entire tunneling, minerals and mining industries. The web-based document library contains more than 140,500 articles, technical papers, books and other documents from industry societies worldwide.

Dig In Today!

Gall Zeidler Consultants

Gall Zeidler Consultants is an international engineering consultancy firm specialized in innovative solutions for tunnel and underground projects. For over 20 years, we use our broad expertise in transportation, infrastructure, water conveyance, energy and mining projects to help our clients overcome challenging conditions and providing innovative solutions from conceptual and planning phases through construction and operation.

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

- Conceptual to Final Design
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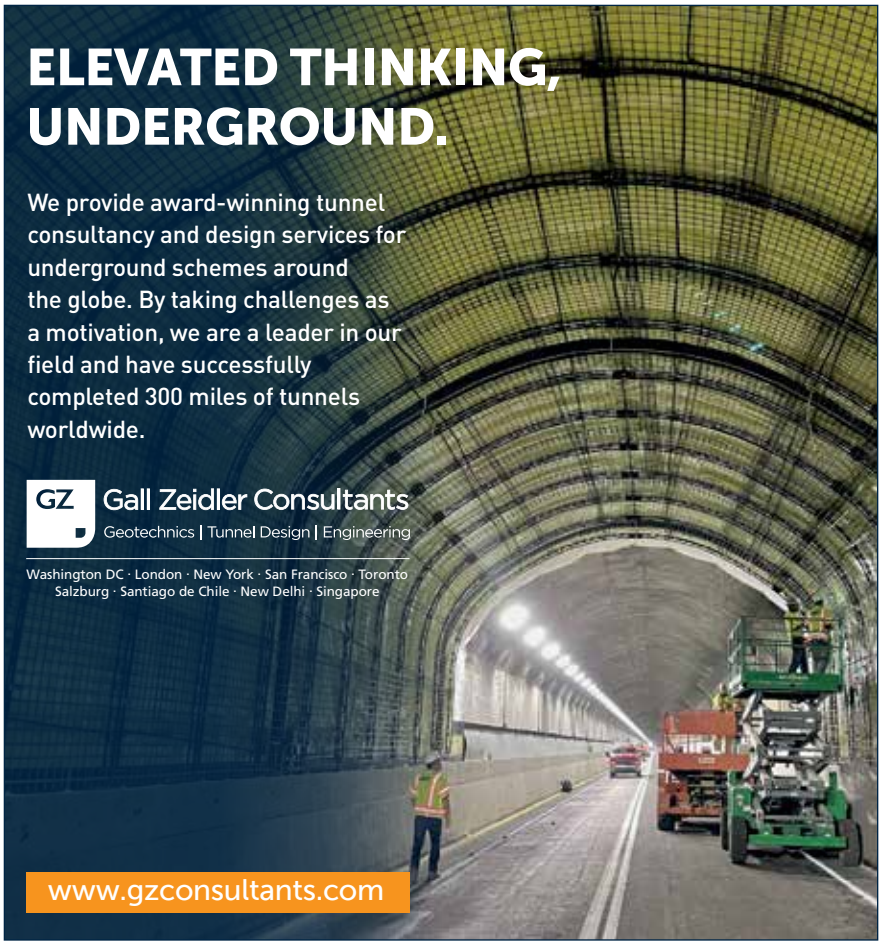
With our diverse team of experts and young professionals, we are represented in all major global markets with offices in North America, Latin America, Europe and Asia.

GZ Gall Zeidler Consultants



Dr. Mole, Incorporated

Doctor Mole, Incorporated is a sole-proprietor consulting practice that was started in January, 2013 when Dr. Brierley stepped down as President of Brierley Associates Corporation. DMI specializes in providing advice to project owners, contractors, and designers about all aspects of the design and construction of underground openings. Dr. Brierley has also been involved with the implementation of scores of subsurface investigations and with the preparation of the Geotechnical Data and Baseline Reports associated with those investigations. As has been noted many times in the project literature, the single-most important aspect of project success for a tunneling project is the provision of accurate and reliable discussions of the ground conditions inside of which the underground openings will be constructed.

DMI is also retained on a regular basis to provide forensic evaluations relating primarily to claims for Differing Site Conditions. Doing "Battle with Mother Earth" is never easy, and when things go wrong during construction it becomes necessary to evaluate what is happening in order to minimize potentially detrimental impacts both to the construction process itself and to existing third party structures and utilities.

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Down for That encourages engineering students to pursue a career in underground construction and tunneling by providing students and professors with introductory industry information including:

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George Fox Conference
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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

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	2023	Under design
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	2022	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	Taylor-Sundit JV awarded
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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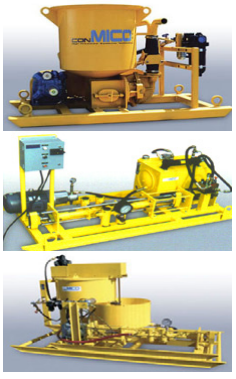

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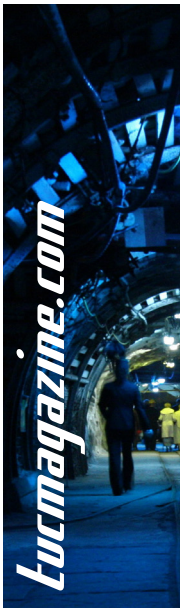

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