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Muck removal and disposal is one of the more mundane but necessary aspects of any tunnel or underground construction project. Increases in environmental considerations have added additional challenges to material handling while recent innovations have moved the process forward. On page 14, experts from Kiewit share their thoughts about the challenges and innovations in material handling. Cover photo courtesy of Robbins.

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Reflections on my term as Chair

And ... WHAM! ... all of a sudden, it's time for my last column as our association's Chair. The term has flown by and so, per the adage, I must've been having fun (most of that is thanks to being able to spend time with all of you). I'm also feeling a strong sense of accomplishment at everything this administration has been able to progress. I thank you all for your belief in me, your support, stepping up to volunteer, providing feedback, participating in conferences and moving the industry forward.

It's traditional that this edition of the column looks back — to establish the benchmark for going forward yet again — and I'm choosing to highlight items from the most recent first rather than chronologically.

In recognition that, from lessons learned, we need to begin impressing the importance of and opportunities within our industry to potential entrants before they hit their final years of college, when decisions may already have been made, we have just established a task force to focus on making an impact with those in kindergarten through grade 12. This is a brand-new initiative that will be led by Sarah Wilson of Delve Underground, and she is looking for motivated volunteers.

This will operate in parallel with and hopefully emulate the flourishing Down for That. The Student Outreach Committee just supported its first tunneling workshop, complementing a plethora of tunnel tours that have been held in the last half-year.

The Owner's Forum, once only active during conferences, recently completed its first "in-between" web-based meeting. We recognize that it can be challenging for owners to participate in UCA as other members do, due to the constraints of the responsibility of their positions, and I am appreciative that this important group is growing and becoming more active.



Michael Rispin
2022-2023 UCA Chair

The Government and Public Affairs Committee (GPAC) is growing, and members participated with the American Society of Civil Engineers (ASCE) in the recent legislative fly-in to Washington, D.C. While the committee is in its early days, I believe that this will be a very important initiative in addressing our strategic ambitions with stakeholder awareness. We simply need to be more structured and persistent with educating decision-makers in the wisdom of underground investment.

The newly expanded UCA Awards program at the North American Tunneling (NAT) Conference received a tremendous amount of positive feedback. It highlighted our industry's achievements and, with its structure, also positioned our winners to compete for recognition on the global stage with the ITA Awards. More expansion is planned, so please stay tuned.

We held a record-setting George A. Fox Conference in January. That was hot on the heels of a record-setting Cutting Edge Conference in November. This reinforces our strategic goal of industry education.

Sandwiched in between, we closed 2022 with the highest-ever level of membership in UCA. This is important as one of our strategic

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Gateway Development Commission highlights progress on Hudson Tunnel Project

The Gateway Development Commission (GDC) Board of Commissioners passed a resolution that finalizes agreements among funding partners on the Hudson Yards Concrete Casing Section 3 on May 5 that will lead to “significant progress and early work beginning in 2023” on the Hudson Tunnel Project, the largest component of the Gateway Program.

The work is described as “the vital portion of the Hudson Tunnel Project linking the new Hudson Tunnel directly to Penn Station New York, for which President Joe Biden announced a \$292 million MEGA grant in January.” The resolution allows work on this element to move into construction, which is expected to begin during 2023.

Other early work projects for the new Hudson Tunnel that are expected to begin construction or procurement this year include the Tonnelle Avenue Overhead Bridge and Utility Relocation Project in New Jersey. Construction is expected during 2023, GDC said in a statement. The procurement processes of the Hudson River Ground Stabilization project and construction of the Palisades are anticipated to launch in 2023 as well.

“This is the year the Hudson Tunnel Project becomes real,” said Alicia Glen, NY Commissioner

and GDC co-chair. “With early construction starting in both New York and New Jersey, we are telling the millions of riders who rely on this route that help is on the way.”

Balpreet Grewal-Virk, NJ Commissioner and GDC co-chair, said: “GDC is making real progress this year pushing vital components of the project forward. I am particularly proud of our focus on working with the private sector to make sure this project is delivered efficiently and expeditiously.”

In addition to the early work, the GDC Board of Commissioners was updated on the overall progress already made on the Hudson Tunnel Project in the early months of 2023.

The GDC board also passed several other resolutions “to continue to build the capacity of the GDC and to advance the Hudson Tunnel Project.”

These include approving \$2.5 million in available stipends for up to four firms to bid on the Hudson Tunnel Ground Stabilization project, a common industry practice that encourages a more competitive and complete bidding pool and ensures the intellectual property of the bids belongs to GDC; establishing committees of the board including audit, governance and operations, and project delivery; and amending the

Hudson Tunnel Project development agreement to incorporate a process for consideration of alternative technical concepts, amend the approval process for certain categories of deviations from design standards and specifications, and expand the membership of procurement evaluation panels.

“Moving forward with early work in partnership with the federal government is vital to this project’s success,” said Tony Coscia, Amtrak commissioner and GDC vice chair. “Our federal support will reduce costs for the local partners and help ensure that the Hudson River Tunnel is a strong, resilient part of the Northeast Corridor for a century to come.”

“We promised that this would be the year that the Hudson Tunnel Project moves from planning to reality, and that is exactly what today’s board action achieves,” noted GDC chief executive officer Kris Kolluri.

“With the agreements and funding now in place, we’ll see construction start this year on the critical concrete casing portion of the project that links the new tunnel to Penn Station. Along with our other early works, the Hudson Tunnel Project is now taking shape more and more each day,” he said. ■

Two TBMS pass milestone on HS2 project

Two Herrenknecht tunnel boring machines (TBMs) have passed the 8.8-km (5.5-mile) mark of their 16-km (10-mile) drive under the Chilterns in England as part of the HS2 tunnel project.

HS2 confirmed that the TBMs called Florence and Cecilia have spent almost two years excavating the twin tunnels between the M25 and South Heath in Buckinghamshire that will help the high-speed rail project protect the environment

while improving connections between London, Birmingham and the north.

Each 170-m (560-ft)-long TBM is lining the project with 56,000 concrete segments to form rings, and grouting them into place as it moves forward.

Designed specifically for the geology of the Chilterns, the first TBMs were launched in summer 2021 from a site near the M25 and have excavated more than 1.8 million m³ of chalk and flint.

As well as digging and lining the tunnels, engineers have also completed the excavation of five shafts that will provide ventilation and emergency access near Chalfont St Peter, Chalfont St Giles, Amersham, Little Missenden and an intervention shaft at Chesham Road.

The 44-m (144-ft) deep shaft at Amersham — which the TBMs have now passed — will be in the

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Tunneling halted at Snowy Hydro project

The tunnel boring machine (TBM) that was halted last year when a 9-m (27-ft) deep hole formed on the surface above it in Australia's Kosciuszko National Park will remain in place until the Snowy Hydro project can prove to the New South Wales (NSW) environment department that moving the TBM will not cause "further damage."

Australia's *ABC News* reported that the NSW Department of Planning and Environment (DPE) said it was investigating the incident and has now placed further environmental conditions on the boring operation.

"Snowy Hydro must prepare a modification report that demonstrates how the project can

safely progress without further environmental damage," the department said in a statement. "Tunnel boring at the Tantangara location is on hold until the department gives approval for operations to continue."

The tunnel being drilled by the TBM named Florence is one of three major tunnels that will form the Snowy 2.0 project, a large hydro-electricity project in southern NSW that is one of the centerpieces of Australia's transition to renewable energy. Snowy Hydro announced in early May that Snowy 2.0 would be delayed by up to two years and was expected to be fully operational by 2029. One of the four main reasons cited by the company for the delay was the issue with TBM Florence.

Snowy Hydro said it took its environmental responsibilities "very seriously" and had been working with the DPE and others since what it called a "surface depression" was identified in December 2022.

"Snowy Hydro has also been working closely with the DPE to provide a scope of works and to progress a modification of the Snowy 2.0 main works planning approval to allow the rectification of this area and provide assurance around future tunneling works," it said in a statement.

It said it expected to submit its modification report to the department "within a week" and was confident the information would "satisfactorily address concerns around future subsidence issues." ■



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Metrolinx releases RFQ for Yonge North Subway Extension tunnel project

The Ontario government announced on April 27 that the search for expert teams interested in building the Yonge North Subway Extension tunnels has begun with the release of a request for qualifications (RFQ). This important milestone brings the project one step closer to getting shovels in the ground on major construction.

The advance tunneling RFQ offers interested companies an opportunity to be included in the bidding process by asking them to present their qualifications and construction expertise.

“The Yonge North Subway Extension is a critical project for York Region that will provide much-needed access to reliable public transit and connect more people to major employment centers in Markham, Vaughan and Richmond Hill,” said Caroline Mulroney, minister of Transportation.

“Together with our partners in Ottawa, York region and the City

of Toronto, we’re demonstrating real progress to make this project a reality and delivering on our plan to build a strong Ontario,” she said.

The package of work includes designing the tunnels, supplying the tunnel boring machines (TBMs), and building the launch shaft and extraction shaft that will be used to lower the TBMs into the ground and bring them to the surface again.

The RFQ also includes design and construction of the walls that will support the underground stations and emergency exit buildings and relocating existing utilities along the route.

The Yonge North Subway Extension will put 26,000 more people within a 10-min walk of transit and is expected to reduce daily travel times for commuters by up to 22 minutes. It will cut the distance traveled by personal vehicles by 7,700 km (4,789 miles) during rush hour and reduce greenhouse gas emissions by more than 4.8 kt (5,300 st) each year.

Through detailed plans and careful construction, the successful tunneling team will dig out the tunnel for the subway extension that will bring TTC Line 1 service to Vaughan, Markham and Richmond Hill.

The announcement follows news of important progress on the approximately 8-km (5-mile) extension. Work has started at Finch Station on early upgrades to accommodate future subway service.

Metrolinx and Infrastructure Ontario will review the submissions made through the advance tunneling RFQ and will create a shortlist of qualified teams that will be invited to bid on the tunneling contract through a request for proposals.

Ontario is investing \$70.5 billion over the next decade to transform public transit in the province, which includes the largest subway expansion in Canadian history, the Ontario Line, the Scarborough Subway Extension, the Eglinton Crosstown West Extension and the Yonge North Subway Extension. ■



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Chair's column: Much was accomplished in two years

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goals is industry and association growth and the hard numbers tell a story.

Additionally, it contributes to a virtuous cycle: more members lead to more volunteers that lead to more contributions that lead to more value creation that leads to more members.

The 2022 World Tunnel Congress and ITA General Assembly saw our member nation organization candidate, Sanja Zlatanic, elected to the Executive Council. Exemplified with her efforts, the United States continues to be recognized as a very strong contributor on the international industry scene.

We got back last year to a post-COVID, in-person NAT Conference, which was highly successful by all accounts. Of note, during that conference, we also held the inaugural Past Chairs Meeting, whereby a forum was established to garner feedback and

receive experienced counsel from those past leaders still active in the industry.

The first Project Watch List was published 1.5 years ago, with the intent of highlighting for society's stakeholders the importance of projects needing to be approved, funded and built.

The Rapid Excavation & Tunneling Conference (RETC) was our first conference back in-person, going all the way back to June 2021. At that meeting, we began our mentoring program for scholarship winners. That program continues at all NAT, RETC and Cutting Edge conferences now, and the efforts of motivated mentors will continue those relationships between conference events.

Volunteer leaders continue to foster relationships with liaison organizations across the industry, leveraging our association's efforts with those of other stakeholders, with the intent of maximizing exposure and progress with all

stakeholders.

Finally, I'd like to recognize the "as-yet-unreferenced in this column" groups in our Workforce Sustainability category — Women in Tunneling, Young Members and Teach the Professors — all of which continue to get stronger and more active and make differences for the industry.

I thank my employer, Strata Worldwide, for the unconditional support of my work time spent as UCA Chair. The next column will come from incoming Chair, Erika Moonin, and I look forward to continuing to serve our association as Past Chair.

I have great gratitude for Bob Goodfellow, as he steps down from the rank of officers, for all that he has done and the support he has given me. Thanks also to the stalwart SME staff who do a lot of heavy lifting and support all us volunteers in our support of our association.

Tunnel on! ■



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Amtrak begins B&P Tunnel Replacement Program work in Baltimore

Amtrak announced that construction activities for its B&P Tunnel Replacement Program launched on March 10 in the Halethorpe and West Baltimore areas. The work includes replacing aging wooden ties with new concrete ties, installing new rail, and completing track drainage improvements.

“This initial project will directly reduce impacts during later construction phases and maximize the benefits of the new Frederick Douglass Tunnel with higher track speeds and greater system capacity,” said Amtrak executive vice president, Capital Delivery, Laura Mason. “Our partners at the Federal Railroad Administration recognize the importance and urgency of this project and have provided \$8 million in key funding to help us complete this critical infrastructure work. We are also grateful to Baltimore Mayor Brandon Scott and the state of Maryland for their partnership and support.”

This project is funded by a grant from the FY 2019 Federal-State Partnership for State of Good Repair Program. These upgrades will enable high-speed operations on all four tracks along this track segment.

“The collaboration between the state of Maryland, Amtrak, our federal partners and Baltimore is making the long-awaited replacement of the B&P Tunnel a reality,” said Maryland Transportation Secretary Paul J. Wiedefeld. “This initial work by Amtrak is laying the foundation for the new Frederick Douglass Tunnel, and will help us improve mobility, access and service for riders throughout the region.”

The overnight work associated with track and tie replacement will take place on Track A from Winans to Bridge interlockings and is not

expected to impact rail service. Bridge interlocking is located north of West Baltimore Station, and Winans interlocking is at the south end of Halethorpe Station. This first phase of the project is targeted for completion early this summer, with additional project work related to the replacement of an existing turnout in Winans with a new high-speed turnout in a future phase.

At nearly 150 years old, the B&P Tunnel is Amtrak’s oldest tunnel on the Northeast Corridor and a single point of failure for both MARC and Amtrak trains. The 1.4-mile tunnel, connecting Baltimore to Washington, D.C., suffers from a variety of age-related issues such

as excessive water infiltration, a deteriorating structure, and delays that impact more than 10 percent of weekday trains.

The \$6 billion program will eventually be advanced by Amtrak and its partners by using federal funding provided by the Infrastructure Investment and Jobs Act (IIJA), also known as the Bipartisan Infrastructure Law (BIL). The program consists of several investment projects to construct new bridges, rail systems and track, an ADA-accessible West Baltimore MARC station and the new Frederick Douglass Tunnel, which will include two new high-capacity tubes for electrified passenger trains. ■

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HS2: Tunnels will connect London and Birmingham

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middle of a road junction just outside the Buckinghamshire town. A “headhouse” will be built on top of the shaft to house safety equipment, with a flint-faced boundary wall and a prepatinated zinc roof to help match the natural tones of the surrounding landscape.

Once complete, trains will pass through the tunnel at speeds of up to 320 km/h, providing zero-carbon journeys between London, Birmingham and the north while freeing up capacity on the existing rail network.

“The Chiltern tunnel will take HS2 underground and safeguard the woodlands and wildlife habits above the tunnel as well as significantly reducing disruption to communities during construction and operation of the new railway,” said Martyn Noak, HS2 Ltd’s head of Tunnel Engineering. “I’ve been very impressed with the progress made by Florence and Cecilia as they make their way unseen beneath the

Chiltern Hills. It’s great to see how much progress they and the teams excavating the five shafts have made and I’d like to thank everyone involved in getting us this far.”

The two TBMs are operated by, Align, a joint venture formed by Bouygues Travaux Publics, Sir Robert McAlpine and VolkerFitzpatrick.

Each machine has a crew of 17 people working in shifts and supported by more than 100 people on the surface managing the logistics and maintaining the smooth progress of the tunneling operation.

“Florence and Cecilia reaching our third shaft at Amersham is a great achievement for not only the tunneling team and the team involved in excavating and preparing the shaft, but also the supporting teams on the surface at the South Portal, manufacturing the concrete segments required to line the tunnel and processing the spoil from the tunnels,” Coralie Peroux, tunnel manager for Align, said. “In particular, I would like to pay credit to the Align Shafts team, working

with our supply-chain partners KJVJ and Keltbray, who have been working tirelessly over the last few months to ensure the shaft is ready for the arrival of Florence and Cecilia.”

Approximately 2.7 million m³ of material — mostly chalk and flint — will be excavated during the construction of the tunnels and used for landscaping. Once construction is complete, the temporary buildings at the south portal will be removed and the site landscaped with around 90 ha of new wildlife-rich chalk grassland habitats.

Chalk grassland used to be widespread across the hills of southeast England and are considered habitat of international conservation significance with just 700 ha left across the Chilterns.

HS2 currently has five TBMs in the ground with a further five due to be launched over the coming years. Together they will create 64 miles of tunnel between London and the West Midlands, including major tunnels on the approach to London and Birmingham. ■



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Calgary Green Line names development partner

Following a successful procurement of the Green Line project, Calgary's new light rail transit (LRT) system, the Green Line board has approved the development-phase agreement and selected Bow Transit Connectors (BTC) as Green Line's development partner.

The Green Line project is the largest infrastructure investment in Calgary's history. It comes with \$5.5 billion in commitments from the government of Canada, government of Alberta and the city of Calgary.

BTC includes Barnard Constructors of Canada LP, Flatiron Constructors Canada Ltd and WSP Canada Inc., along with their financial advisor EllisDon Capital

Inc. Collectively, they will bring shared expertise in underground, aboveground structures and LRT design and construction to deliver phase 1 of the Green Line LRT project.

In addition to the lead construction and design team, BTC are proposing their subconsultants, which, to date, include:

- Delve Underground.
- Platinum Engineering Ltd.
- Egis.
- IBI.
- GEC Architecture.
- Architecture 49.

As additional agreements are finalized, Green Line will share

updates about this dedicated group of subcontractors who will be working collaboratively with the Green Line team through the development and implementation phases.

The development phase is scheduled to begin in May 2023 and be an approximately 16-month process. The timeframe was negotiated with BTC during final negotiations of the development-phase agreement as the more advanced the design is, the higher confidence there is in costs.

At the conclusion of the development phase, the goal is to sign the project agreement and begin the implementation phase. This goal remains on track for 2024. ■

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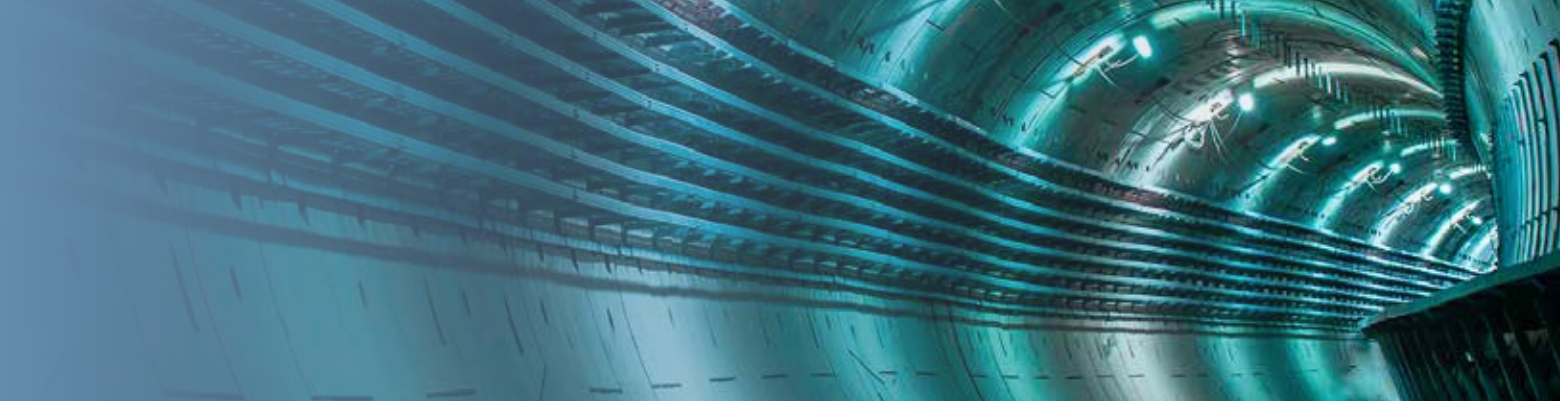
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Potomac River CSO Tunnel	DC Water and Sewer Authority	Washington	DC	2023	CSO	24,000	18	Proposal bid 4/23/2023
Minneapolis Central City Parallel Tunnel	City of Minneapolis	Minneapolis	MN	2023	CSO	4,200	10-19	Final planning
I-70 Floyd Hill Highway Tunnel	Colorado Dept. of Transportation	Denver	CO	2023	Highway	15,840	60 x 25	Under design
Folsom Area Storm Water Improvement	SFPUC	San Francisco	CA	2023	CSO	4,000	12	Under design
Downtown Extension (DTX)	TJPA	San Francisco	CA	TBD	Transit	TBD	TBD	Under design
CA High Speed Rail (Northern Section)	CA High Speed Rail Authority	Fresno	CA	2023	Transit	TBD	TBD	Design 3Q 2023
CA High Speed Rail (Southern Section)	CA High Speed Rail Authority	Bakersfield	CA	2023	Transit	TBD	TBD	Design 3Q 2023
West Santa Ana Line	LACMTA	Los Angeles	CA	2023	Transit	TBD	20	RFQ pending
Ontario Airport Tunnel	San Bernardino Co. Trans. Authority	San Bernardino	CA	2023	Transit	22,000	24	Under design
Gateway Tunnel Project	Amtrak	Newark/New York	NJ/NY	2023/2024	Transit	14,600	28	PDP Procurement ongoing
2nd Ave. Phase 2	NYS-MTA	New York	NY	2023	Subway	16,000	20	Fed approval process ongoing
2nd Ave Phase 3-4	NYS-MTA	New York	NY	2024-2029	Transit	89,600	20	Under study
Fredrick Douglas Tunnel	Amtrak	Baltimore	MD	2023	Rail	40,000	32	SOQs submitted 5/19/23
Alum Creek Relief Tunnel Phase 1 Phase 2	City of Columbus	Columbus	OH	2023 2024	Sewer	30,000 21,000	18 14	Under design Under design
Ontario Line North Extension	Metro Linx	Toronto	ON	2023	Subway	29,500	20	RFP in 2023
West Vaughn Sewage Servicing Project	York Region	Toronto	ON	2023	Sewer	36,000	10	RFQ shortlist completed
Yonge North Subway Extension	Metro Linx	Toronto	ON	2023	Transit	40,000	20	RFQ Pending
Blue Line Extension	Societe de transport de Montreal	Montreal	QC	2023	Transit	19,000	33	Under design
REM-S Project	Societe de transport de Montreal	Montreal	QC	2023	Transit	23,000	33	Under design
Southerly Storage Tunnel	NEORS	Cleveland	OH	2023	CSO	18,000	23	Under design
DELCORA Wastewater Tunnel	DELCORA	Chester	PA	2023	CSO	45,500	13	Under design
Enbridge Line 5 Tunnel	Enbridge	Traverse City	MI	2023	Oil	23,760	12	Proposals received
Mill Creek Trunk Improvements	City of Nashville	Nashville	TN	2023	CSO	13,800	10	Under design
Green Line LRT	City of Calgary	Calgary	AB	2023	Transit	9,000	40	RFP submitted
Nose Hill Project	City of Calgary	Calgary	AB	2023	CSO	10,800	10	Under design
Kensico-Eastview Connection Tunnel	NYC-DEP	New York	NY	2024	Water	11,000	27	Under design

TUNNEL NAME	OWNER	LOCATION	STATE	BID YEAR	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	STATUS
Silver Line Extension	Boston Transit Authority	Boston	MA	2023	Transit	8,400	22	Under design
Yonge North Subway Extension	Metro Linx	Toronto	ON	2023	Transit	40,000	20	RFQ Pending
Stanley Park Water Supply Tunnel	City of Vancouver	Vancouver	BC	2023	Water	5,000	15	RFQ Q4 2023
ALCOSAN CSO Ohio River Allegheny River Monongahela River	Allegheny Co. Sanitary Authority	Pittsburgh	PA	2025 2028 2030	CSO CSO CSO	20,000 28,000 28,000	18 18 18	Under design Under design Under design
Germantown Winghocking Relief	City of Philadelphia Water	Philadelphia	PA	2025	CSO	28,000	20	Under design
Project Connect Subway Program	City of Austin	Austin	TX	2025	Transit	8,500	20	Design delayed
West Seattle to Ballard Extension	Sound Transit	Seattle	WA	2025	Transit	10,500	20	Under design
Northside Interceptor Tunnel	City of Akron	Akron	OH	2023	CSO	6,600	16.5	Bidding
Taylor Massey Tunnel	City of Toronto	Toronto	ON	2025	CSO	20,000	15	Under study
Quebec City - Levis Tunnel	Quebec Trans. Ministry	Quebec	QC	2025	Transit	27,230	60	Under study
Del Mar Bluffs Tunnel	SANDAG	San Diego	CA	2025	Rail	TBD	TBD	Under study
Fraser River Tunnel	BC Ministry of Transportation	Vancouver	BC	2025	Highway	3,000	TBD	RFP expected
Queensway Tunnel	Region of Peel	Toronto	ON	2025	Sewer	18,000	9	RFP Ongoing
Stormwater Control Program	Harris Co. Flood Control District	Houston	TX	2026	CSO	52,800	25-40	Under study
LA Metro Sepulveda Pass Corridor	Los Angeles MTA	Los Angeles	CA	2026	Transit	55,000	TBD	Under design
D2 Subway - 2nd Light Rail Alignment	Dallas Area Rapid Transit	Dallas	TX	2026	Transit	7,230	22	Delayed
Flushing Bay CSO Tunnel	NYC-DEP	New York	NY	2026	CSO	16,500	22	Under study
Cross Harbor Freight Tunnel	PANYNJ	New York	NY	TBD	Rail	25,000	30	Under study
Superconducting Maglev Project - Northeast Corridor	TNEM/BWRR	Washington	DC	TBD	Rail	146,500	43	Under design
Big Creek Storage Tunnel	NEORS	Cleveland	OH	2026	CSO	22,450	20	Under design
Metropolitan Tunnel Program - Northern Tunnel Southern Tunnel	MWRA	Boston	MA	2027 2028	Water Water	23,760 55,000	10 10	Under design Under design
Horizon Lateral Tunnel	Southern Nevada Water Authority	Las Vegas	NV	2027	Water	42,000	9	Delayed
Inner Harbour West Tunnel	City of Toronto	Toronto	ON	2027	CSO	18,400	20	Under design

To have your major tunnel project added to the Tunnel Demand Forecast, or to update information on a listed project, please contact Sanja Zlatanic at szlatanic@hntb.com.

Material-handling innovations and challenges



An overview of the extensive Robbins conveyor system for the DigIndy tunnels below Indianapolis, IN. Photo courtesy of Robbins.

When a major tunneling project commences in an urban area there is often a great deal of attention paid to the tunnel boring machine (TBM) that will be used to create the tunnel. These massive machines capture the attention of the general public and naming competitions are a great way to engage the public in a positive manner. What gets much less attention but is of great importance is what happens to the material that is removed from the earth by the TBM to create the tunnel.

According to Shane Yanagisawa, principal at Osprey Engineers, muck removal and disposal is one of the more mundane but difficult tasks with every tunnel project no matter the size or end use of the tunnel. Advancements in conveyor-belt technology, such as retractable-belt technology, and vertical-belt-storage technology has allowed for more consistent production from TBMs and improved efficiencies. The introduction of multiservice vehicles (MSVs) and rubber-tired transportation vehicles has also helped increase efficiencies in regard to the removal of muck as well as the delivery of materials to

the tunnel face. However, the issue of muck remains a challenge. Increased environmental concerns add another level of complexity to the process.

T&UC recently reached out to material-handling experts at Kiewit, including Abner da Silva, Kiewit underground tunnel superintendent; Christof Metzger, Kiewit underground construction manager; Kurt Kroner, environmental compliance manager, CP2 project and Tee Galbraith, Kiewit logistics coordinator at Fermi to learn more about the innovations and challenges in material handling and muck removal and disposal.

T&UC: What are the primary challenges regarding material (muck) handling in the tunneling and underground construction industry?

da Silva: The transportation of tunnel muck presents a number of challenges in urban areas, especially in densely populated areas. Heavy trucks can contribute to the worsening of the traffic, they bring an extra risk on public roads, pollution and if not cleaned properly, they can bring dirt from the site onto public areas. Hence, a comprehensive planning of the transport routes, identification of adverse conditions and its impacts (are needed). For example, is there a stadium near the job site? How is it going to be on game days? A contingency

William Gleason, Editor



Tunnel construction in Rio de Janeiro, Brazil. (Photo: Henrique Freire/GERJ.)

plan needs to be in place to minimize problems and risks when handling muck.

In addition, in soft-ground tunneling, the soil needs to be conditioned with products to reduce cutterhead torque and friction, improve face stability, reduce torque on the screw conveyor, and reduce adhesion to metal surfaces, among other benefits. Different types of products can be used in the same tunnel project, depending on the geology of the face, and the treated soil can have a different consistency from the in situ soil. The tunnel spoil will then need to be tested to determine potential reuse and/or disposal as waste according to its classification.

T&UC: How many projects use conveyors versus muck cars and how has that changed in the past 10 years?

Metzger: It may not have changed significantly within the last 10 years. It is a project-specific decision process, and many factors need to be considered. Both methods come with advantages and disadvantages.

Whether a conveyor belt is used or not, it does not change the need for a different, and in the case of a conveyor belt usage, additional logistic concept. The TBM will need material supply and tunnel liner segments, and the crew also needs to be brought in to the TBM.

The conveyor belt assembly is often a critical path operation. For this reason, a conveyor belt needs to bring performance-related advantages. A rail-bounded system or the use of muck cars can be used universally. Here are

some considerations for the use of conveyor belts:

- **Length of the tunnel:** In most cases the effort to assemble and remove a conveyor belt is not economical, and muck cars might be a more economical approach. However, the longer the tunnel, the more advantages a conveyor belt will bring to the table.
- **Alignment, especially tight and changing radii:** Conveyor belts can cause challenges in curves, especially S-curves. A train is guided by tracks.
- **Access to the tunnel:** If shafts are in place, a vertical conveying system needs to be installed. Using a train and muck cars will require a cycle study to get the muck cars dumped on time. A vertical conveyor promises a higher performance based on the continuous operation. In that case, it is much easier to feed the vertical conveyor with a tunnel conveyor as transferring the muck material from tracks to the belt.
- **U.S. Mine Safety and Health Administration (MSHA) requirements.** In gassy conditions, equipment may need to be explosion proof. Both systems need to be checked for their pros and cons accordingly.
- **Emission:** Conveyor belts are usually “clean air” equipment. In the case of locomotives, the difference between e-locomotives (battery) and diesel will make a significant difference. Diesel locomotives will require a more extensive ventilation as well.



Material being dumped at Rondout.

T&UC: Multiservice vehicles (MSV) are not yet widely used in North America, what are the possibilities for more MSV usage?

Metzger: The availability of MSVs in North America is limited. The more projects utilizing this approach, the more used equipment will be on the market allowing for the option to become more competitive. MSVs are not a shelf product, and are typically manufactured to meet the specific project requirements. This results in a relatively long lead time. A growing demand will end up in a wider product portfolio and may reduce the specific design phase and lead time. The big advantage for MSVs is the capability of managing steeper grades and tighter radii. The more projects on the market with steeper grades, the higher the demand for MSVs will be. Generally, it will still be a project-to-project decision.

T&UC: In what situation are MSVs a better choice than a rail car system?

da Silva: MSVs are a better option when there is site layout restriction, steep ascents/descents, and when other activities need to be performed in the invert of the tunnel

concurrently with the excavation; since they don't need a track system and have excellent mobility, they can avoid the double handling of material, saving time and cost. As an example, in the new metro line for the Olympic Games in 2016 in Rio de Janeiro, Brazil, the tunnel was excavated using an earth pressure balance (EPB) TBM supported by MSV and a belt conveyor system. The ability to pour roller-compacted concrete in the invert of the tunnel as the TBM excavated was crucial to delivering the project on schedule. The metro line was operational in only four months after the TBM hole through — it wouldn't be possible to achieve such a tight schedule if a rail track system supporting the TBM had yet to be removed after the hole through, pour roller-compacted concrete, and then perform the works for the permanent rail system.

T&UC: What innovations are you aware of that are taking place in material handling?

da Silva: The use of vertical conveyor belts to dispose of muck in shafts. The Shoreline project in Ohio is using a vertical conveyor belt with buckets to transport the material out of the shaft. The alternative to using muck buckets requires a complex hoist system to be efficient.

While conveyors can often be used for changes in elevation, it requires a specific amount of floor space per increase in elevation. The vertical belt conveyor rises straight up to the surface, fully enclosed, with a minimal ground footprint.

T&UC: Environmental considerations play a crucial role in the planning and execution of underground construction projects. How have these considerations altered your work on recent and/or current projects?

Kroner: Proper planning and early strategic positioning on environmental issues have offset impacts. Owners now invest in extensive characterization of soil and groundwater conditions to establish environmental baselines. Rather than confine the risk to the contractor or delivery team, the environmental scope can be well defined and supported by ample environmental data. Owners also engage with regulatory agencies early to establish agreements and to obtain permits for the handling of groundwater and soil. This preplanning helps mitigate cost and schedule impacts by having conditions and requirements well defined. Most projects now have a specification requirement for an environmental compliance manager. This level of expertise is necessary whether specified or voluntarily provided by the contractor to navigate the voluminous data available and to strategically plan. This environmental professional will direct the project using available and new data.

The BART Silicon Valley Extension Phase 2 project performed prebid environmental investigations along the project alignment and worked collaboratively with regulatory agencies to review and approve procedures for the management of potentially contaminated materials generated during construction. The procedures contained thresholds for excavated material reuse and export. Areas containing contaminants requiring special handling were fully characterized to allow assessment by the project team for ensuring worker health and safety, and to properly estimate offsite disposal options.

By engaging in capable and knowledgeable environmental support early in the process, the environmental risks could be effectively managed and be an overall benefit to the owner and contractor.

T&UC: What are the greatest environmental challenges regarding material handling?

Kroner: Worker health and safety. The environmental investigations performed along the project alignment reveal not only a great deal of information to develop disposal costs but also the necessary worker health and safety requirements. The environmental soil sampling data identify contaminant concentrations in the soil from previous industrial activities, and also naturally occurring substances such as asbestos, silica and arsenic. Engineering controls, primarily ventilation, are necessary

to minimize employee exposures. Personal protective equipment designed for the known contaminants is specified for workers that come into direct contact with excavated materials. Monitoring is performed to verify the effectiveness of the control measures and to make adjustments to ensure that work is performed within permissible exposure levels for substances present during construction.

Material disposal. Material disposal is constrained by many factors including truck count restrictions, trucking hours, fuel cost, labor issues, distance, weather closures, disposal costs and environmental screening. Screening of the soil is important to secure disposal at sites that are most desirable based on vicinity, cost and sustainability. If the environmental baseline data are insufficient to classify the soil for disposal, additional sampling will be required prior to construction or during construction. Early discussion with landfills and disposal sites is necessary to determine if lower-cost options can be utilized. If sampling is required during excavation, a sampling program must identify sample turnaround time and adequate soil holding areas while results are pending. Alternative disposal sites must also be ready if disposal is rejected due to exceedance of the screening criteria. Sustainable disposal options, such as quarry reclamation, wetlands creation and landfill capping may have strict soil screening criteria that will need to be evaluated to determine if project soils can be considered.

T&UC: Can you explain the material-handling innovations taking place at the LBNF project at Homestake Mine in South Dakota, and those at the Rondout Project in New York?

da Silva: At Rondout the spoil was loaded on muck cars and hauled from the tunnel to the shaft by train. The shaft is 300 m (900 ft) deep and a comprehensive hoisting system was developed to transport personnel and material supply and fly out the spoil of the excavation. The collar-mounted, base-frame structure was able to fly out a 20-cu yd loaded muck box, dump it on the surface, fly it back down and set it back on the train car all in seven minutes. Each train composition had seven muck cars making the total cycle in less than an hour, enough to keep up with the excavation.

Galbraith: At Fermi LBNF, the project required the refurbishment of the material hoisting and handling system largely idle since the early 2000s. Underground, the work involved the rehabilitation of an ore pass to and loading pockets at the 5,000-ft level. On the surface, the project team refurbished the surface crusher system and then installed a 1,700-ft conveyor system crossing an active highway to the previous mines open pit. The system is designed to handle a maximum of 2.7 kt/d (3,000 stpd) and has processed approximately 453 kt (500,000 st) to date. ■

Environmentally friendly soil conditioning for EPB TBMs — The state of environmental considerations around the world

Environmental considerations are widely present in the modern world, and there is a global push in most industries for sustainability and environmental consciousness. In the tunneling market, many projects being built are intended to benefit the environment.

One critical aspect of tunnel projects that must be considered is muck handling and disposal. Tunnel boring machines (TBMs) generate a lot of muck. Earth pressure balance (EPB) machines are one of the most common TBMs, especially in urban areas. Chemical products such as foaming agents and polymers are added to the soil to allow for the safe and effective operation of EPB machines. When it exits the TBM the muck produced is laden with these soil-conditioning chemicals. These residual chemicals may pose an environmental impact if improperly managed.

Special disposal restrictions on EPB muck can add logistical challenges and increase the overall cost of a project, as acceptable disposal sites may be farther away with the possibility of more expensive disposal fees.

Several countries in Europe have developed programs intended to minimize the environmental impact of tunnel muck. As a direct response, MAPEI has developed innovative new foaming agents with significantly lower ecotoxicity and higher biodegradability, and their use has been widely adopted in these countries.

Many localities around the world have limits for substances such as heavy metals and hydrocarbons but these are not used in the formulation of foaming agents, while other potentially harmful ingredients common in foaming agent formulations like alcohol and glycol remain unregulated.

Soil-conditioning overview

With the addition of water, air and special soil conditioning agents, including foams and/or polymers, soil

conditioning is used to modify the characteristics of the ground, making it more suitable for tunneling with EPB TBMs. Well-conditioned soil improves face stability, reduces wear on machines, improves the flow of material out of the chamber, increases productivity and reduces downtime. Proper soil conditioning is critical to the success of any EPB TBM project.

Foaming agents. The most common type of soil conditioners are foaming agents. They are concentrated solutions that are first mixed with water and then passed through a foam generator with the addition of air to create a foam. The foam is injected into the cutting head, mixing chamber and/or screw conveyor. There are several parameters of the soil conditioning that may be adjusted including:

- Concentration (cf) — the volumetric ratio of foaming agent to water.
- Foam expansion ratio (FER) — the volumetric ratio of air to foam solution.
- Foam injection ratio (FIR) — the volumetric ratio of foam to soil.

On an EPB TBM, the operator of the soil-conditioning system will adjust these parameters as needed for the specific ground conditions.

Composition of foaming agents. Foaming agents are typically formulated with the following ingredients:

- Surfactants.
- Polymers.
- Solvents.

Surfactants are the main component of most soil conditioners. They lower the surface tension of water to aid in the generation of foam. Different foaming agents may contain different types of surfactants, such as cationic, anionic and others.

Polymers are included in foaming agents to enhance the technical properties of the foam, such as half-life, lubrication and dispersion characteristics. Polymers may be of either synthetic or natural origin. Solvents are used in some foaming agents and include chemicals like alcohols, glycols, dichloromethane and more. Although solvents, if present, are typically present in low quantities, they are not rapidly degradable and are toxic to the environment.

C. Oñate Salazar and T. Murt

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Technical aspects. With the proper balance of ingredients, foaming agents are designed to meet technical requirements for excavating with EPB TBMs. In choosing which soil conditioners to use, preliminary analysis and testing is typically done before the start of the project. First, relevant project information is analyzed, including review of TBM characteristics, tunnel alignment, geotechnical baseline report (GBR), hydrological aspects of the tunnel route and past projects in the area. Next, preliminary laboratory testing is performed with soil samples acquired along the alignment, typically from investigative borings. Testing done on the natural soil include moisture content, density, grain size distribution and Atterberg limits. Next, soil conditioning agents are mixed with the soil, which is then tested for slump, flow, visual consistency, stickiness and impermeability.

Soil-conditioning parameters and doses are adjusted until the soil exhibits behavior ideal for EPB tunneling. These tests are useful to find the most suitable products for conditioning, and to determine the initial soil conditioning parameters. Once tunneling begins, the soil conditioning parameters are optimized on the TBM. As the geology changes along the alignment, the parameters are further adjusted and refined.

Technical performance is a critical aspect of soil conditioners, but as the construction industry moves to more environmentally conscious practices, the impact of soil conditioners must be considered.

Environmental impact of soil conditioning

A tunnel project can create an enormous amount of spoil. As an example, a tunnel 10 km (6 miles) long with a diameter of 10 m (33 ft) would require the removal of approximately 1,000,000 cu yd of soil. Conditioning this soil for excavation would require 757,000 to 908,000 L (200,000 to 240,000 gal) of foaming agent, given typical dosing.

Management of muck. Muck is often thought of as waste that needs disposal, but in the right conditions, muck can be a valuable resource. While excavated material from hard-rock tunnels is widely considered the most valuable and easiest to process type of spoil, soft-ground muck can be valuable too, and engineers and contractors are continually looking for ways to better utilize soft-ground spoils. In a 1977 handbook sponsored by the U.S. Department of Transportation titled “Muck Utilization Planning,” many of the possible uses for tunnel muck were considered (see Table 1). Table 1 summarizes information from the publication and demonstrates some of the best uses for different types of soft-ground tunnel muck.

Today, these various uses remain relevant to soft-ground muck; however, it is important to note that the handbook was published before EPB TBMs became popular or their use in tunneling became widespread. The presence of soil conditioners and how they would affect the muck was not considered. Today, research programs

like the DRAGON Project (a collaboration between the governments of Austria, France, Germany, Switzerland and the UK) and the “Re-Muck” program in Italy continue to push for efficient reuse of muck as a resource (International Tunneling and Underground Space Association ITA report No. 21, April 2019). These programs envision a more sustainable future of tunneling.

Rather than disposing of tunnel muck in a landfill, these programs advocate for repurposing and reuse. Efficient use and recycling of tunnel muck can reduce the need for mining of mineral resources while sending less material to landfills. Often, carbon emissions can be reduced by minimizing material handling and transportation. Environmentally friendly soil conditioners play a critical role in this process, allowing for more options and flexibility in the reuse of EPB TBM muck.

Development of environmentally friendly soil conditioners

Many manufacturers are working to develop soil conditioners that are less harmful to the environment. With large investments in research and development, MAPEI has developed one such new product line of

TABLE 1

Muck utilization suitability chart.

Category	Soft-ground muck	
	Sand and gravel *	Silt and clay*
A. Construction material		
Engineered, compacted fill	1	3
Controlled fill	1	2
Uncontrolled fill	1	1
Sanitary landfill (cover material)		
Daily cover material	2	1
Permanent cover material	3	1
B. Specialized material		
Bituminous concrete aggregate	1	3
Portland cement concrete aggregate	1	3
Pavement base and subbase aggregate	1	3
Lightweight aggregate	3	2
Portland cement	3	1
Fired-clay product	3	1
Source: Liu, 1977.		
1 = Excellent, 2 = Satisfactory, 3 = Poor		

FIG. 1

EC50 to *Daphnia magna*, comparison of Polyfoamer ECO line to traditional foaming agents.

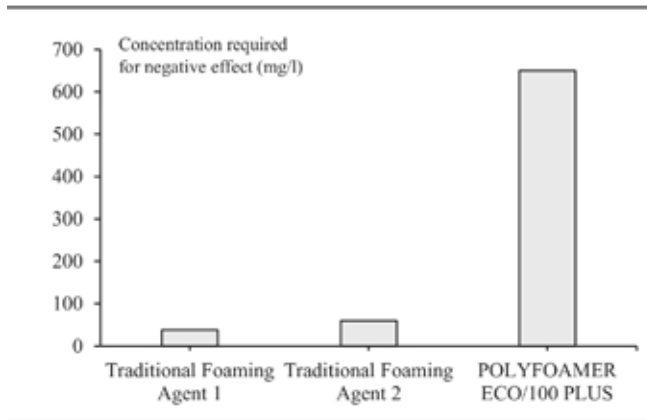


FIG. 2

LC50 to *Danio rerio*, comparison of Polyfoamer ECO line to traditional foaming agents.

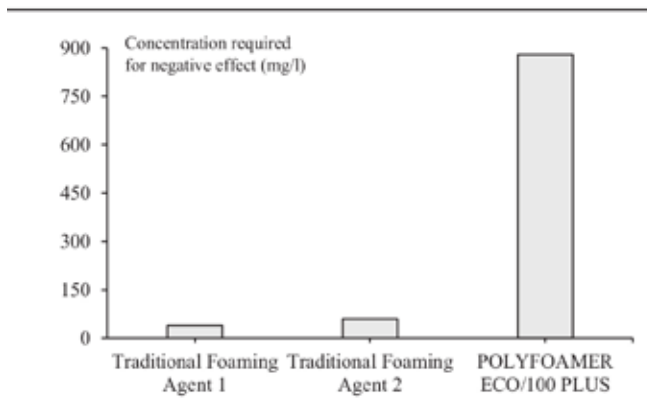
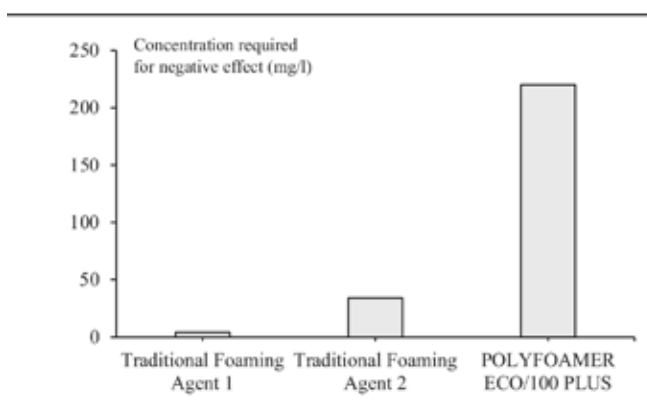


FIG. 3

IC50 to green algae, comparison of Polyfoamer ECO line to traditional foaming agents.



foaming agents called Polyfoamer ECO.

These new foaming agents are based on biodegradable anionic surfactants in combination with a natural biodegradable polymer. They contain no glycols or other solvents with low biodegradability (common to many traditional foaming agents). While significantly less harmful to the environment, with minimum ecotoxicity and high biodegradability, the foaming agent maintains a high technical performance standard, comparable to that of traditional foaming agents.

Environmental impact. When considering the environmental impact of soil conditioners, criteria for comparison testing must be defined. Two important environmental benchmarks for soil conditioners are ecotoxicity and biodegradability.

Ecotoxicity. Ecotoxicity is defined as the amount of a chemical product required to have an adverse effect on populations of living organisms exposed to it. Exposure testing is done on a variety of aquatic and terrestrial organisms. Adverse effects are recorded including lethality, inhibition of growth, movements or reproduction.

The ecotoxicity of the newly developed foaming agents is far lower than those of traditional foaming agents. Figures 1, 2 and 3 show comparisons with selected soil conditioners' toxicities to the planktonic crustacean *Daphnia magna*, fish *Danio rerio*, and green algae, respectively. The toxicity toward *Daphnia magna* (Fig. 1) is measured according to the Organization for Economic Cooperation and Development (OECD) Test No. 202, and the values registered are EC50, the concentration of each product at which 50 percent of the initial population of *Daphnia magna* is immobilized in 48 hours.

The toxicity toward *Danio rerio* (Fig. 2) is measured according to OECD Test No. 203, and the values registered are LC50, the lethal concentration of each product at which 50 percent of the population is killed in 96 hours.

The toxicity toward green algae (Fig. 3) is measured according to OECD Test No. 201, and the values registered are IC50, the inhibitory concentration of the test substance that results in 50 percent inhibition of growth rate of the green algae in 72 hours.

These figures demonstrate that the new foaming agent is 10 to 15 times less toxic toward these living organisms than traditional foaming agents.

Biodegradability. Biodegradability is the ability of a material to break down over time. Biodegradability of chemicals is typically evaluated considering the chemical oxygen demand (COD) and the biochemical oxygen demand (BOD), which measures how much oxygen is consumed to degrade the organic content. The lower the organic content of the foaming agent introduced to the soil, the lower the oxygen demand will be.

The state of environmental considerations. Around

the world, no one standard exists for quantifying the environmental impact of tunnel spoils or the soil conditioners contained in them. When considering the environmental impact of soil conditioners, much of the world has some catching up to do.

The most common testing done on tunnel muck does not consider soil-conditioning agents. For example, European guidelines 2008/98/CE establish a test known as lixiviation, which determines the concentration of several harmful substances that may present in soil. Most are naturally occurring in trace quantities, and include heavy metals like lead, cadmium and mercury, as well as hydrocarbons. However, since soil conditioners do not contain these materials, the environmental impact of soil conditioners themselves is not considered or evaluated.

Projects in the United States, like many other countries around the world, generally do not consider biodegradability or ecotoxicity of soil conditioners present in muck. Limitations are typically related to hydrocarbons and heavy metals only. Because regulations do not exist, traditional soil-conditioning agents are widely used, even those with a high dose of solvents that may be particularly harmful to the environment.

On the other hand, countries such as Italy, Denmark, the UK and others use a holistic, case-by-case process. In practice, testing of soil conditioners begins in the design phase of a project. First, the biodegradability and ecotoxicity of potential soil conditioning agents are evaluated alone in their pure state at an independent laboratory. This establishes baseline values for the soil-conditioning products that are being considered. In the next phase, laboratory work begins with soil samples from the tunnel, where soil conditioning parameters and dosages are determined and the conditioned soil is evaluated for both technical attributes and environmental aspects (ecotoxicity and biodegradability). Finally, as the excavation begins, and throughout the course of the job, regular tests are conducted on the muck to ensure compliance with biodegradability and ecotoxicity guidelines established by respective environmental regulatory agencies.

Once the muck leaves the tunnel, it must be stockpiled until it has been deemed safe for transport for final disposal or reuse. Tests on the conditioned soil are carried out at different times (after one day, three days, seven days, and so on) to measure biodegradation. Curves can then be plotted to determine when the muck has reached an acceptable threshold for biodegradation and ecotoxicity. This way, muck conditioned with rapidly biodegradable, low-toxicity foaming agent is able to pass the tests for

removal from the site in shorter time. Reducing this waiting time through the use of environmentally friendly soil conditioners is of particular benefit to jobs in urban areas with small site footprints.

Conclusion

Excavated material disposal is a critical part of any tunneling job and is especially important for EPB TBMs. In general, soft-ground spoils are less desirable for reuse than rock. In addition, the chemicals present in the conventional EPB muck make disposal even more difficult, and it is not uncommon for projects to be negatively impacted due to the limited muck disposal options and cost.

Global regulations, protocols or standards should be studied and instituted for TBM muck management. The use of environmentally friendly soil conditioners is not only about respect for the environment and sustainability, but may also reduce project costs. In some cases, the use of environmentally friendly soil conditioners may allow reuse of the excavated soil, while also avoiding longer trucking distances needed for special muck disposal. Several miles of EPB TBM tunnels have already been completed using new environmentally friendly soil conditioners. This demonstrates that ecofriendly soil conditioners bring an exceptional opportunity because they are formulated with natural ingredients that provide the high technical performance of traditional foaming agents, but greatly decrease the impact of EPB TBM muck on the environment. ■

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Innovative approach for dust control in tunnel construction

Airborne disease-causing dusts are found throughout the tunnel construction process, including in excavation, shotcreting and material loading and transporting. Not only does dust cause immediate jobsite challenges of reduced visibility, lost materials, lower productivity and additional wear and tear on equipment, respirable crystalline silica (RCS) exposure at hazardous levels can also lead to a myriad of health problems for tunnel workers including lung cancer, silicosis, pulmonary disease and kidney disease. Silicosis is the most common occupational lung disease worldwide and is often referred to as the “modern-day asbestos.”

It is estimated that up to two million construction workers in the United States are exposed to RCS in 600,000 workplaces (OSHA, 2017). The risk of dust-related diseases increases with exposure levels.

Workplace health and safety legislation now place strict requirements on the management of dust, with many countries lowering the workplace exposure limits for RCS. For example, Australia recently lowered limits to $0.05 \mu\text{g}/\text{m}^3$ over an eight-hour working day (Safe Work Australia, 2020).

In 2016, the U.S. Occupational Safety and Health Administration (OSHA) reduced the limit for exposure levels for construction workers to $25 \mu\text{g}/\text{m}^3$ as an eight-hour time-weighted average under any foreseeable conditions (OSHA, 2016). Restrictions continue to tighten as awareness of the dangers of RCS increases worldwide, resulting in significant impacts on construction projects.

Many known methods exist for dust control in tunnel construction, including dilution and displacement ventilation, water spray, foam, respirators and wet and dry dust collectors that operate onboard but separate from excavation equipment. The effectiveness of each method is determined by many factors. Identifying these factors is critical in designing a successful dust control program.

In accordance with the National Institute of Occupational Safety and Health (NIOSH) (CDC, 2015) global hierarchy of controls, dust collectors and water suppression are both engineering controls that can help isolate workers from hazardous dust. While these methods can be more costly up front compared to administrative controls or personal protective equipment (PPE), they are generally more effective over the long term and can provide cost and operational savings over time.

Water suppression uses spray systems to apply water

and/or chemicals that weigh down dust particles and make it less likely for them to become airborne. The effectiveness of spray systems depends on the applied water's velocity, the orientation of the sprayers, the size and location of the spray nozzles, and the type and size of the dust particulates in the air. These low-tech systems are simple to design and operate, and the equipment is relatively low cost. However, there are several drawbacks to the water-suppression method. These include:

- Many materials are hydrophobic and fail to mix with water.
- Water cannot be used in freezing temperatures.
- Overwetting is common due to the large volume of water needed, causing excessive moisture in the working area and material buildup on equipment and transfer points.
- Droplet size of the water mist also must correctly match the size of the dust particulates, or it cannot adhere to dust and effectively suppress it.

Mobile dry dust collectors provide an effective alternative. By collecting dust at its source when using a roadheader, hydraulic hammer and/or drill and blast, they keep the job site clean and dry, while improving air quality and visibility for workers. They can collect a wider size range of dust particulates and are more effective at limiting RCS and other dangerous contaminants. Furthermore, mobile dust collectors can be configured to work in a variety of ways to conserve space in the working area while keeping workers protected. Such configurations will be explored in this article with the introduction of Grydale mobile dust collectors and key projects that have used them to provide effective ventilation and at source dust control for station, shaft, cross passage and adit excavation.

Ventilation design systems in tunneling

Ventilation and dust control determinant factors. A critical aspect of tunnel construction is ventilation design, so that workers' exposure to fumes, dust and silica are reduced to safe and acceptable levels. There are many types of ventilation designs and as each tunnel is unique, so too is each ventilation design. Every ventilation system has limitations in terms of dust control, with the selection of the system being dependent upon:

- Geology.
- Climate.
- Tunnel dimensions.
- Location and site access.

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- Construction method and sequence.
- Excavation rate targets.
- Cost of materials.
- Ease of maintenance.

There are three main factors affecting the typical volume of air flow required within tunnel construction works. Safe Work Australia and several other safety organizations in other countries have adopted standards for these areas. They include:

- Air flow: a minimum of 0.5 m/s (1.64 fps).
- Diesel plant: calculated at 0.066 m/s (0.217 fps) per kW of diesel.
- People: calculated at 0.25 m/s (0.082 fps) per person working within the tunnel.

These all combine to determine the type and capacity required for a ventilation and dust extraction system.

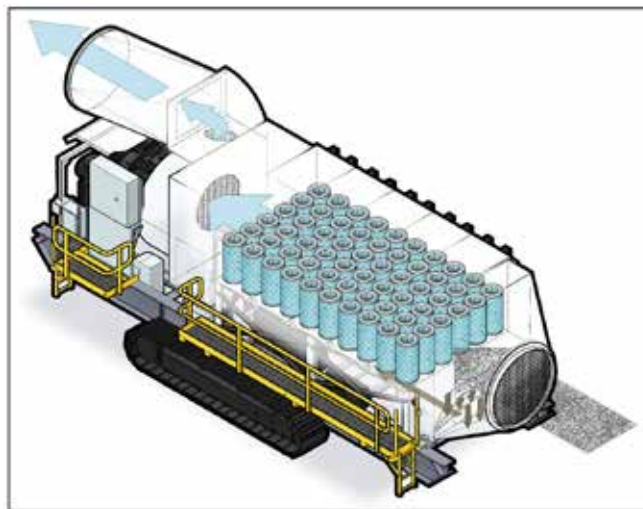
Common ventilation systems. A forced ventilation system is the most common type of ventilation system used in tunnels under construction. Much like a forced-air system for a personal residence, air outside the tunnel is forced into the tunnel via a system of ducting and fans, creating a pressure differential between the tunnel and outside atmosphere. The higher atmospheric pressure at the tunnel face causes air to flow through the tunnel and back out into the environment, carrying with it all the dust, diesel particulates and other airborne contaminants. This also means that the contaminants are drawn past workers and equipment as air makes its way out of the tunnel, making this system the least effective way to control exposure to dust.

Another common ventilation system is the overlap ventilation system. In overlap ventilation systems, air is pushed into the tunnel using a fan, and the dust scrubber is overlapped with the ventilation outlet. Negative pressure is used to pull air through the tunnel and create two air flows within the tunnel. As air flows need to be balanced, it is critical when using this system to have a ventilation design that works with the construction sequence. An overlap ventilation system is normally deployed in the extraction face of a roadheader or other similar sequential excavation method (SEM) tunnels, and is best suited for long road and rail tunnels.

An extract ventilation system, also known as exhausting or reverse ventilation, is where air is drawn through the tunnel from the outside atmosphere and exhausted via a single duct to a scrubber to deliver clean air to the atmosphere. Air inflow needs to balance with air exhaust volume. Scrubbers can be located within station boxes, where louvres balance airflow into the tunnel or within the shaft. These systems work well for short tunnels where they can be installed as permanent solutions for the duration of the project, reducing risks of contact with contaminants at the tunnel face and contaminated air

FIG. 1

Schematic of a Grydale 50-m³/s (105,000-cfm) track-mounted, hybrid-powered dust collector.



mixing with the surrounding tunnel air.

While forced ventilation is the most common approach in tunnel construction, overlap ventilation and extract ventilation systems, when properly designed and used with the appropriate dust collector(s), provide more effective solutions to dust control during tunnel construction.

Use of mobile dust collectors for dust control

Grydale mobile dust collectors (Fig. 1) use a centrifugal fan to draw dirty air into the unit through one or multiple air intakes via ducting. Larger dust particles fall into the drop-out box and are separated from the air stream, which increases the life of the filters. Dust and fumes are trapped on the filters, forming a “cake” on the surface as air passes through the filter house. A reverse-pulse filter cleaning system cleans the filters using an onboard air compressor.

Dust particles are discharged from the machine via the augers and rotary valves, either onto the site floor, via incline augers to bulker bags, or as a wet slurry. An air-velocity probe monitors the air speed, and the variable-speed drive turns the centrifugal fan up and down to maintain the required air volume.

Different mobility options (Table 1) including skid-mounted, caster wheel, hydraulic stepper and track-mounted units allow mobile dust collectors to be used at every stage of shaft, tunnel, station and cross-passage construction. Depending on mobility type and project parameters, mobile dust collectors can deliver forced air from the surface or provide targeted dust extraction at source in the underground excavation area. To add further adaptability to the needs of each construction site, dust collectors can be built to use diesel, electric or hybrid power.

Mobile dust control case studies

Metro Tunnel, Melbourne — Central Business District Stations

TABLE 1
Comparison of mobility options.

Skid	Caster wheel	Hydraulic stepper	Track
<ul style="list-style-type: none"> Used for benching and ancillary works where a high level of mobility is required for a short duration to capture dust at source. Controlled with remote control. Largest profile mobility option. 	<ul style="list-style-type: none"> Used for cross passages in TBM rail tunnels where space is limited. More maneuverable than a skid. Can be mounted on utility platforms. Intermediate profile mobility option. 	<ul style="list-style-type: none"> Designed to walk 6 m (19 ft) in 30 minutes, in line with typical roadheader advance rates. Predominantly used at the tunnel face. Works well when steady advancement is needed without having any downtime in production activities. Self-propelled mobility. Intermediate profile mobility option. 	<ul style="list-style-type: none"> Moves up to 2–4 km/h (1.24 to 2.48 mph). Used for benching and ancillary works where a high level of mobility is required for a short duration to capture dust at source. Controlled with remote control. Largest profile mobility option.

Tunnel section: Stations

Excavation method: Roadheader/cut and cover

Ventilation system: Extract

Mobility type: Tracks, skids, caster wheel

Air volume: 60 m³/s (skid), 30 m³/s (track), 10 m³/s (skid and caster wheel)

The Metro Tunnel is a key rail infrastructure project underway in Melbourne, Australia that includes the construction of twin 9-km (5.59-mile) rail tunnels and five new underground stations. Site geology consists of interbedded siltstone and sandstone known as the Melbourne Formation, with a minerology of primarily quartz.

The Melbourne metro stations are being built as trinocular caverns, where three overlapping tunnels reach a platform width of about 19 m (62.34 ft) — one of the widest metro platforms in the world. The stations employed a cut-and-cover methodology using traditional top-down excavation and was mined by roadheaders. The Cross Yarra Partnership, a consortium consisting of John Holland Pty Ltd, Lendlease Engineering Pty Ltd and Bouygues Construction Pty Ltd, selected Grydale machines for at-source dust extraction during shotcreting and bolting of the walls as well as for general ventilation when the cover was installed. The station's location in the heart of the central business district (CBD) presented several unique challenges, including space and noise constraints.

The system used nine skid-mounted electric mobile dust collectors each generating 60 m³/s (125,000 cfm) of air volume for general ventilation of the CBD North (four units) and south stations (five units). At both stations, dust collectors were mounted on the surface within acoustic sheds, leveraging a full extract system to deliver clean air to the underground working area, as seen in Fig. 2. Grydale designed the ventilation system around this revolutionary approach to minimize

FIG. 2

Ducting extends from the dust collector mounted at the surface into an underground station in the heart of Melbourne, Australia.



machine movements in a confined area with the main benefit being to the personnel underground working in a clean environment.

On the underground Parkville Station, directly north of the CBD Stations, one diesel 30-m³/s (60,000-cfm) mobile dust collector on tracks and three electric 10-m³/s (20,000-cfm) drag skid units are being used during shotcreting to provide short-term dust extraction at the source as well as serving as general ventilation for areas with dead zones.

For tunnel cross-passage excavation, two electric caster-wheeled units creating 10 m³/s (20,000 cfm) air volume provided dust control at the source. These units were designed with caster wheels, allowing the units to slide onto the tightly constrained cross-passage platforms for the duration of construction. Three diesel 30-m³/s (60,000-cfm) track units have been used

for dust extraction within back-end works at various project work sites.

Using multiple sizes and styles of mobile dust collection units provided the required amount of airflow to manage dust by the most effective means during station development.

City Rail Link (CRL) — Karangahape Station

Tunnel section: Station

Excavation method: Roadheader

Ventilation system: Extract

Mobility type: Skid

Air volume: 60 m³/s

The City Rail Link (CRL) is Auckland's first underground rail line and the largest transport infrastructure project in New Zealand. The 3.45-km (2.14-mile) twin tunnel includes the construction of two new inner-city stations, Karangahape (K-Road) Station and Aotea Station. The K-Road Station has a unique layout and dimensions and is being excavated by two Mitsui S200 and Mitsui S300 roadheaders. The Link Alliance Joint Venture (Vinci Construction Grand Projects S.A.S, Downer NZ Ltd, Soletanche Bachy International NZ Ltd, WSP Opus (NZ) Ltd, AECOM New Zealand Ltd, Tonkin+Taylor Ltd and CRL Ltd.) is managing construction of the tunnels and stations.

K-Road's ventilation design was separated into 15 construction stages and designed around the last stage when maximum airflow was required. Each stage represents changes to the tunnel area as construction advances. Ventilation modeling confirmed that a 450-kW electric 60-m³/s (125,000-cfm) dust collector would meet the ventilation requirements for the entire station excavation.

Construction began in August 2020 with the Mercury Lane temporary shaft, which is 15 m (49.21 ft) wide and 27 m (88.58 ft) deep. The shaft serves as an access point to the mined tunnels for all excavation equipment. Ventilation requirements for the excavation of the temporary shaft were met by a 90-kW axial fan with an open-circuit capacity of 46 m³/s (97,468 cfm). The axial fan continued to be used throughout the construction of K-Road to increase air flow into the tunnel to balance the extraction rate.

The fan was mounted alongside the dust collector on a mezzanine within an acoustic shed on the surface and connected via 1,600-mm (63-in.) steel ducts to the excavation area through the shaft. The use of rigid steel ducting helps to reduce pressure loss within the ventilation design.

The Mitsui S200 roadheader was launched from the Mercury Lane shaft to excavate the first tunnel platform and two intermediate adits before breaking through at the Beresford shaft. The tunnel stub (where the passing TBM will pick up excavation within the station) was excavated using a twin header on a 14T excavator.

The Mitsui S300 was then used to overcut the tunnel and brattice was installed to block open sections of tunnel that would otherwise have resulted in air loss to create sections within the tunnel. Once brattice work was complete, the Mitsui S200 was launched in the second tunnel, following the same extraction method back toward Mercury Lane.

Sydney Metro — Central Station, Central Walk

Tunnel section: Station and underground pedestrian walkway

Excavation method: Excavators — buckets and drum cutters

Ventilation system: Extract

Mobility type: Skid

Air volume: 50 m³/s

Sydney Metro is Australia's biggest public transport project, extending the existing rail network in the country's most populous city. Construction is currently underway to expand the system under Sydney Harbor and the Central Business District, including 66 km (41 miles) of twin tracks and 31 stations by 2024.

Central Station is an existing underground station undergoing construction. New developments include expanding the station to include a new 19-m (29.53-ft)-wide underground pedestrian concourse that will provide access to existing and new platforms through an extensive elevator system. Central Station and its landmark Central Walk were awarded to Laing O'Rourke.

An electric skid-mounted dust collector with 50 m³/s (105,000 cfm) capacity was selected as the best solution based on footprint, cost and cleaner energy. The dust collector was mounted on the surface at the main access shaft, with ducting running down at a 90-degree angle before turning under to run along the tunnel drive. Locating the dust collector at the surface reduced the plant footprint within the excavation area. Small, portable axial fans were also used to direct air flow into corners and prevent dead zones.

There are eight escalators and eight shafts along Central Walk: four on the southern and four on the northern side. When construction of each section commenced on the southern side, the coinciding escalator shaft was opened to the surface, and dust extraction was provided to the area by the dust collector. Once excavation was completed, extraction ducting was returned to the furthest excavation face. Air was then drawn into the working area through the access and escalator shafts. This process was followed for the northern side of Central Walk.

Fiberglass-reinforced panel (FRP) works followed excavation. A brattice wall was installed to separate the fit-out area from the excavation area. To ensure sufficient airflow, the brattice wall required openings to provide air in both areas. The openings needed to have a cross-sectional area below 25 m² (269 sq ft);

FIG. 3

In-tunnel dust collector on tracks extracting dust at its source during excavation.



otherwise, the FRP area would not receive ventilation from the surface-level dust collector.

WestConnex — 3A (M4-M5 Link) and 3B (Rozelle Interchange)

Tunnel section: Mined tunnels

Excavation method: Roadheader

Ventilation system: Overlap

Mobility type: Hydraulic steppers, tracks

Air volume: 10 m³/s, 20 m³/s, 30 m³/s, 40 m³/s, 50 m³/s, 60 m³/s

WestConnex is Australia's largest infrastructure project connecting a link between the inner city, west Sydney, the Sydney Airport, and southwest Sydney in a continuous 33-km (21-mile) motorway. This will be Australia's most extensive underground network of urban road tunnels and is expected to significantly reduce capacity constraints and traffic congestion. Construction will consist of four stages, with 3A and 3B being the final two stages of the project, scheduled for completion in 2023.

Stage 3A, managed by the Acciona/Samsung/Bouygues (ASB) joint venture, is the WestConnex M4-M5 link and consists of twin 7.5-km (4.66-mile) tunnels to accommodate up to four lanes of traffic in each direction. Stage 3A is being mined by 28 roadheaders.

Stage 3B, managed by John Holland/CPB (JHCPB), is the Rozelle interchange, consisting of a group of underground tunnels mined by 22 roadheaders. The geology consists of Hawksberry sandstone with dykes and fault zones present.

Both sections primarily used an overlap ventilation system. As 3A consists of twin tunnels with no stations, the ventilation design was relatively straightforward. However, the design of 3B was both intricate and complex. From an isometric view, the interchange

basically resembles a plate of spaghetti, with sections of tunnels having less than 4 m (13 ft) of cover. In addition, mainline cavern spans were up to 28.49 m (93.5 ft) with ventilation facilities as high as 21.03 m (69 ft) in the tunnel.

Stage 3A has 41 Grydale dust collectors: 25 × 50 m³/s (105,000 cfm) hydraulic stepper units and 16 × 50 m³/s (105,000 cfm) tracked units, both using hybrid power. Stage 3B had 28 units: 22 × 40 m³/s (85,000 cfm) and six 60 m³/s (125,000 cfm) hydraulic stepper, hybrid-power units, plus rentals of 10 tracked units in varying sizes ranging from 10 m³/s (20,000 cfm) to 50 m³/s (105,000 cfm) (Fig. 3). On the Rozelle Interchange project, silica dust levels have been more than halved compared to other projects completed previously by JHCPB.

Summary

RCS dust has always been present in tunneling, but increased health and safety regulations now necessitate careful monitoring and removal to protect workers from disease-causing air. Tunnel owners and designers are expected to include dust-control measures in their concepts, while contractors are needing to increasingly implement and work with dust-control equipment and technologies. While PPE, administrative controls and water suppression provide varying levels of protection, dust collectors generally are the most effective at removing dust while simultaneously preserving the working environment. As RCS regulations increase and workplace exposure limits shrink, mobile dust collectors are positioned to help owners, designers and contractors of hard-rock and mixed-ground tunnels maintain compliance and protect tunnel workers during the excavation of stations, shafts, cross passages, TBM tunnel adits or for mined (non-TBM) tunnels where dust is a concern. ■

Acknowledgments

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Wireless optical displacement sensor for convergence and divergence monitoring

The automation of monitoring in general appears undeniably tempting right up to the moment at which prices are discussed. That is when suddenly manual surveys seem not so outdated anymore.

Obviously, this perspective is rather short-sighted if automation is applied where its advantages can be exploited, for example:

- In areas where access is limited, difficult or dangerous.
- In projects where frequent recording rates (that is, shorter than one day) are required.
- Where long-term observations (that is, longer than one year) are desired.
- Where it takes care of repetitive procedures to release human resources for decision-making tasks.
- Any combination of the above.

The nature of tunneling more or less represents all of the above. Monitoring work is not only repetitive, but can potentially disrupt and delay tunnel construction or operation because of constrained access conditions. Such delays can give rise to significant cost and schedule issues.

A common parameter in tunnel monitoring is convergence as observation of changes in the tunnel profile perpendicular to the alignment. This can be conducted as life-cycle monitoring of ageing masonry tunnels as well as temporary observation of deformation induced by adjacent construction measures, or even in advance and construction of the tunnel itself.

In all of the above cases, wireless condition monitoring (WCM) is an intelligent solution with regard to costs, ease of installation and efficiency. The optical displacement sensor (ODS) is a typical component of a modern WCM system, representing unrivalled simplicity in convergence monitoring.

Convergence

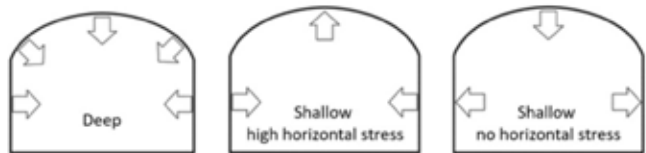
Tunnel deformation. Excavation of a tunnel, or close to an existing tunnel, will cause volume loss, and thus a disturbance of the surrounding medium. To re-establish the initially lost equilibrium, depending on the material, the ambient environment starts to settle with the tendency to fill the void represented by the tunnel or cavity.

The design of a tunnel profile and lining type is intended to deflect external loads to maintain stability and establish a new final equilibrium with the surrounding ground. Only if this precondition is reached can operation of the tunnel be safe and provide support of the overburden, for example, in bearing urban infrastructure.

Therefore, it is essential to observe tunnel deformation

FIG. 1

Scenarios of convergence (Erlandsson, 2020).



as a component of a project's holistic monitoring concept.

Depending on factors such as the tunnel profile, surrounding regime and overburden, the tunnel can experience various types of deformation (Fig. 1). As convergence we consider the displacement of a point toward or away from the interior: that is, the center point of the profile area. For a circular profile this would be the direction perpendicular to the outside tangent. For efficient convergence observation it is crucial to estimate the pattern of deformation in advance to distribute sensors appropriately and yield representative results. Segmental lined tunnels will deform at the joints as the segments can be considered rigid, while masonry-lined tunnels might deform homogeneously and require more thorough consideration of placement of the sensors.

Common observation techniques. The strategy of continuous observation depends on a variety of criteria, not least those already mentioned in the introduction. Generally speaking, monitoring is the observation of change, and thus the comparison of an in situ current state with an initial state some time in the past, represented by a zero or baseline measurement. In addition, the parameters observed need to be identical and comparable in both epochs, which might require some information about the environmental conditions. In the case of geometric observations like convergence, the location of the observed spot must be identical or at least be restored with sufficient precision. The latter becomes increasingly significant if the tunnel undergoes renovation, or the initial survey is carried out when only the preliminary lining is installed.

The first and foremost consideration would be the observation frequency. If annual observation repetition is required and access is not an obstacle, automatization is hardly economical. Manual observations can be conducted using geodetic total stations, tape extensometers or in modern days, even terrestrial laser scanning:

1. For total station observations, the tunnel profile is equipped with reflectors, ideally prisms that are observed from the total station's location by horizontal and vertical angle and slope distance

FIG. 2

Convergence observation utilizing total stations.



(Fig. 2), which are converted into local coordinates at millimeter accuracy. The linear distance between these coordinates represents the observation parameter. Depending on the spacing between the profiles and the visibility along the line of sight, a number of profiles can be observed from one standpoint before moving onward.

2. To observe convergence using a tape extensometer, eye bolts will be installed at the opposing ends of the intended chord and the extensometer temporarily hooked into them. The reading can then be taken from the micrometer. Tape extensometers are easy to use and provide high accuracy up to ± 0.2 mm. The measurement will require some effort and support such as hydraulic access platforms. In any case, the measurement tape or wire has to be removed after measurement as it would impede tunnel works or hamper operation.
3. Laser scanning covers the tunnel surface with an enormous density of measurements and can provide valuable information, particularly in the case of inhomogeneous deformation or irregular surfaces. However, identification of discrete points might be difficult and the extraordinary volume of data requires some effort in data processing and most probably, some manual intervention.

All of the above methods require qualified personnel operating the survey equipment, working “through the tunnel” by observing section after section. This sequential strategy limits the observation frequency significantly and makes short observation intervals of less than one day unrealistic, or at least, highly inefficient.

Automation of observation. Automation is a valid strategy to overcome the observation obstacles encountered by manual surveys. To achieve automation, the survey equipment needs to be permanently installed. Hence, tape extensometers are already disqualified as they would interfere with tunnel and construction operations.

Theoretically, laser scanners could be installed, but the hardware cost would usually prohibit the permanent installation of multiple instruments.

Thus, robotic total stations (RTS) remain a widely used means of deformation observation. Here, by far the biggest share of hardware investment lies in the total station itself. To minimize these costs, multiple convergence sections would be observed from one location. This seems efficient,

but it has drawbacks. The quality of observation will decrease with increasing distance as dust, fuel emissions and other sources of haze cause the line of sight to be blurred and physical obstructions such as traffic or machinery block it entirely. Measurement at distance is further complicated by increasing distance, making targets appear closer to each and therefore harder to discriminate (Fig. 2). To make things worse, the RTS itself will most likely be located in an unfavorable position on a bracket mounted to one side of the tunnel. Hence, alternatives might be required.

In recent years, miniaturization has led to the development of devices referred to as “nodes,” that combine sensor, data transmission and power supply in a single compact housing. The key term here is WCM, and their ease of use makes them attractive alternatives in many of the scenarios described.

Wireless observation constellation. WCM systems essentially consist of three components: (1) the sensor node, (2) the gateway and (3) the data-management platform.

Compact design and low power consumption of the node allow easy installation of the field equipment even by nonexperts with only minimal maintenance required for up to 15 years depending on the sensor. The nodes establish communication between an implemented sensor, such as a MEMS tilt sensor and/or a laser-based ODS, or a connected external sensor (such as a potentiometric crack meter, vibrating wire strain gauge or PT100 temperature sensor). The data is transmitted either via 868/915-MHz LoRaWAN-based signal or meshed 2.4-GHz Wi-Fi frequency to a gateway. It is temporarily stored at the gateway and transferred either via cellular network or ethernet landline to a remote central server.

Wireless communication minimizes installation effort and reduces the risk of accidental damage or vandalism causing loss of data that cabled systems can experience. The long battery life reduces the need for maintenance to almost zero and allows for redeployment on multiple short-term projects if not required for long-term lifecycle monitoring.

Intelligent systems enable remote system modification according to the stage of works, related expectations of the development of changes, or requirements of contingency measures.

Last but not least, WCM allows easy modification and expansion of the system by gradually adding more and even different sensors, all communicating within the same platform without the need for additional cables. It is relatively simple to relocate or replace elements of the system; for example, to focus resources close to the tunneling face as construction progresses. Even the subsequent extension by additional sensor types is reduced to the mere hardware installation.

The data-management platform provides access for multiple users with adequately defined user roles. The data

FIG. 3

A section-diagram screenshot from the data-management platform.



are stored and further processed if required. In the event of predefined threshold values being breached, automated alarms can be sent to approved stakeholders.

Case studies

Costa Blanca — Martorell Tunnels — Spain. As part of the Mediterranean Corridor project, the Spanish rail infrastructure operator ADIF needed to upgrade three old tunnels in the Catalonia region for use by bigger, faster trains. Located on the line between the towns of Martorell and Castelbisbal, each tunnel was several hundred meters in length. Main contractor Dragados was tasked with strengthening the linings, lowering the track and installing overhead electrification.

By lowering the invert, the overall tunnel geometry was altered and there was a need to closely observe whether the redistribution of loads would jeopardize structural integrity. Continuous monitoring was instructed to compare predicted and actual movement. This was viewed as essential to protect the workforce and provide timely warning of any significant deformation that would require a response from the construction team.

The requirement for near real-time monitoring throughout the works made automated monitoring the obvious, and probably only, choice. Conditions for long-distance optical observations were expected to be highly dusty, with sight lines blocked by construction machinery and materials. The use of total stations was therefore rejected.

Dragados and its assigned monitoring consultant, INSTOP, opted for a Senceive WCM system using laser distance sensors (ODS) in a triangular arrangement with a node at each spring line and one at the crown (Fig. 3). Although also relying on optical observations, the distances observed in this configuration are much shorter and therefore more reliable than in any applicable total station arrangement.

The ODS nodes include a three-axes MEMS tilt sensor enabling observation of rotational movement at each location regardless of the node orientation, as well as measuring the distance to a reflective target. Arrays of ODS nodes were installed at 25-m intervals such that the Costa Blanca tunnel featured 30 ODS profiles, Martorell tunnel 27 profiles, and Castelbisbal tunnel 35 profiles.

Achieving the nominal submillimeter accuracy not only depends on the environmental conditions — for example, the medium the laser beam has to travel through — but also on the quality and orientation of the target. Aiming at rough and/or oblique surfaces decreases accuracy as the incidence point might shift inadequately. Therefore, specific targets were installed to provide a reflective, smooth surface at 90° incidence angle. In addition to the distance measurements, the ODS's three-axes MEMS tilt sensor allows the observation of rotational movements without the node being restricted to horizontal oriented installation.

Besides the challenging environment, one more

reason for choosing WCM was the tight schedule, which provided a very short window for installation. Because the system is configured before installation, and because of its modular characteristics, a wireless system is easy to install, even by nonspecialists. At four sections per hour, an entire tunnel installation was completed within a single working day.

At the Costa Blanca and Martorell tunnels, the system included instruments to automatically observe longitudinal settlement. The system consisted of fixed-length beams daisy-chained in cardanic wall mounts with wireless tilt nodes fixed to the beams. Via trigonometric functions, any longitudinal tilt could be converted into vertical displacement by the known length of the beam. The accumulation of the incremental vertical displacements along the chain yielded longitudinal settlement or upheaval. As the components of the system were located relatively far apart, the long-range LoRaWAN system was the chosen communication platform. Each tunnel was equipped with its own gateway serving a system with the furthest node 1.2 km (0.8 mile) away. Gateways also received signals from the nodes located in the other tunnels — at distances of up to 8 km (5 miles). However, to maintain redundancy, the multigateway constellation was retained.

Specific diligence was required on the Martorell tunnel as the city of Martorell and its high-rise buildings were located directly above. A number of rod extensometers were therefore installed to observe vertical ground movement at three levels (3 m, 6 m and 9 m), each communicating its readings to the solar-powered gateway via multichannel vibrating wire nodes.

All of the systems were delivered preconfigured and with all sensors functioning. It was therefore possible to

check system performance within minutes of installation, avoiding the need for potentially disruptive repeat visits to the site.

The renovation of the three tunnels, including their intermediate galleries, was completed within three months with a monitoring system of more than 400 nodes in place for about four months. After demobilization, the components were redeployed on other INSTOP projects.

Chipping Sodbury Tunnel — UK. A comparable situation to the previous case was encountered in the Chipping Sodbury Tunnel near Bristol, UK. The structure, which was completed in 1902 and thus is more than 100 years old, is 4,000 m (13,100 ft) in length and features a brick-lined arch profile 8.4 m (28 ft) wide and 6.4 m (21 ft) high. To comply with modern requirements there was a need to lower the track by 150 mm in places to achieve the required clearances for a new alignment design including electrification.

Again, a tight schedule and challenging site conditions, plus the need to keep trains running, necessitated a solution using automated monitoring methods. The monitoring consultant, AECOM, had gained experience in similar renovation projects and could therefore use the proven technology of WCM. Tunnel geometry, obstructions by traffic, and construction activity as well as dusty, humid atmospheric conditions prohibited total station observations.

Unlike in the Spanish tunnels, it was possible to access cellular signal reception throughout the entire length of Chipping Sodbury Tunnel. Therefore, Senceive's proprietary communication platform FlatMesh could be employed. Due to the greater bandwidth of the 2.4 GHz signal, the platform provided optimized synchronization and short message pulses for high-frequency observations. The wireless mesh platform provided significant redundancy and therefore a high level of system reliability.

Hence, establishing communication proved to be relatively straightforward by simply installing gateways at regular intervals to gather the data from adjacent nodes.

As stated, three-axes tilt sensors can be installed in any orientation without the necessity of prior leveling. Therefore, the initial approach was to install daisy-chained tilt beams within the tunnel section representing deformation arrays. AECOM chose miniaturized Senceive NanoPlus MEMS tilt nodes for compactness and confidence in the IP68 performance under the expected wet and dusty ambient conditions. The use of shape arrays had been considered but rejected because each chain would have needed its own gateway, whereas data from numerous tilt sensors could be gathered at a single gateway, saving time and money.

As the work progressed it became impractical to install beam chains at some locations where tunnel curvature meant they would have projected into the tunnel and caused an obstruction. Hence, individual

tilt beams were installed only at crucial locations, still employing more than 200 nodes throughout the tunnel. Where convergence observation was required, tilt nodes were substituted by ODS nodes positioned to measure the distance to the opposite wall.

Permanent online access to the data-management platform allowed remote temporary deactivation of the inherent alarming during blockage of the line of sight by construction works to avoid false alarms.

The tracks were lowered one after the other; the behavior of the remaining track was observed using rail-specific vibration resistant tilt node. A total of 843 of these high-G tilt nodes were installed at 3-m (9-ft) centers within and adjacent to the immediate area of impact. In addition, it was considered crucial to ensure proper operation of the tunnel drainage, realized by a subsurface culvert located in the center of the tunnel. It was expected that any significant impact on this structure would result in measurable deflection of the invert and thus the track, so additional tilt nodes were installed on sleepers to observe movement related to the invert.

Conclusion

The monitoring programs described here found that neither of the presented projects encountered significant deformation. However, because the works were conducted under the umbrella of risk mitigation by meticulous observation of structural changes and deformation, they could be progressed with confidence and efficiency.

The use of the optical displacement sensor in particular enabled analysis of convergence in situations that would not have been possible with other methods. The use of automated wireless systems in general demonstrated that their capability encompasses the entire workflow from data acquisition via transfer and processing toward multiuser data visualization and thus provision of the observed parameters to all involved disciplines without delay.

Looking forward, the obtained information can be fed into the "observational method," the feedback loop suggested by Peck (1969), confirming or refuting the design assumption in a "learn-as-you-go" procedure. This allows timely modification of processes to optimize construction progress and reduce the hazard risks.

An additional advantage of the presented solutions is that the initial installation ("ab initio" system) can be expanded to multisensor, multipurpose systems by successively adding sensors in response to changing conditions and requirements (a "best-way-out" method).

The ease of use of the system promotes the common and efficient utilization of automated methods in physical and commercial risk mitigation, even at early stages, by making "deformation monitoring an integral part of decision making in the design-construction-supervision maintenance system" (Kavvas, 2005). (References available from the author.) ■

OneTunnel.org now available to UCA members

One of the many benefits of being a member of the UCA is access to technical information. That access is now even better with the launching of OneTunnel.org, a collaborative effort among multiple professional societies to place the world's most comprehensive collection of tunneling, underground construction and mining research at your fingertips.

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quality information that can be trusted.

"OneTunnel.org is an excellent resource for the professionals in the tunneling industry and facilitates sharing of the knowledge and technology related to the best practices in tunneling," Jamal Rostami, Ph.D., PE, director of excavation engineering and Earth Mechanics Institute (EMI), professor of mining engineering and underground construction and tunneling, Colorado School of Mines. Editor-In-Chief, Tunneling and Underground Space Technology (TUST) and Vice President of International Tunneling Association (ITA). "As a practitioner, teacher, and researcher, I can appreciate the value of OneTunnel.org more than others since it allows me to find useful information about various projects and pro-

cesses involved in tunneling and share that with my students, use the information in my research, and benefit from the precedents in the ongoing projects I am involved with."

OneTunnel.org is a benefit that is included in your UCA membership.

"The database can be a useful, and sometimes a critical resource to the engineers as it allows them to look at the track records of various projects when they plan, design, and construct the underground spaces and tunnels," said Rostami. "The available data can be reached by all on a worldwide basis and complements the available technical content that is available through World Tunneling Congress (WTC), technical journals such as and trade journals." ■

Delve Underground appoints new leadership

Delve Underground announces two new appointments to expand the organization's talented leadership team. John Kaplin will join the firm's executive leadership as chief development officer and Rachel Martin has been appointed California regional manager. Both Kaplin and Martin bring a wide range of experiences and expertise that will be impactful to Delve Underground's mission and strategic initiatives.

"I am incredibly excited to work alongside both John and Rachel in these leadership roles," said Victor Romero, Delve Underground president. "They both have a deep knowl-

edge of our company and clients and will be instrumental as we work toward the firm's vision to provide fulfilling opportunities in a collaborative and inclusive workplace that inspires bold, responsive infrastructure solutions."

Kaplin is a vice president and Principal and has been with the firm since 2013. He has 36 years of experience in design and construction management of heavy civil projects using a variety of project delivery methods. As chief development officer, he will be responsible for leading and aligning strategic, marketing, and project initiatives for Delve Underground across the firm's geographic footprint. For the past six

years he has served as Delve Underground's California regional manager, and prior to that was the construction management practice lead.

Martin takes over the role of Delve Underground's California regional manager. She is a principal engineer based out of the firm's Walnut Creek office and has 21 years of experience in design and construction management of civil projects focused on the fields of water, wastewater, and hydropower. As a vice president and California regional manager, she will be responsible for operations in the San Francisco, Walnut Creek, San Diego and Pasadena offices. ■

Coming Events



Cutting Edge Conference

Advances in Tunneling Technology | November 13-15, 2023 | Austin, TX

Nov. 13-15
Austin Marriott Downtown,
Austin, TX



George A. Fox Conference

Feb. 7
New York Hilton Midtown,
New York, NY

More information:

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

The Cutting Edge: Innovation, new technology and moving the industry forward

Editor's note: This column was first published in the March issue of *T&UC* without the included image. This is the full column.

There is an adage that goes: "If you do what you always did, you'll get what you always got." And while that may be a zone of comfort for some, history shows that it typically leads to stagnation, at best, and demise, at worst. Others might rally to the cry of "change and grow or die," or "evolution is the natural progression." Wherever you may stand in the spectrum, it's hard to argue that innovation, in



Michael Rispin
2021-2023 UCA Chair

its many possible incarnations, has made the industry what it is today. Further, innovation has increased the competitiveness of tunneling with other alternatives such as those built on the surface or at elevation.

So, where do we go from here ... and how quickly?

It seems clear that the element of risk, particularly in terms of cost, is the primary headwind against innovation. I don't think anyone necessarily innovates for the sake of it but rather because, with different

approaches or implementation of new technologies, they visualize a better future state. One should always measure the potential benefit against what could go wrong ... but not be paralyzed by it. Fortune also reportedly favors the brave and, for some like the British Special Air Service, it becomes their motto (They who dare, win!). So, by all means, evaluate and mitigate risk but do not reject innovation. You will pay a price in the long term.

A decade ago, the UCA took the innovative step of partnering with *Tunneling Journal* and creating the annual Cutting Edge Conference, a forum conceived with the intent of showcasing novelty, innovation, current issues and future visions in the tunneling industry. I have had the privilege as Chair to be a part of the organizing committees of the last two conferences (2021 in Dallas, TX and 2022 in Long Beach, CA). The feedback received for this two-day, single-track forum has been overwhelmingly and effusively positive. If you have not yet attended, I encourage you to do so in 2023 and beyond. It feels like real momentum is building behind this event.

In 2021, it was my honor to moderate a panel, comprised of one owner, engineer, contractor supplier and academic, to discuss the state of innovation in our industry. We discussed how good or bad we thought we were, what obstacles needed to be removed to foster innovation, and how did we measure innovation and its effects. The discussion was brisk, with great input and perspective from the audience. While celebrating that the industry has moved forward, there was also acknowledgment that our industry tends to be a

technology adoption laggard, that cut-and-paste specifications are completely counter to innovation and adoption of new technologies, and that owner bodies tend to be against things that have not been proven somewhere else.

Hey, somebody's got to be first; and then there is the rush to lead the way to be second. In the 2022 conference, there was an engaging panel of owners, with four representatives willing to sit and comment on tunneling from their perspectives, and to entertain questions from the audience. It was asked whether owners would be supportive of first-time innovation on one of their projects. One respondent stated confidently that if it was in respect to means, materials and methods, they would, provided a requisite risk analysis had been completed. A second panel member had a different take with the response being along the lines of "we can only do so much," elaborating that there would be reticence to try things that were not already applied elsewhere.

Contractors tell me that they want to innovate more, particularly where efficiency, cost and/or safety benefits can be realized on their projects at-hand, but that their hands get tied if it's something "new." Engineers may be open to evaluating new tech but, somewhere between avid interest and convincing their client that it is the way to go, enthusiasm gets lost. Suppliers, while happy to provide the tried-and-true, also keenly understand the need to innovate



or their business will suffer when the next best mousetrap comes along from a competitor. But there also must be a receptive audience. Does this illustration strike a chord for anyone?

All industry participants have a part to play. Coming full circle, where do we go from here? It seems that in terms of stakeholder awareness (infrastructure owners, society-at-large), our industry is in the public eye more now than ever. We have the opportunity to show how the industry has innovated and got us to where we are now. We also have a burden to continue innovating, enabling the building of safer, bigger and better underground infrastructure, in lieu of alternatives at the surface.

Tunnel on! ■



RETC2023

June 11-14, 2023
BOSTON, MA

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Whether you are looking for something new to solve a problem or want to connect with current vendor partners, RETc brings it all together on the Exhibit Hall Floor. Meet with over 180 exhibitors, enjoy food and beverages, and take advantage of extended learning opportunities at the NEW IdeaXchange stage. Badges are required for admittance.

Monday, June 12

Exhibit Hall Open	5:00 pm – 7:00 pm
Exhibit Hall Opening Reception	5:00 pm – 7:00 pm
<i>Sponsored by JENNMAR Civil and Turnstone Industrial Solutions</i>	
IdeaXchange Sessions	5:15 pm – 6:45 pm

Tuesday, June 13

Exhibit Hall Open	11:00 am – 2:00 pm
Exhibit Hall Lunch	11:30 am – 1:00 pm
IdeaXchange Sessions	11:30 am – 1:50 pm

Exhibit Hall Open	4:00 pm – 7:00 pm
Exhibit Hall Reception	4:00 pm – 7:00 pm
<i>Sponsored by DSI Tunneling</i>	
IdeaXchange Sessions	4:30 pm – 6:25 pm

Wednesday, June 14

Exhibit Hall Open	9:00 am – 12:00 pm
IdeaXchange Sessions	9:30 am – 11:25 am

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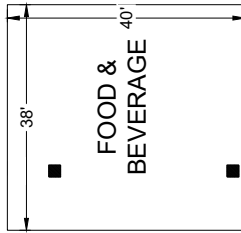
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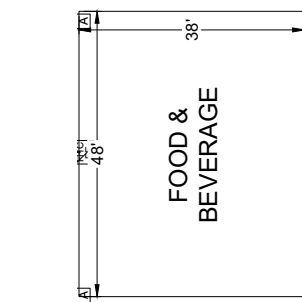
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Schnabel is a leading nationwide design-build contractor that provides customized earth retention and specialty foundation solutions for clients throughout the construction industry. They are well known for their unique blend of family pride, technological innovation, specialized equipment, extensive field experience, and engineering excellence that enables them to provide economical solutions and quality construction services to their clients.

Schnabel Engineering

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We help develop the structures and systems that are crucial parts of modern life by engineering quality solutions, managing risk, and providing specialized expertise.

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Women in Tunneling Breakfast Sponsor

For more than a century, Black & Veatch has been developing the water conveyance and storage infrastructure that has built communities across the nation and around the world. As your needs evolve and grow, our experienced team is at the cutting edge of innovation, helping clients address the challenges of today, while planning for a more sustainable tomorrow. With a focus on sustainability and resilience that starts with you, we deliver long-term value to water, sanitation and stormwater clients at every stage of the project lifecycle. Learn more at www.bv.com/water.

Brierley Associates

Women in Tunneling Breakfast Sponsor

Brierley Associates is a nationwide tunnel, trenchless, geotechnical, and geo-structural design firm that specializes exclusively in the planning, design, and construction of subsurface projects. "Creating Space Underground" is our mission and our passion. Founded in 1999, the firm has grown to more than 85 geotechnical and geo-structural engineers and geologists specializing in underground construction. Working across the U.S. in various ground conditions gives us the ability to effectively interpret geotechnical conditions, understand the strengths and limitations of existing construction technologies, and methods that enable owners and contractors to successfully mitigate risk.

Delve Underground

Women in Tunneling Breakfast Sponsor

Delve Underground is a leader in heavy civil engineering, serving the transportation, water, wastewater, and energy industries. Specializing in tunnel design, we provide innovative solutions to the most challenging underground problems. We offer comprehensive design, construction management, and dispute resolution capabilities. Our expertise includes civil, structural, and geotechnical engineering. Founded in 1954, as Jacobs Associates, Delve Underground is an employee-owned firm with 21 offices and 350 team members throughout the United States, Canada, Australia, and New Zealand. www.delveunderground.com

Jay Dee Contractors

Mobile App Banner Ad Sponsor

We've never been ones to back down from a challenge. It is this mentality that has guided our company for nearly 60 years, giving us the experience necessary to tackle even the most complex projects. Recognized as the pioneer of the pipe jacking tunneling method, there is no challenge too great for our team to overcome.

Our team of skilled employees, paired with an extensive inventory of equipment, has allowed us to build a project portfolio that varies in size, scope and level of complexity. To date, Jay Dee has constructed and rehabilitated over 200 miles of underground spaces and tunnels in a variety of soil conditions, including soft ground and hard rock.

AZTEC/TYPSA Engineering

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AZTEC/TYPSA is a multi-discipline engineering and environmental firm assisting public and private clients to plan, develop, design, construct, and maintain critical infrastructure projects around the world with permanent offices in 43 countries and 3,300+ staff worldwide. We provide our clients a one-stop shop covering all disciplines, including Geotechnics, Structural Engineering, MEP, ITS, Architecture, Ventilation and FLS, and BIM throughout the whole lifecycle of major underground projects. Over the last 15 years alone, we have been involved in over 1,100 miles of tunnels with experience in a wide range of construction methods, challenging ground conditions and dense urban environments.



EXHIBITOR LISTING & BOOTH NUMBER

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Acciona Infrastructure Canada Inc.	113	Geo-Instruments	909	Richway Industries	823
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Advanced Concrete Technologies, Inc	825	Geosense Ltd	626	ROBODRILL S.A.	527
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AECOM	223	Gomez International, Inc	617	Rocvent Inc	815
Aerix Industries	319	Grydale USA	910	Roxard Industries	528
AGRU America, Inc	214	GZA GeoEnvironmental, Inc	114	Ruen Drilling, Inc	322
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Alpine Equipment	615	Hager-Richter Geoscience, Inc	610	Schauenburg Flexadux Corp.	835
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Gall Zeidler Consultants	711	QSP Packers, LLC	728	Zitron USA	329



EXHIBITORS

ABC Industries, Inc

Booth 415

For over 90 years, ABC Industries continues to be a leading supplier of high quality, customized ducting solutions in mine, tunnel and underground construction operations worldwide. As these operations continue to evolve, ABC proactively collaborates with industry professionals to engineer unique, premium ventilation products. A new innovative addition to ABC's arsenal, RigiVent™ is a flexible, interlocking ducting solution for positive pressure applications requiring minimal storage and ease of handling. Similar to RigiDuct®, RigiVent™ is constructed from filament wound fiberglass rovings and reinforced with polyester fibers for added strength and resiliency. Visit our website to see more innovative solutions.

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Main Office

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Phone: (574) 267-5166
www.abc-industries.net

ABC Ventilation Systems

Booth 120

ABC Ventilation Systems is a world leader in mine and tunnel auxiliary ventilation solutions. Our commitment to always remaining the benchmark for quality, innovation and customer service ensures our end users receive unmatched products and support. Presently, our manufactured product offerings include: ToughVent High Efficiency Fans, HardLine Performance Ducting, HardLine Silencers, FlexLine Performance Ducting, Engineered Inflatables and Quality Accessories to complement all product lines.

Products & Services

Ventilation Systems, Materials and Equipment

Main Office

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Saskatoon, SK S7K 1W2 Canada
Phone: (306) 653-4303
abcventilation.com/

Acciona Infrastructure Canada Inc.

Booth 113

Products & Services

Construction - Contracting Services
Consulting Engineers

Main Office

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Ackcio

Booth 1027

Ackcio builds reliable wireless data acquisition systems for industrial monitoring applications. Ackcio's flagship solution, Ackcio Beam, is an industrial data acquisition platform that uses a patented long-range wireless mesh network to monitor sensors accurately and reliably in both above-ground and underground environments.

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Mining Equipment
Tunnel Communication Systems and Equipment

Main Office

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www.ackcio.com

Advanced Concrete Technologies, Inc

Booth 825

Advanced Concrete Technologies, Inc. is the North America division of German based Wiggert & Co manufacturer of comprehensive concrete batching plants, mixers, automation/control systems, batching equipment, concrete distribution systems. Amongst the well-known brands are the high shear HPGM planetary counter-current mixer, High output DWM twin shaft mixer, WicoMix concrete plants, CentroMix concrete plants, HydroMat microwave moisture measuring technology and the WCS PC based control system. ACT delivers highly efficient, fully integrated equipment solutions to the concrete industries and fulfills the demands for today's highest quality and environmental standards.

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Advanced Infrastructure Design

Booth 908

Digital tunnel inspection

Products & Services

Consulting Engineers

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AECOM

AECOM

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Booth 223

With more than 2,000 miles of transit, roadway, water and energy tunnel projects worldwide, AECOM is at the forefront of the industry. Our 500 tunneling experts and 2,000 geotechnical engineers develop innovative, award-winning solutions for our clients' toughest challenges worldwide. AECOM understands that specialized services are vital to a successful project. We bring extensive expertise in ESG and digital design, including alternative delivery and construction management. We provide fully integrated services to each aspect of large-scale tunnel design, management, inspection, rehabilitation, ventilation and FLS, and construction. We are driven by a common purpose to deliver a better world.

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Geological, Geotechnical Services and Equipment

Main Office

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www.aecom.comtunneling

Aerix Industries

Booth 319

Aerix Industries, manufactures and supplies a dynamic product line of integrated engineered foam liquid concentrates, enabling its customers to produce and install high quality lightweight backfill, ideal for annular grouting, tunnel arch backfill and flowable fill. The company's foams also allow its customers to transport tailings, sand, or other construction materials using minimal amounts of water. Aerix Industries dedication to research and technical support has allowed it to provide advanced engineered foam solutions to the construction and mining industries for more than 80 years.

Products & Services

Grouting Services, Equipment and Materials

Main Office

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Allentown, PA 18106 United States of America
Phone: (610) 398-7833
Email: info@aerixindustries.com
www.aerixindustries.com

AGRU America, Inc

Booth 214

AGRU America, Inc. is the world's leading manufacturer of flat die extrusion geomembranes, concrete protective liners and tunnel liners. The company also supplies vertical barrier systems and large diameter piping systems for the U.S. and international civil/environmental markets. AGRU America is part of the worldwide AGRU Group, an Austrian family-owned business since 1948



with production facilities in Austria, the U.S., Germany and China, and distribution in over 80 countries worldwide.

Products & Services

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Tunnel Lining and Support Materials
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Wastewater Management Products
Water Treatment Plant and Materials

Main Office

500 Garrison Rd
Georgetown, SC 29440 United States of America
Phone: (843) 546-0600
Email: salesmkg@agruamerica.com
www.agruamerica.com

AlgaHer S.A.

Booth 927

ALGAHER is specialized in the design and production of tunnel segment gaskets. ALGAHER has a wide range of geometries focused on satisfying every project needs. R&D is one of the most important feature for this company whose technical staff has developed recently a new integration system for cast-in gaskets model, giving solution to real challenges of the current market. ALGAHER is involved in many overseas projects where currently is the only gaskets supplier for all sectors of

HS2 in the UK. ALGAHER is also supplying gaskets in the USA for PAWTUCKET tunnel.

Products & Services

Segment Accessories

Main Office

CTRA. CORELLA Km1
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Phone: +34 941 182 153
www.tunnelsegmentgaskets.com

Alpine Equipment

Booth 615

For 50 years Alpine/Rockwheel Americas has been a trusted supplier of equipment for the underground, construction, and mining sectors. Our Rockwheel line of hydraulic drum cutter attachments allow for rapid and precise removal of rock and concrete. Rockwheels are available for excavators in any size class. We also supply innovative hydraulic rotary soil mixing attachments for use in remediation, stabilization, and solidification projects. All products are available on a rental basis with purchase option. Alpine's experienced team can help with job-specific customization and is always available for technical support, service and parts.

Products & Services

Ground Improvement Equipment and Services
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Rotary Drum Cutters

Underground Excavation Services and Equipment

Main Office

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Phone: (814) 466-7134
Email: info@rockwheelamericas.com
www.rockwheelamericas.com

Amalgamated Mining & Tunneling

Booth 426

Main Office

6932 Roper Rd. NW
Edmonton, AB T6B 3H9 Canada
Phone: (801) 243-2065
www.amt-inc.ca

Amberg Technologies Ltd

Booth 430

Whether it's a subway tunnel in London, a hydroelectric plant on the Amazon river, the Gotthard Base Tunnel in Switzerland or a high-speed rail route in China: Construction projects of this magnitude are nothing unusual for Amberg Technologies AG. The Swiss company is one of the global leaders specializing in user-friendly

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AECOM

Pictured:

Grand Central Madison, New York City

Contact:

Paul Nicholas
Vice President, AECOM Tunneling Practice
paul.nicholas2@aecom.com

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EXHIBITORS

surveying solutions. Geophysicists and surveyors as well as software and hardware engineers at the headquarters in Regensdorf design customized solutions for georeferenced data capture and processing in infrastructure installations. The company offers its customers field-proven products as well as customer-specific services for railway surveying, tunnel surveying and tunnel seismic.

Products & Services

Geological, Geotechnical Services and Equipment
Laser Guidance Systems
Survey Equipment and Lasers

Main Office

Trockenloosstrasse 21
Regensdorf-Watt, Zurich 8105 Switzerland
Phone: +41 44 870 92 22
Email: info@amberg.ch
ambergtechnologies.com/

AMIX Systems Ltd

Booth 1023

AMIX Systems Ltd. is a design, engineering and fabrication team that solves problems for today's most challenging grout mixing & backfill projects. We take complex project needs and build automated, self-cleaning products and systems that simplify the grout mixing process. If you are retrofitting existing plants, we're your solution. Our team has a deep expertise in systems design and control automation. It's not about selling systems, we're on a mission to help companies reduce their overall equipment costs and make significant advances in productivity. We now have rental equipment available for all your grouting applications! Contact us for more information.

Products & Services

Grouting Services, Equipment and Materials

Main Office

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www.amixsystems.com

AMR PEMCO, Inc

Booth 1011

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Rocky Gap, VA 24366 United States of America
Phone: (276) 326-2611
Email: sales@amrpemco.com
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Antraquip Corp

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Booth 523

USA based Antraquip is a leading manufacturer of drum cutter attachments for excavators (roadheader attachments), electrically driven roadheaders, and various tunnel support products. While AQ roadheaders are consistently used for tunnel excavation projects in soft rock, Antraquip drum cutters are frequently being used in the tunnel industry for various applications including tunnel excavation (even in hard rock where blasting is not possible), shaft sinking, tunnel enlargement, and refurbishment projects. Products within Antraquip's expanding tunnel support division include lattice girders, steel sets, arch canopy systems, and more. Rely on Antraquip, North America's mechanized rock excavation experts for your next tunnel project.

Products & Services

Roadheaders
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Scaling
Tunnel Boring Equipment
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Phone: (301) 665-1165
Email: info@antraquip.net
www.antraquip.net

Arup

Booth 126

Arup employs a multidisciplinary Total Tunnel Design approach to tackle some of the world's most complex underground challenges. Beyond the core tunnel disciplines of civil architecture, geotechnics, machinery and soil mechanics, our global team includes experts in ventilation, lighting, MEP, acoustics, fire, drainage, safety and public health. By integrating these skills, our tunnel designs are lower-risk and more efficient, effective and affordable. The designs our Total Tunnel Design approach makes possible are also sustainable, reducing excavation and materials by effective space proofing and lining system optimization and introducing innovations such as extracting heat from tunnel linings.

Products & Services

Consulting Engineers
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Main Office

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Phone: (212) 896-3000
Email: tunnel-design@arup.com
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ASI Marine

Booth 831

ASI specializes in providing hyperbaric intervention planning and management services for soft ground tunnel construction projects, and remote tunnel inspection for flooded tunnels. Our Hyperbaric services include consultation for all hyperbaric needs including; planning, risk assessment, safety and adherence to local regulatory requirements. We also provide full hyperbaric intervention support; hyperbaric workers and worker training, specialized equipment with maintenance program and servicing of the air-lock and supporting systems. ASI has been a global leader in remote inspections for more than 30 years, providing accurate and repeatable data for maintenance planning while delivering safe solutions for industry.

Products & Services

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Avanti International

Booth 618

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Booth 219

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EXHIBITORS



BabEng, LLC

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Booth 219

Energy, enthusiasm, and knowledge – these are some of the qualities that drive our passion for understanding the world of underground works and making the most out of any TBM tunneling project. BabEng, is a worldwide engineering and consulting company specializing in underground works. Detailed knowledge about TBMs makes us a highly qualified project partner, able to complete critical tasks and solve problems from feasibility study to design and construction to contract closure. Tunnelsoft, a division of BabEng, offers software that is specifically tailored to the needs of TBM tunneling. It's everything you need for in-depth tunneling analysis and documentation.

Products & Services

Computer Hardware and Software
Consulting Engineers
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Main Office

28205 203rd Ave SE
Kent, WA 98042 United States of America
Phone: (253) 630-2221
Email: contact@babeng.com
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Ballard Marine Construction

Booth 312

A leader in tunnel, shaft, caisson and pipeline construction support services for premier tunneling and mining contractors, as well as joint ventures. Ballard has a reputation for managing highly complex tasks in a cost effective and efficient manner. We have experienced supervisory personnel and a full complement of experienced and qualified compressed air workers, dive medical technicians, hyperbaric nurses, hyperbaric physician assistants, and other specialty personnel. Ballard owns and maintains related equipment from shuttles to tunnel specific saturation systems (SAT).

Products & Services

Construction - Contracting Services
Tunnel Boring Equipment

Main Office

727 S 27th St
Washougal, WA 98671 United States of America
Phone: (360) 695-5163
Email: liam.obrien@ballardmc.com
www.ballardmc.com/projects/tunnel-support/

BarChip Inc

Booth 424

Provides synthetic fibers for concrete.

Products & Services

Concrete Reinforcement

Main Office

PO Box 471007
Charlotte, NC 28247 United States of America
Phone: (704) 843-8401
www.barchip.com

Bauer Foundation Corporation

Booth 524

BAUER Foundation Corp. (BFC) is a Florida corporation and the U.S. subsidiary of the world-wide operating BAUER Group based in Schorbenhausen, Germany. The BAUER Group is a world-renowned foundation contractor, designer and builder of the world's finest foundation equipment. BAUER Foundation Corp. as part of the BAUER construction division, is a nation-wide leader in the execution of complex excavation pits, ground improvement, deep foundations and vertical seals, utilizing the most up to date equipment and installation techniques. BAUER Foundation Corp. provides all types of foundation solutions and services for industrial, commercial, residential and governmental construction projects.

Products & Services

Ground Freezing
Grouting Services, Equipment and Materials

Main Office

13203 Byrd Legg Dr
Odessa, FL 33556 United States of America
Phone: (727) 992-1769
Email: estimating@bauerfoundations.com
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Bekaert

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Booth 411

Bekaert, your global partner for smart reinforcement of your tunneling and mining project. We optimize your project by providing innovative, cost-effective and safe solutions. We offer a range of Dramix® steel fibers directly produced in the US to meet all Made In USA / Buy America requirements. Dramix® steel fiber reinforcement offers you sustainable and durable solutions which saves steel, concrete, and time while reducing the CO₂ footprint of underground projects worldwide. We have a team of technical experts available, specifically dedicated to the underground construction world.

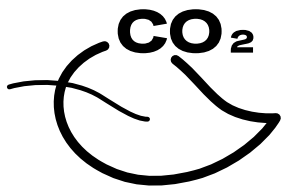
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Concrete Reinforcement
Engineering Design and Services for Tunnels
Shotcrete Equipment, Supplies, and Services



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Bessac

Booth 313

Tunneling equipment and TBM manufacturer, special trenchless equipment. Tunnel and Micro Tunnel contractor.

Products & Services

Tunnel Boring Equipment
Tunnel Lining and Support Materials

Main Office

5161 Arapahoe Rd, Ste 420
Centennial, CO 80112 United States of America
Phone: (786) 570-0532
www.bessac.com/

Brokk Inc

Booth 514

BROKK is the world leader in electrically powered remote controlled demolition machines, which are used extensively in tunneling, cross-passages, shaft sinking, micro-tunneling, scaling, and other underground construction applications. BROKK machines can be equipped with a variety of attachments, such as hydraulic breakers, rock drills, rotary drum cutters, digging buckets, beam manipulators, and shotcrete nozzles. Boasting an impressive power-to-weight ratio, these compact machines can operate effectively in

limited access, confined spaces, with zero-emissions. Operators can remain at a safe distance while they maneuver BROKK machines in challenging areas underground.

Products & Services

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Brookville Equipment Corp

See our ad on p. 16

Booth 518

BROOKVILLE is a leading manufacturer of rail-mounted diesel and battery-powered tunneling locomotives and personnel carriers. Featuring planetary final drive gear reducers at each wheel end to divide driveline torque, shock loading for reduced stress and longer service life, and liquid-cooled internal wet disc brakes to extend brake life and provide maximum braking capacity for long, continuous grades, BROOKVILLE units are designed for dependability. Optional equipment features include explosion proofing and patented on-board rerailing systems to enhance safety in all work environments. BROOKVILLE also manufactures rubber-tired equipment, ideal for steep tunnel grades, inspections, and maintenance for non-tracked projects.

Products & Services

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Main Office

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CAB

See our ad on p. 17

Booth 818

For over 45 years CAB has been supplying the tunneling and mining industry with high quality hangers and safety products. CAB hangers are widely recognized for their high strength, quality and important safety features. They are designed to safely support all types of sensor, data, control, communication and electrical cables in above and below ground operations. With the growing importance of Safety in the Industries, CAB has greatly expanded its line of Safety Products in recent years. This includes products such as high-visibility streamers, markers, tubes, bags, and apparel.

Products & Services

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EXHIBITORS

Carroll Technologies Group

Booth 808

Carroll Technologies Group is a leading provider of Communications, Electronics, and Safety Equipment for the tunneling and mining sectors. We distribute products for over 80 manufacturers, repair/calibrate over 75% of those products, and have a service team on hand to help facilitate those needs. Our company is dedicated to give you a service model 24/7 and we focus on the individual needs of our customers by providing a robust stock of the products they need at all times. Our number one goal is taking care of our customers and building a strong relationship.

Products & Services

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Safety Products
Tunnel Communication Systems and Equipment

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Email: jj@carrollengineeringco.com
www.carrolltechnologiesgroup.com

CBE GROUP

Booth 627

CBE Group designs and manufactures segment moulds, automated plants for segment production and segment handling equipment for tunnel projects all over the world. The company ensures assembly of precast plants, staff training and maintenance worldwide. Its offices are located in France, with two production sites in France and China. Since its creation in 1987, the company has achieved 620 projects and produced more than 29 500 moulds. Recent achievements include: High Speed 2 (UK), HRBT (USA), Snowy Hydro (Australia), Grand Paris (France), Sao Paulo L2 (Brazil), Sydney Metro West (Australia), Shanghai Metro (China), Chennai Metro (India), CR105 (Singapour), and more.

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Precast Concrete Linings
Segment Accessories
Tunnel Lining and Support Materials

Main Office

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Saint-Avertin 37550 France
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Email: cbe@cbegroup.fr
www.cbe-tunnels.com

CDM Smith

CDM Smith

See our ad on p. 18

Booth 608

CDM Smith provides lasting and integrated solutions in water, environment, transportation, energy and facilities to public/private clients worldwide. As a full-service engineering and construction firm, we deliver exceptional client service, quality results and enduring value across the entire project life-cycle. CDM Smith's underground construction staff includes geotechnical, structural, and civil engineers and geologists located across the globe. With a full range of tunnel-related services, we

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EXHIBITORS

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Products & Services

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Booth 422

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Pumps and Pumping Equipment

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Chengdu Foresight

Booth 932

Established in 2006, Chengdu Foresight Composite Co., Ltd. is an integrated manufacturer of flexible and semi-rigid PVC ventilation ducts for underground mines and tunnels with over 15 years of service to customers worldwide. We have a complete industrial chain from base fabric, PVC calendered membrane, lamination, semi-coating, and finished products. Product sales outlets are all over the country and exported to Europe, America, the Middle East, Southeast Asia, Africa, and other countries and regions. The company has obtained SGS, ISO9001 quality system certification, MSHA certification and D & B certification, and multiple product certifications.

Products & Services

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Tunnel Boring Equipment
Tunnel Lining and Support Materials
Underground Utility Materials and Operations
Ventilation Systems, Materials and Equipment

Main Office

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www.pvc-textile.com

CJGeo

Booth 809

CJGeo specializes in annular space and abandonment grouting using cellular concrete, and water stop grouting. From neutral carrier buoyancy grouting to managing 23MGD leaks, CJGeo is a trusted partner throughout the Eastern United States for tunneling, utility and mining customers.

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Grouting Services, Equipment and Materials

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Crux Subsurface, Inc

See our ad on p. 19

Booth 519

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Grouting Services, Equipment and Materials
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David R. Klug & Associates, Inc

See our ad on p. 20

Booth 213

David R. Klug & Associates, Inc. provides manufacturers representative services to the underground civil and mine construction industries. The company specializes in products and services for soft ground, conventional, and NATM/SEM tunnels. Expertise is offered in the supply of componentry used in precast tunnel linings

inclusive of EPDM gaskets, plastic and steel connectors, grout lifting assemblies and steel segment moulds plus final lining forming systems for C-I-P 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 mesh and rebar reinforcement plus specialty grout systems for tunnel backfill requirements.

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Delve Underground

See our ad on p. 21

Booth 522

Delve Underground is a leader in heavy civil engineering, serving the transportation, water, wastewater, and energy industries. Specializing in tunnel design, we provide innovative solutions to the most challenging underground problems. We offer comprehensive design, construction management, and dispute resolution capabilities. Founded in 1954, as Jacobs Associates, Delve Underground is an employee-owned firm with 21 offices and 350 team members throughout the United States, Canada, Australia, and New Zealand.

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Derrick Corporation**Booth 427**

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Dibit Measuring Technique USA, Inc.**Booth 716**

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Dr. Sauer & Partners Corp**Booth 317**

Dr. Sauer & Partners has been in practice in the United States for over 30 years, and employs tunnel engineers at main offices located in Washington D.C., London and Salzburg. The firm provides cost effective and innovative tunneling solutions using conventional mining approaches to owners and contractors. Dr. Sauer & Partners is recognized worldwide as one of the leading consultants for design and construction supervision of tunnels and underground structures. The application of

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EXHIBITORS

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DSI Tunneling LLC

See our ad on p. 23

Booth 408

DSI has provided ground support products to the underground construction industry for over 100 years. With our signature 4 flange liner plate and superior beam bending capabilities we are the premier supplier of steel supports to tunnels and mines. We also offer engineering services from design through bidding to stamped submittals. Our range of products include DSI

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Duham Geo Slope Indicator

Booth 702

Geotechnical and structural instrumentation

Products & Services

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www.durhamgeo.com

E-BERK

Booth 118

E-BERK has launched its first TBM (Tunnel Boring Machine), E-3301 on May 2017. E-BERK has reached 12 TBM production capacity per year. E-BERK has been manufacturing spare parts for TBMs since 2002. E-BERK configures and manufactures Cutterhead in demanded diameters and sizes for all types of Tunnel Boring Machines (TBM) suitable for various geological conditions. The Multi-Purpose Tunnel Service Vehicle (MSV) is produced in only four countries in the world and is produced now by E-BERK Tunneling & Foundation Technologies as well. E-BERK company has actively participated as a solution partner for more than 100 projects.

Products & Services

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Tunnel Boring Equipment
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EC Applications - Tunnel Lining

Booth 115

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Ecoequipment Rentals

Booth 517

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Epiroc

Booth 508

Epiroc is a leading global productivity partner for the mining and infrastructure industries. With cutting-edge technology, Epiroc develops and produces innovative, safe and sustainable drill rigs, rock excavation and construction equipment and tools. The company also provides world-class service and solutions for automation and interoperability. The company is headquartered in the US near Denver, Colorado. Employing approximately 450 people, it extends its reach through a nationwide network of service centers and drilling distributors.

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Equipment Corporation of America

See our ad on p. 24

Booth 709

Equipment Corporation of America is a leading full service distributor of specialty foundation equipment. We represent the Obermann/MAT line of slurry mixing and handling equipment as well as Bauer, RTG, Klemm, Pilemaster, Dawson, HPSI, Word, Pileco, Allu, and Digga brands. ECA offers sales, rentals, parts, service and technical support throughout the eastern US as well as Canada from 9 strategic locations.

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Everest Equipment Co

Booth 516


Since 1975, Everest Equipment Co. has been a designer and manufacturer of underground construction forms in North America. Everest is your formwork source should your project require shaft formwork, blast-proof shaft formwork, types of tunnel formwork, California switches, underground gantries and equipment. Everest is proud to encompass sales support, engineering, fabrication and onsite servicing of formwork designed to meet the requirements of underground forming. The formwork expertise has assisted contractors in underground tunnels, vehicular tunnels, hydro development projects and pre-cast primary liner segments. Its Canadian operation supports the products through many core employees that have built their careers with Everest.

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FPT Infrastructure*Booth 431*

FPT Infrastructure repairs, protects and enhances the vital infrastructure that moves and connects us. With systems for structure waterproofing, ground stabilization, foundation and wall protection, and movement joint sealing, FPT can supply customized solutions for tunnel, trench and underground construction projects. Visit booth 431 to meet our team and learn more about our global experience in infrastructure preservation and protection.

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Microtunneling Equipment, Tools, and Supplies
Soil Conditioning Equipment and Materials
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Main Office

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Fugro*Booth 730*

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Gall Zeidler Consultants*See our ad on p. 25**Booth 711*

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 engineering services cover all stages of a project: Conceptual to Final Design, Program & Construction Management, Construction Site Support, Tunnel Inspection & Rehabilitation, Mine Access Tunnels & Shafts, Independent Design Verification Services, Building Information Modeling (BIM)

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Gall Zeidler Consultants

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The Pawtucket Combined Sewer Overflow Tunnel in Providence, Rhode Island.



EXHIBITORS

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Main Office

44345 Premier Plz, Ste 210
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www.gzconsultants.com

GCP Applied Technologies

Booth 324

GCP, a Saint-Gobain company, is a leading provider of construction materials that includes TYTRO™ solutions for tunnels and DE NEEF® injection materials, along with high-performance waterproofing products for buildings and infrastructure. The GCP portfolio offers solutions for different environments and uses, so builders have the best options available for specific applications. With products that last longer and make construction more energy efficient and less wasteful, GCP makes a tangible difference on the carbon footprint of our planet. GCP is focused on continuous improvement for its customers, end-users, and the environment.

Products & Services

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Tunnel Lining and Support Materials

Main Office

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gcpat.com/en/injection-materials

Geocomp Corp/GeoTesting Express, Inc

Booth 611

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Soil Conditioning Equipment and Materials

Main Office

125 Nagog Park
Acton, MA 01720 United States of America
Phone: (978) 635-0012

Email: info@geocomp.com
www.geocomp.com

Geo-Instruments

Booth 909

GEO-Instruments provides automated solutions for monitoring the safety and stability of buildings, excavations, bridges, railways, roads, tunnels, dams, embankments, and slopes. We help clients manage risk by installing advanced monitoring systems and automating the collection, processing, and delivery of alarms, data, and reports. Established in 2003, GEO-Instruments has acquired a reputation for getting results and providing excellent customer service. Our team has extensive experience in instrumentation, information technology, civil engineering, and construction. GEO-Instruments also maintains a large inventory of rental equipment and specializes in sales, rentals, calibrations, and repair of InstanTel vibration monitors and seismographs.

Products & Services

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Geological, Geotechnical Services and Equipment
Instrumentation Equipment and Services

Main Office

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Phone: (401) 782-1045
www.geo-instruments.com

GEOKON

Booth 423

GEOKON is a recognized world leader in the manufacture of structural and geotechnical instrumentation. Founded in 1979, GEOKON offers a full complement of instrumentation for industries including tunnels, dams, mines, piles, bridges, pipelines, landfills, embankments, transportation and wind turbines. GEOKON incorporates state-of-the-art manufacturing processes and equipment to produce the highest quality and performing products on the market. GEOKON has been awarded ISO 9001:2015 registration from both ANSI•ANAB, USA and UKAS of Great Britain. GEOKON products are supported by an experienced team of factory-trained associates ready to assist with instrument design, selection and installation. All products include a full, 13-month warranty.

Products & Services

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Instrumentation Equipment and Services

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Geosense Ltd

Booth 626

Geosense is a leading UK manufacturer and global supplier of geotechnical instrumentation. Our history includes the support of iconic international projects across tunnels, metros, deep foundations, dams, and others. We specialize in Vibrating Wire and MEMS technologies,

alongside data logging options, and other sensor types. For RETC, Geosense will showcase recent product innovations. These include our redeveloped in-place-inclinometer (slimmer, lighter, proven performance) and IPI-X (combining both tilt and settlement monitoring via a single borehole). In support of our North American customers, Geosense has recently opened a US office located in New York.

Products & Services

Geological, Geotechnical Services and Equipment
Instrumentation Equipment and Services

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GeoSonics/Vibra-Tech

Booth 925

If you are managing a construction project that uses heavy equipment or blasting, your project will create off-site vibrations that can put your organization and reputation at risk. Since 1949, GeoSonics/Vibra-Tech has been providing vibration and blast consulting services. We have the tools and experience to help you manage your construction risk. Our Remote Monitoring Technology continuously collects and posts data to a customized website, keeping project personnel notified through email/text alarms. Remote monitoring capabilities bring the field to you whether you need vibration, noise, dust, geotechnical or environmental monitoring.

Products & Services

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Geological, Geotechnical Services and Equipment
Instrumentation Equipment and Services

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Gomez International, Inc

Booth 617

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Main Office

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Phone: (520) 836-7869
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Grydale USA

Booth 910

Grydale manufacture a patented range of fixed, mobile and onboard industrial dust collectors, being used to solve dust and fume problems within major tunnelling, mining, quarrying, abrasive blasting and construction projects. Major tunnel contracts include, Melbourne Metro, (VIC), WestConnex (Sydney, NSW), Sydney Metro (NSW), CRL (Auckland, NZ), HS2 (UK), Neom (Saudi Arabia) and more. We have mobilized source extraction and hold the patent for manufacturing self-propelled dust extractors, making the JMS M Series unique in the market. RDO Equipment Co are the North American Dealer for the Grydale product range and able to provide local sales, rental, service and support.

Products & Services

Dust and Fume Control Technology
Ventilation Systems, Materials and Equipment

Main Office

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Email: info@grydaleusa.com
www.grydaleusa.com

GZA GeoEnvironmental, Inc

Booth 114

Focused on construction, GZA's Contractor Services is intimately familiar with the fast-paced complexities

of tunneling, heavy-civil, highway, and marine construction projects. Empowered by a team of dedicated engineers and decades of experience on small to mega-large construction projects, we are prepared to assist contractors with a variety of high-quality services including: Geotechnical Instrumentation, Automated Air Quality, Vibration, Noise, Dust & Weather Monitoring and Analysis, Excavation Support Design, Deep Foundation Testing, Pre-Bid Value Engineering, Pre- and Post- Construction Structural Condition Survey, Structural Construction and Demolition Engineering, Environmental Services, Construction Management

Products & Services

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Consulting Environmental
Geological, Geotechnical Services and Equipment
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Main Office

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H+E Logistics USA, Inc

Booth 211

Conveyor belt systems

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**HAGER-RICHTER
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Hager-Richter Geoscience, Inc

See our ad on p. 28

Booth 610

HAGER-RICHTER GEOSCIENCE, INC. is a well-established small business that specializes in Surface and Borehole Geophysics for Engineering applications (NAICS 541360). The firm has been in business since 1984, has earned a national reputation, and has a nationwide practice. Hager-Richter is headquartered in Atkinson, New Hampshire and has had a fully staffed and equipped New York/New Jersey Regional Office in New Jersey since 2001. Hager-Richter has extensive experience in providing high resolution surface and borehole geophysical services to support tunneling infrastructure projects throughout the U.S.

Products & Services

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Hatch

Booth 107

Hatch is an international consulting engineering firm offering multi-disciplinary, design and construction management in the transportation, water, energy, mining and metals sectors. Our global presence of 65 offices and 10,000 staff worldwide, includes 21 offices and 1,000 staff in the USA. Hatch has deep roots in the North American tunneling industry for over 65 years. Hatch has participated in the design & delivery of some of the most complex tunnels and underground infrastructure projects in the world. We are passionately committed to the pursuit of a better world through POSITIVE CHANGE. Please join us at RETC 2023 booth #107.

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Herrenknecht Tunnelling Systems USA, Inc

See our ad on the Inside Front Cover

Booth 206

Herrenknecht is a technology and market leader in the area of mechanized tunnelling systems. As the only company worldwide, Herrenknecht delivers cutting-edge tunnel boring machines for all ground conditions and in all diameters – ranging from 0.10 to 19 meters. The Herrenknecht product range includes tailor-made machines for all sorts of tunnels. Furthermore, Herrenknecht supplies an entire range of innovative machines for the mechanized construction of underground mining infrastructures. The company also produces state-of-the-art deep drilling rigs that drill down to depths of 8,000m and plants for the exploration of shallow geothermal energy. Company: www.herrenknecht.com, LinkedIn: www.linkedin.com/company/herrenknecht-ag/

Products & Services

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HNTB Corp

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Booth 216

With 3800 professionals, HNTB is a leader in providing solutions to infrastructure problems nationwide. The firm has a long history in design and engineering services for tunnels and underground construction. HNTB has completed award-winning projects on some of the country's most complex projects, including highway, transit, rail, aviation and water resources. HNTB's experts have the insight and knowledge to provide state of the art innovative solutions to tunneling challenges, from small diameter excavations to designing the largest bored tunnel in the world (Alaskan Way Tunnel)--utilizing both conventional tunneling methods (sequential excavation) or mechanized tunneling for variety of ground conditions.

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Tunnel Lining and Support Materials
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Booth 225

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Booth 706

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Booth 934

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Consulting Engineers

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Inflatable Packers International LLC

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Booth 914

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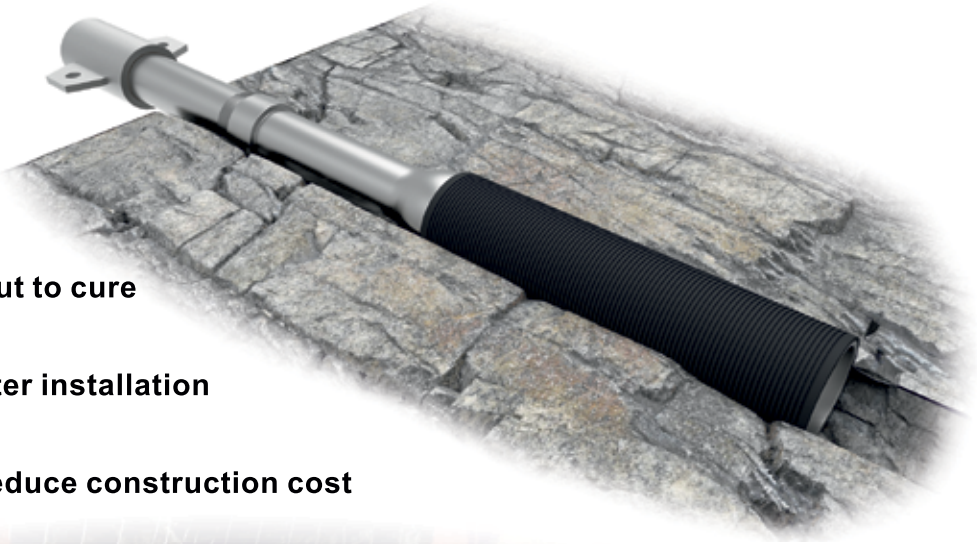
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Innovative Wireless Technologies

Booth 922

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Booth 1009

Inzwa Technologies is committed to taking the headaches out of your geotechnical monitoring. How? By providing vibration, tilt, and sound monitoring equipment that is easy to install and activate right out of the box, and a plug-and-play geotechnical data platform that can host a plethora of third-party devices for centralized, 24/7 visibility of all sensor data on a job site.

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Booth 512

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Phone: (720) 446-6603
Email: m.brown@iotaautomation.com.au
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J.H. Fletcher & Co

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Booth 930

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Booth 726

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JCK Underground, Inc

Booth 331

JCK Underground provides Owner Advisor, Engineering and Construction Management services for tunnel and underground projects. We provide public and private project owners and other consultants with specialized underground expertise and support throughout the entire project life-cycle, including early planning, design, procurement, construction and asset management. Our experts have spent entire careers in the underground and tunneling business as planners, designers, construction managers, and contractors. This breadth of varied experience and resources help our clients properly manage the risks associated with implementing their programs.

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Main Office

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JENNMAR Civil

See our ad on p. 35

Booth 123

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Products & Services

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Kayden Environmental Services

Booth 109

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EXHIBITORS

geotechnical specialty contractor, Keller has provided solutions to these challenges for almost 100 years. Our solutions for tunneling include diaphragm walls, ground freezing, secant piles, dewatering, jet, permeation and compensation grouting, and instrumentation and monitoring. By connecting global resources and expertise with local knowledge and focus, Keller develops innovative, practical, and cost-effective solutions to geotechnical challenges. Keller builds projects designed by others and offers full design-build services for any geotechnical construction application.

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Kiewit Infrastructure Co

See our ad on p. 37

Booth 128

Products & Services

Construction - Contracting Services

Main Office

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Booth 622

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Malcolm Drilling Co Inc

Booth 425

Malcolm Drilling is a renowned geotechnical and foundation contractor that has been serving the construction industry since 1962. Malcolm specializes in providing innovative solutions for complex and challenging ground engineering projects across the US. With a team

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Products & Services

Drilling Services and Equipment
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Grouting Services, Equipment and Materials
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Shotcrete Equipment, Supplies, and Services
Slurry Services and Machines

Main Office

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MAPEI Corp

See our ad on p. 41

Booth 106

Tunneling, underground construction and mining projects have unique and challenging characteristics due to their complexity. MAPEI's UTT (Underground Technology Team) engineers and experts understand these challenges and focus on providing a broad range of products and technologies along with expertise and know-how for the tunneling, underground construction and mining industries. These solutions include chemicals for shotcrete, mechanized tunneling, injection and waterproofing technologies. Many of these products are manufactured in North America by MAPEI with the goal of completely satisfying every technical requirement of our customers, from applicator to the contractor to the client.

Products & Services

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Shotcrete Equipment, Supplies, and Services
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Main Office

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Master Builders Solutions

Booth 607

Master Builders Solutions is a leading supplier of underground construction solutions to support tunneling success, even in highly challenging ground conditions. Master Builders Solutions has the largest range of products and services available to meet needs and solve problems in TBM and conventional tunneling, whether in soft ground or hard rock conditions. We offer a full range of MasterRoc® tunneling products such as soil conditioning foams and polymers, anti-clay agents, tail sealants, anti-abrasion agents, dust suppressants, bearing seal greases, EP2 greases and annulus grouts, plus product for sprayed concrete and injection for ground consolidation.

Products & Services

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Main Office

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Matrix Design Group

Booth 1022

Matrix designs, manufactures and sells innovative technological products that help keep people safe. Originally focused on the underground coal mining industry, Matrix has expanded into new industrial markets in the United States and globally.

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McDowell Equipment Ltd

Booth 718

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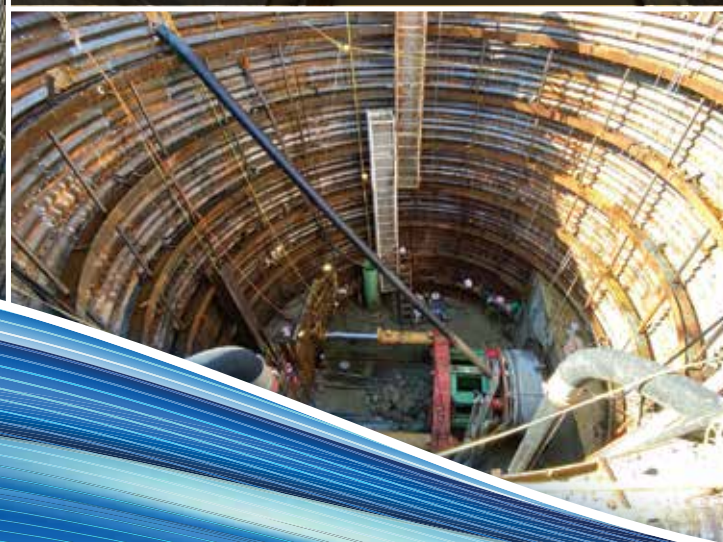
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RETC2023

DEMANDING CONDITIONS

**DEMAND
JENNMAR.**



JENNMAR Civil and TURNSTONE Industrial Solutions, LLC offer a wide range of products used in supporting, building, and rebuilding our infrastructure from above and below ground. Our strength lies in our ability to offer our customers solutions in every phase of their projects. We manufacture arch systems, girders, liner plates and Impact Resistant Laggings® and much more. Whether mining, rehabbing, ventilating or re-supporting transportation, water, wastewater or infrastructure tunnels, our team of experienced engineers and technicians are with you every step of the way, from initial consultation to qualified instruction and on-going technical support to make your project a success!



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

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EXHIBITORS

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Underground Excavation Services and Equipment
Underground Locomotives and Rail Haulage Equipment

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MCT Group Inc

Booth 834

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www.mct-usa.com/en/

Messinger Bearings

Booth 416

Surpassing 100 years, Messinger Bearings is one of an elite few companies in the world capable of producing large (up to 25 feet in diameter), custom-designed bearings in limited quantities for tunnel boring machines (TBMs). In fact, Messinger focuses on manufacturing new and expert repairing of large custom bearings in low volumes for special applications. Messinger goes above and beyond supplying just the bearing, offering complete solutions (field inspection, bearing storage tanks, etc.). With Messingers expanding core of expertise and experience, its customers can expect a quick response, unparalleled application support and timely delivery to better support the tunnel market.

Products & Services

Tunnel Boring Equipment

Main Office

10385 Drummond Rd
Philadelphia, PA 19154 United States of America
Phone: (215) 824-4987
www.messingerbearings.com

Michels Corp

See our ad on p. 39

Booth 708

Michels is an industry-leading utility contractor. A sampling of our deep foundation services for tunneling consist of design/build of a multitude of ERS systems, soil

nails, secant piles, soldier piles, tiebacks, grouting, and steel sheeting. Michels has the experience in a variety of tunneling techniques, including Earth Pressure Balance Tunnel Boring Machines (TBM), hard rock TBMs, conventional drill blast tunneling, sequential excavation methods (SEM), remote-controlled tunneling systems and microtunneling.

Products & Services

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Underground Excavation Services and Equipment

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www.michels.us

MILLER

MILLER

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At Miller, we strive to bring our customers the best valued projects with safe practices, fair pricing, superb service, and outstanding quality. Our projects are delivered on time and within budget by an honest and hard-working team of professionals. We are committed to long term relationships with new and existing customers. Our expertise ranges from design-build portal facilities, raise bore shaft excavation, conventional shaft excavation, concrete shaft lining, steel shaft lining, hoisting systems, ventilation fans, bath house facilities, and heavy civil concrete foundations.

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Email: miller@millercontracting.us
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Miller Sales and Engineering

Booth 824

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MineARC Systems

Booth 916

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Products & Services

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Safety Products
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Ventilation Systems, Materials and Equipment

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Lancaster, TX 75134 United States of America
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Email: james.rau@minearcusa.com
www.minearc.com



Mining Equipment Ltd

See our ad on p. 40

Booth 417

Mining Equipment has been supplying the mining and tunneling industries with quality rebuilt underground equipment for more than 30 years. The business has grown to encompass new ventilation equipment, Jetair fans, and new rolling stock, C.S. Card and Moran Engineering. Mining Equipment, Jetair and Mine Hoists International are currently doing business in North and South America, Australia, Asia, Africa and Europe.

Products & Services

Ventilation Systems, Materials and Equipment

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Mott MacDonald

Booth 509

Mott MacDonald provides tunnel design and engineering solutions for rail and transit, road, water/wastewater conveyance, CSO storage, and cable and communications. With a reputation for technical excellence, Mott MacDonald identifies practical approaches to tunneling, equipment selection and contracting approaches. Expertise includes soft ground and rock tunneling, cut and cover, underground caverns, immersed tube tunnels, jacked tunnels, and microtunneling. Complementary skills in technical areas include tunnel rehabilitation, ground stabilization and treatment, tunnel systems, ventilation, and life safety and security. With 16,000 employees worldwide, Mott MacDonald is one of the world's largest employee-owned companies.

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Booth 926

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MTS /Polaris Underground Solutions

Booth 1007

Tunnel Boring Machines - Microtunneling - System2 - Smart Combination

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Naylor Pipe Co

See our ad on p. 42

Booth 707

Naylor Pipe is manufactured in accordance with ASTM A-139, A-211 & A-252 specifications. Diameters from 4" to 96", and thicknesses from 1/16" to 1/2". Also available are the necessary fittings and connections including the exclusive Naylor Heavy Duty Wedgelock Coupling to complete your pipe system.

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Booth 911

Nexans AmerCable is the leading manufacturer of TBM power cables in the United States. Some of the largest TBMs in the world are powered by our Tiger® Brand cables, which are designed to provide safer, longer service life. Our flexible, high-quality power, control and instrumentation cables provide reliable operation in the harshest tunneling environments. Nexans AmerCable is the industry leader in engineering support and product innovation.

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Nicholson Construction Co

Booth 311

Founded in 1955, Nicholson is a leader in geotechnical construction, providing a wide range of deep foundation, earth retention and ground treatments services on projects throughout the United States. For tunnels, Nicholson constructs access shafts with diaphragm walls and jet grout columns and the company supports operations with a wide variety of grouting and earth retention techniques. Nicholson has offices around the country to address each region's unique geotechnical construction needs.

Products & Services

Grouting Services, Equipment and Materials

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www.nicholsonconstruction.com

North American Drillers LLC, a Shaft Drillers International Company

Booth 724

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Phone: (304) 291-0175
Email: cwillis@shaftdrillers.com
www.nadrillers.com



Northwest Laborers-Employers Training Trust

See our ad on p. 43

Booth 817

The Safety and Hazard Awareness for Tunnels (SHAFT) courses are designed to teach skills for working safely in tunnels constructed using a tunnel boring machine (TBM). The program was developed by the Northwest Laborers-Employers Training Trust with input and

consultation from several organizations. In addition to classroom lecture and discussion, participants have the experience of training in a simulated, lifelike tunneling environment.

Products & Services

Educational

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www.nwlett.edu

Palmieri S.p.A.

Booth 314

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Drilling Services and Equipment



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Michels Construction provides safe, reliable and cost-effective solutions for foundations, earth retention and ground improvement projects. We design and build shafts and bracing systems to connect underground work areas and the surface while keeping crews and equipment separated from water, groundwater, rock and soil.

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Email: info@palmierigroup.com
www.palmierigroup.com

Parsons

Booth 918

Parsons is a technology-driven engineering services firm with 75 years of experience in the engineering, construction, technical, and professional services industries. We have successfully delivered some of the largest and most complex tunneling and underground construction projects in the world. From planning and design through construction management and operations, Parsons provides a complete range of services for water, wastewater, and transportation tunnels. Whether your project involves soft ground, rock, or mixed-faced conditions, our dedicated staff of more than 100 tunnel professionals have the experience and skills to manage the risks and deliver safe, economical, and innovative solutions.

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www.parsons.com

Pini Group USA Inc.

Booth 832

Pini Group is a Swiss leading engineering services provider with more than 70 years of experience and a leading role in several major European projects. The Group offers high-end engineering and consulting services in the domain of underground works, in a digital way. Today the Group operates worldwide, with particular focus on the US market, supporting Contractors & Owners in the design, tender and execution phase. The unique strength of the Group concerns tunnels located underneath moderate to extremely high-water table in soft ground/rock mass (Lake Mead intake No. 3 tunnel, Nevada; 3RPORT tunnel, Indiana; Outfall tunnel, LA).

Products & Services

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Consulting Environmental

Main Office

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Phone: (440) 317-1551
www.pini.group

Poltinger Precision Systems GmbH

Booth 116

Manufacturer of Underground Navigation Solutions for TBMs, Roadheaders, Pipejacking/Microtunneling and other types of tunnelling machines. Additional products for conventional mining as well as surveying related services are offered as well.

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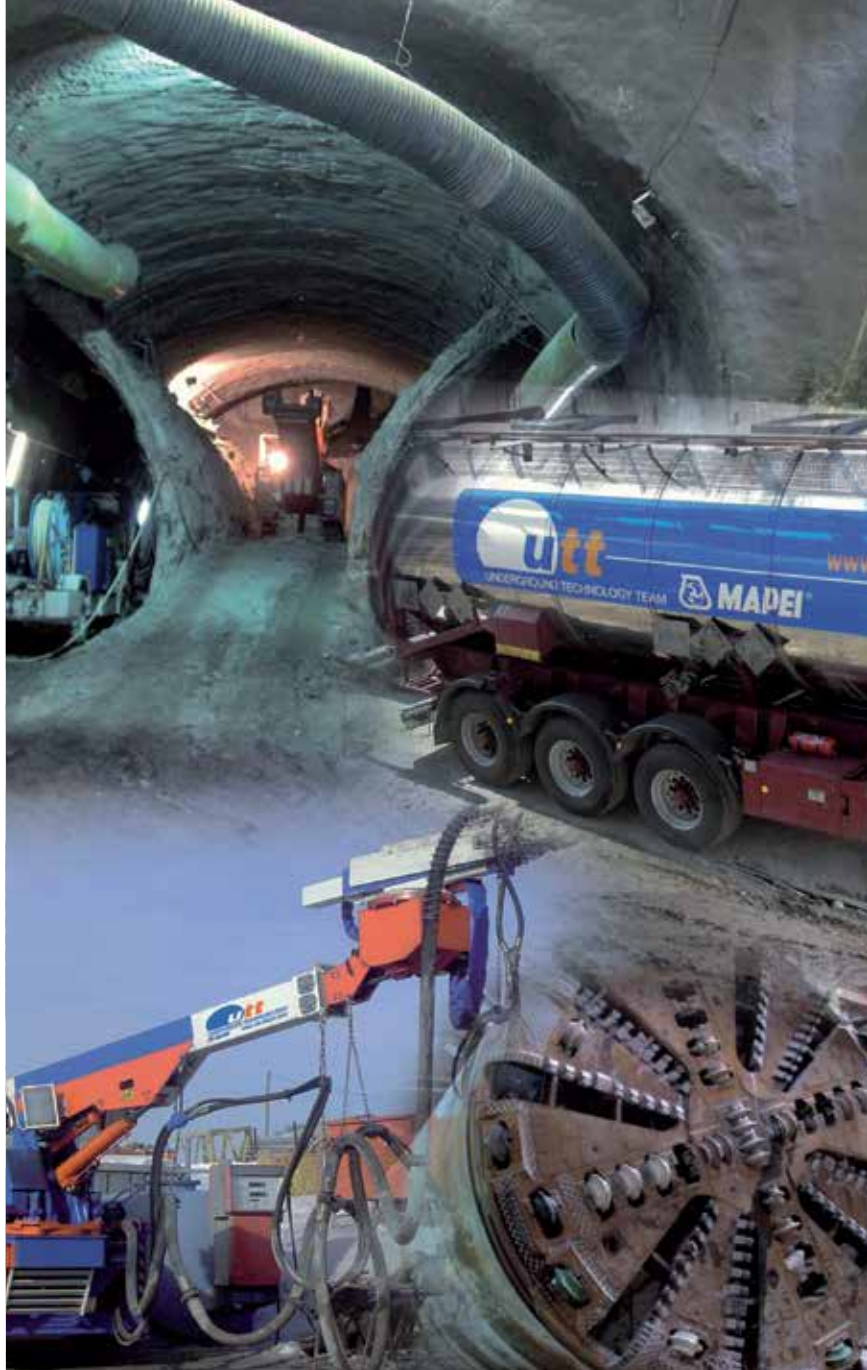
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Promat International NV

Booth 117

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PSC Crane and Rigging

Booth 826

Products & Services

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Putzmeister America, Inc

See our ad on p. 45

Booth 529

Products & Services

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Main Office

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www.putzmeister.com

QSP Packers, LLC

Booth 728

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Richway Industries**Booth 823**

Richway Industries is the premier manufacturer of equipment and foam concentrate for the production of cellular concrete. With equipment capable of producing up to 100 yards per hour, it's ASTM C869 foam concentrate, and over 40 years of foam generation and manufacturing experience, Richway can help with all of your cellular concrete needs. Because foam concentrate formulation & production, as well equipment design & production, are done in our own facility, we can also provide solutions for other aspects of your business. Richway knows foam and equipment.

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Robbins**Booth 409**

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Rock TBM's
Soft Ground Shields
Tunnel Boring Equipment

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www.RobbinsTBM.com

Northwest Laborers Training

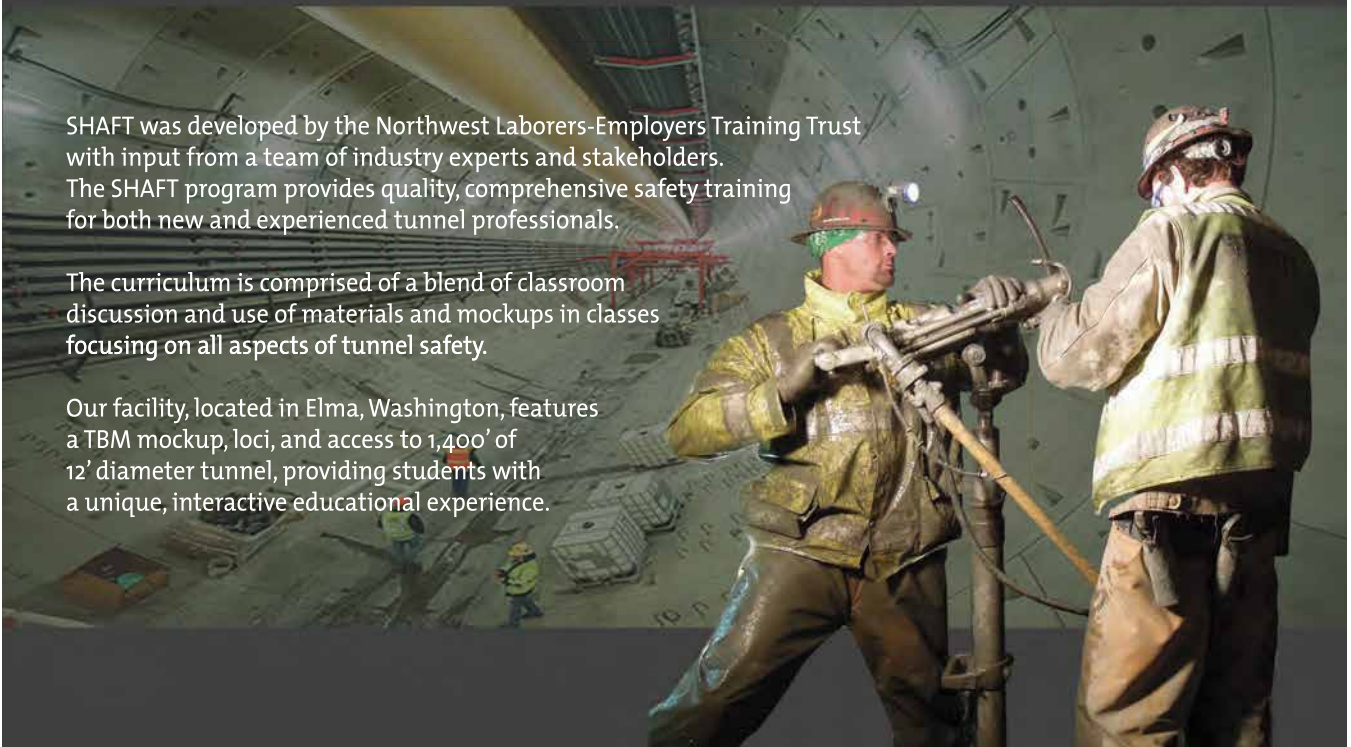
nwlett.edu/SHAFT



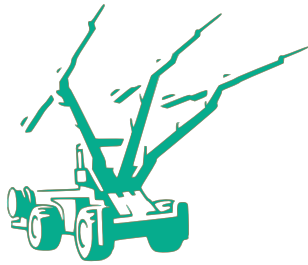
SHAFT was developed by the Northwest Laborers-Employers Training Trust with input from a team of industry experts and stakeholders. The SHAFT program provides quality, comprehensive safety training for both new and experienced tunnel professionals.

The curriculum is comprised of a blend of classroom discussion and use of materials and mockups in classes focusing on all aspects of tunnel safety.

Our facility, located in Elma, Washington, features a TBM mockup, loci, and access to 1,400' of 12' diameter tunnel, providing students with a unique, interactive educational experience.



EXHIBITORS



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ROBODRILL S.A.

Booth 527

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www.robodrill-sa.com

Rocscience, Inc

Booth 923

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Roxard Industries

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Ruen Drilling, Inc

Booth 322

Ruen Drilling provides drilling services including surface, underground, and horizontal directional core drilling for the geotechnical, exploration and geothermal industries throughout the U.S., South America and Asia. Drilling equipment includes truck, track, skid, and helicopter supported core drills. Rig capacities are to 10,000 ft. vertical or angle and 3,000 ft. horizontal. Crews are all trained in achieving a high degree of core recovery for the client. Recent projects include: Devils Slide Tunnel, Irvington Tunnel, Caldecott Tunnel 4th bore, Route 9 Tunnel in Hong Kong, Highway 53 Tunnel in Puerto Rico, White Sands Missile Range and Mt. Olympus Pipeline No. 6.

Products & Services

Drilling Services and Equipment

Main Office

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www.ruendrilling.com

Sandvik Mining and Rock Solutions

Booth 412

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www.rocktechnology.sandvik

Schauenburg Flexadux Corp

Booth 835

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Booth 833

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Booth 806

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Booth 323

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Seequent

Booth 308

Seequent is the subsurface software company within Bentley Systems, the infrastructure engineering software company. Together, we are helping build a more resilient future by connecting the built world above ground with the hidden world below it. We share a vision that connecting software, teams, and data leads to better understanding and ultimately better decisions – for people and the planet.

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Senceive Corp

See our ad on p. 47

Booth 811

monitoring technology, sensor, nodes mesh networks

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Booth 525

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Slurry Services and Machines
Tunnel Boring Equipment
Water Treatment Plant and Materials

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Shannon & Wilson, Inc

Booth 612

Since 1954, Shannon & Wilson has been a pioneer in developing effective underground solutions to complex site development problems. This includes exploration, design, plans and specifications, and construction management and support on over 800 soft ground and hard rock tunnel projects, ranging from trenchless to the world's largest diameter tunnels. Resources include over 300 staff from the corporate headquarters in Seattle, Washington, and branch offices in Alaska, California, Colorado, Florida, Missouri, Oregon, Utah and Wisconsin. Shannon & Wilson offers services in geotechnical site evaluations, and assessments of tunnels and related structures, groundwater and dewatering, seismicity, instrumentation, environmental, and natural resources.

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Shotcrete Technologies, Inc

Booth 722

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Products & Services

Tunnel Lining and Support Materials

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www.shotcretetechnologies.com

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Booth 906

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Products & Services

Instrumentation Equipment and Services

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www.sigicom.com

Sika Corporation

Booth 316

Sika Corporation is a global specialty chemicals company with over 100 years of experience. For tunneling, Sika offers a wide variety of products such as chemical admixtures and fibers for concrete, repair and protection products, waterproofing products and equipment for shotcrete. Sika is at the forefront when it comes to efficiency improvements in tunneling and mining, reducing excavation times with faster shotcrete solutions and optimizing the cost performance of concrete in all underground operations. With a fully integrated and smart, high quality product portfolio, we are your ideal business partner to continue forging ahead in underground construction.

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Simem Underground Solutions, Inc

Booth 723

Simem Underground Solutions (SUG), with 30+ years of experience provides fully automated material handling and production systems for TBM bi-component grout, hydrated bentonite, lightweight cellular grout, shotcrete, concrete, mining backfill, and water filtration. SUG designs, engineers, and manufactures colloidal mixer plants, pumping and delivery systems, and integrated automation and controls packages for tailored turn-key solutions to meet the toughest project demands. Our in-house design, mechanical, structural, electrical, and automation engineering team delivers solution continuity for seamless on-site installation, commissioning, and field training. 24-7 technical support, CAD documentation, and spare parts inventories are in place to ensure optimal solution up-time.

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Main Office

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Phone: (604) 621-7008
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SIXENSE

Booth 315

Sixense is a leading provider and integrator of automated real-time instrumentation and monitoring services (geotechnical, structural, and environmental). With over 25 years of global experience, Sixense has built a reputation for safety, environmental awareness, client care, technical excellence, and cutting-edge innovation. Sixense has been involved in many iconic, large urban tunnel programs in Northern America like the Alaskan Way (Seattle), West Side Extension (Los Angeles), Purple Line (Baltimore), Hampton Roads Bridge Tunnels (Norfolk), Ontario Line South (Toronto), Hwy 401/409 undercrossing (Mississauga), etc. Are you looking for peace of mind on your projects? At Sixense, we have you covered!

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SoilFreeze Inc

See our ad on p. 48

Booth 727

SoilFreeze Inc. provides temporary frozen soil shoring systems to support excavations and provide ground-water cut-off. Our technology can be used for; ground water cut-off, in situ-isolation barriers, foundation excavation shoring, cross passages, adits, ground stabilization and more. We design, fabricate, install and maintain customized freeze systems for each client's needs. We serve both the private and public sectors and have a substantial list of successful projects and satisfied clients. SoilFreeze Inc. has advanced and refined freeze technology to create freeze systems that are mobile, reusable, and expandable to address the needs of any sized project and urban locations.

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Southern Nevada Water Authority

Booth 429

Water Utility Services - Owner

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STM Industriale SpA**Booth 802**

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**Strata Worldwide | Tunneling**

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Booth 827

Strata Worldwide is a global leader in advanced underground safety products and technologies. A suite of technologies that support a safer, more productive working environment and that are backed by a company with 30 years of underground and customer support experience. Product offerings include: underground networking for communications, tracking and real-time monitoring; emergency refuge chambers; proximity detection and collision avoidance; artificial intelligence sensors for accident prevention; and a collection of specialty resins, polymers and waterproof liners. Polymer Rubber Gel for leak repair and restoration, and the Boraidd® line of TBM ground conditioners and shield sealant

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Technical Tunnelling Components LTD (TTC)

Booth 309

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Terratec / Kelley Engineered Equipment

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TLT-Turbo

Booth 428

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Booth 217

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EXHIBITORS



TPH & GEOFORM North America

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Booth 629

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TRE ALTAMIRA Inc

Booth 731

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Treviicos

Booth 111

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Trimble Inc

Booth 624

Trimble Tunneling provides fast and reliable solutions for survey and construction professionals to complete underground projects with confidence. Trimble's technology portfolio reduces field time by automating survey workflows while providing flexibility in the office to customize and deliver key construction quality control and analysis data. From tunnel construction survey to automated instrumentation and monitoring, Trimble enhances productivity and confidence throughout the tunnel project lifecycle.

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Tsurumi Pump

Booth 822

Tsurumi Pump is a submersible pump manufacturer that supplies pumps worldwide for many projects including tunneling. Tsurumi pumps are capable of handling flows from 50-5000 gpm @ heads up to 750 feet. Wear parts are made of wear resistant materials capable of handling entrained solids commonly found in tunneling applications. Pump features such as dual inside mechanical seals that do not require cooling from or come in contact with the abrasive liquid being pumped is just one of the reasons Tsurumi Pump has become the pump of choice in mines throughout the world.

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Tunnel Business Magazine (TBM)

Booth 513

TBM: Tunnel Business Magazine provides the North American tunneling industry with a trade magazine focusing on North American topics, projects and news. From large diameter tunneling to microtunneling, TBM: Tunnel Business Magazine, published by Benjamin Media, Inc., reports on the issues and topics important to the North American tunneling contractor, engineer and owner. Free subscriptions are available.

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Tunnel Radio of America, Inc

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Booth 531

Tunnel Radio provides RF communication solutions in confined spaces such as tunnels, mines, underground maintenance facilities/machine rooms. TR's target prospects include construction companies that work on infrastructure projects, communications companies that offer above ground and would like to expand their portfolio to include below ground, companies that offer services to site locations. Safety and fail-safe technology keeps you connected, and Tunnel Radio of America has over 35 years of proven installations to ensure that we perform for you.

Products & Services

Tunnel Communication Systems and Equipment

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Tunnel24 GmbH

Booth 122

Tunnel24 GmbH is the microtunneling industry's premier provider of the world's most advanced, innovative and reliable equipment. We are specialized in the purchase and sale of used microtunneling machines and ancillary equipment from the leading manufacturers. Tunnel24 GmbH does also sell new tools, equipment





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EXHIBITORS

and spare parts, such as cutting discs, cutter heads, upsize kits, hydraulic cylinders, navigation systems and components (laser target, gyro compass), slurry pumps, separation plants, centrifuges, pipes and fittings, cables, bentonite mixing and lubrication systems, and much more.

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Tunneling Journal

Booth 413

Tunnelling Journal delivers unrivalled editorial quality that features contemporary, lively, cutting edge articles with specific and unparalleled relevance to the tunnelling contractor, consultant, client and machine manufacturer. Published six times a year, the print copy is partnered with a constantly updated website and a fortnightly newsletter. We also publish Breakthrough magazine for the ITA YM, Canadian Tunnelling for Tunnelling Association of Canada, ITA Activity Report, A&NZ Journal for the Australian and New Zealand tunnelling societies, and organisers of the British Tunnelling Society Conference, and the Cutting Edge Conference in partnership with SME. Visit our booth to pick up your complimentary copies and meet the team.

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Tunnels & Tunnelling

Booth 1006

Celebrating 50 years of service to the tunnelling industry, and packed with information about the business its customers are in, Tunnels & Tunnelling remains the leading underground construction magazine worldwide. Since 1999 T&T offers T&T North America, a bi-monthly magazine dedicated to its customers' regional market, and the official publication of the Tunnelling Association of Canada (TAC). Each edition of T&T informs tunnelling professionals on every aspect of underground construction in five continents. Readers include consulting engineers, clients, contractors and manufacturers in 90 countries. Stay abreast of all developments in the tunnelling industry by subscribing to T&T.

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TunnelTalk

Booth 325

TunnelTalk.com is the most comprehensive record of archive information on tunneling news, videos, project planning and project progress on the web. Despite a technical and website service hiatus at the moment, TunnelTalk is now in its 15th year and is publishing on the web in its associated digital magazine format and we are staying in touch with readers and industry followers via our Social Media accounts and YouTube channels. For industry suppliers, our readers are your next customers! Let's meet in Boston in June!

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VMT USA

Booth 209

As a driving technological force for more than 25 years, VMT has the experience, the capacities and the know-how to develop innovative system and product solutions that support construction companies all over the world to build tunnels and shafts of every size for ever more complex infrastructure projects: VMT's navigation systems for driving equipment, its production and logistics management system for segment production and further innovative system solutions for safety, monitoring and data management play key roles here. VMT products can be combined into efficient, modern, networked solutions that ensure streamlined processes and seamless quality assurance for every tunnel project.

Products & Services

Instrumentation Equipment and Services
Laser Guidance Systems
Microtunneling Equipment, Tools, and Supplies
Roadheaders
Survey Equipment and Lasers
Tunnel Boring Equipment

Main Office

1613 132nd Ave E, Ste 200
Sumner, WA 98390 United States of America
Phone: (253) 447-2399
Email: info@vmt-us.com
www.vmt-us.com

V•ROD

Booth 515

V•ROD composite rebar has been manufactured by Pultrall since 1987. Pultrall manufactures V•ROD re-bars by combining the pultrusion process and an in-line coating process for the outside, sanded surface. The company's manufacturing processes meet ISO 9001 and ISO 14001 standards. In addition, in-house quality control tests are routinely performed along with tests performed by independent laboratories.

Products & Services

Tunnel Lining and Support Materials

Main Office

700 9E Rue Nord
Thetford Mines, QC G6G 6Z5 Canada
Phone: (418) 335-3202
Email: service@pultrall.com
www.fiberglassrebar.com

Watson Bowman Acme

Booth 124

WBA offers expertise in sealing and protecting for all industries including bridge, highway, and tunnel. Solutions are designed with our customers in mind, using high quality materials that are easy to install and even easier to maintain. Our capabilities extend beyond any other manufacturer in the industry, with our ability to create custom designs, and fabricate in-house. WBA is a proud supplier of the complete Omega-shaped Tunnel Seal system. We proudly design and fabricate our clamping system in the United States, reducing lead times on your project.

Products & Services

Control Systems

Main Office

95 Pineview Drive
Buffalo, NY 14228 United States of America
Phone: (716) 341-3238
Email: laura.zakrzewski@watsonbowmanacme.com
www.watsonbowmanacme.com



Williams Form Engineering Corp

Booth 418

Williams Form Engineering Corporation has been providing threaded steel bars and accessories for rock, soil and concrete anchors, post-tensioning systems, and concrete forming hardware systems in the construction industry for over 100 years. Our rock and soil anchor product line includes our Spin-Lock mechanical rock anchors, polyester resin anchors, multiple corrosion protection anchors, soil nails, strand anchors, Manta Ray soil anchors, Geo-Drill Hollow-Bar anchors, and micropiles. For concrete anchoring we offer Spin-Lock anchors, undercut anchors, reusable anchors and cast-in-place anchors. We also have a full line of All-Thread Rebar for tiebacks, micropiles and post-tensioning.

Products & Services

Concrete Reinforcement
Geological, Geotechnical Services and Equipment
Ground Improvement Equipment and Services
Soil Conditioning Equipment and Materials

Main Office

8165 Graphic Dr
Belmont, MI 49306 United States of America
Phone: (616) 866-0815
Email: williams@williamsform.com
www.williamsform.com

Worldsensing SL

Booth 623

Worldsensing is a global IoT pioneer. Founded in 2008, the infrastructure monitoring expert serves customers in more than 70 countries, with a network of global partners to jointly drive safety in mining, construction, rail and structural health. Worldsensing is headquartered in Barcelona and has a local presence in the UK, North and South America, Singapore, Australia and Poland. Investors include Cisco Systems, Mitsui & Co, McRock Capital, ETF, Kibo Ventures, JME Ventures and Bentley Systems.

Products & Services

Geological, Geotechnical Services and Equipment
Instrumentation Equipment and Services
Survey Equipment and Lasers

Main Office

Viriat, 47 10th Floor
Barcelona, Barcelona 08014 Spain
Phone: +34934180585
Email: connect@worldsensing.com
www.worldsensing.com

WSP

Booth 807

WSP is a leader in tunneling and underground construction, from San Francisco to Stockholm. The firm has participated in the design and construction of some of the longest, largest, deepest, and most complicated tunnels in the world, including tunnels built in hard rock, soft ground or mixed-face conditions, and using mining, boring, jacking, cut-and-cover, and immersed tunnel technology. Projects include the Second Avenue Subway in New York City; the Stockholm City Line; the

Eurasia tunnel in Istanbul; and San Francisco's Central Subway. WSP employs 66,000 professionals in over 500 offices across 40 countries.

Products & Services

Consulting Engineers
Engineering Design and Services for Tunnels
Geological, Geotechnical Services and Equipment

Main Office

One Penn Plz, 3rd Floor
New York, NY 10119 United States of America
Phone: (212) 465-5000
www.wsp.com

x-Glo North America Inc

Booth 310

LED Strip Lighting

Products & Services

Control Systems
Lighting Systems
Safety Products
Tunnel Communication Systems and Equipment

Main Office

15 Rita St
Markstay, ON POM 2G0 Canada
Phone: (705) 698-0441
Email: don@x-glo-na.com
www.x-glo.ca

Yamamoto Rock Splitter

Booth 628

Yamamoto hydraulic Rock Splitters offers non-explosive excavation of hard rock without noise, vibrations or flyrock. The excavator-mounted splitters are based on the wedge principle and are the largest of its kind on the market. Applications include open pit excavation, highway widening, building foundations, shaft-sinking and tunnelling. The first unit of Yamamoto Rock Splitter was supplied in 1981. The method has become a standard for excavation in sensitive areas. We offer two models, HRB-1000 for 4" holes and HRB-1700 for 5" holes. Yamamoto is the ideal choice if you don't want to blast!

Products & Services

Hydraulic Hammers and Drills
Shaft Drilling and Raiseboring Equipment
Tunnel Boring Equipment
Underground Excavation Services and Equipment

Main Office

3 Germay Dr. Unit 4 #2882
Wilmington, DE 19804 United States of America
Phone: (646) 543-8940
Email: info@yamamotorocksplitter.com
www.yamamotorocksplitter.com

Zitron USA

Booth 329

Ventilation, Fans, Ducting and Dust Control

Products & Services

Control Systems
Dust and Fume Control Technology
Ventilation Systems, Materials and Equipment

Main Office

PO Box 2668
Beckley, WV 25802 United States of America
Phone: (304) 253-0777
Email: Caleb@zitron.com
www.Zitron.com/us

ADDITIONAL RETC SUPPORTERS



PRODUCTS & SERVICES

Abrasion and Impact Resistant Materials

E-BERK-Booth 118
FPT Infrastructure-Booth 431
JADCO Manufacturing Inc-Booth 726
Roxard Industries-Booth 528
Technogenia Lasercarb Oklahoma Inc-Booth 735

Air Locks and Bulkheads

ASI Marine-Booth 831

Blasting Services and Supplies

GeoSonics/Vibra-Tech-Booth 925

Computer Hardware and Software

BabEng, LLC-Booth 219
Inzwa Technologies-Booth 1009
Rocscience, Inc-Booth 923
Sequent-Booth 308
SIXENSE-Booth 315

Concrete Mixing and Transportation Equipment

Advanced Concrete Technologies, Inc-Booth 825
Fiori Group S.p.A-Booth 614
McDowell Equipment Ltd-Booth 718
MCT Group Inc-Booth 834
Putzmeister America, Inc-Booth 529
Simem Underground Solutions, Inc-Booth 723
Treviicos-Booth 111

Concrete Reinforcement

BarChip Inc-Booth 424
Bekaert-Booth 411
Continental Building Materials-Booth 112
GCP Applied Technologies-Booth 324
MAPEI Corp-Booth 106
Sika Corporation-Booth 316
Williams Form Engineering Corp-Booth 418

Construction - Contracting Services

Acciona Infrastructure Canada Inc.-Booth 113
ASI Marine-Booth 831
Ballard Marine Construction-Booth 312
Crux Subsurface, Inc-Booth 519
Dibit Measuring Technique USA, Inc.-Booth 716
EC Applications - Tunnel Lining-Booth 115
GZA GeoEnvironmental, Inc-Booth 114

Hatch-Booth 107
HYTORC-Booth 706
Kiewit Infrastructure Co-Booth 128
Michels Corp-Booth 708
MILLER-Booth 814
North American Drillers LLC, a Shaft Drillers International Company-Booth 724
Parsons-Booth 918
Pini Group USA Inc.-Booth 832
PSC Crane and Rigging-Booth 826
Richard Goettle, Inc-Booth 936

Consulting Engineers

Acciona Infrastructure Canada Inc.-Booth 113
Advanced Infrastructure Design-Booth 908
AECOM-Booth 223
Arup-Booth 126
BabEng, LLC-Booth 219
Delve Underground-Booth 522
Dr. Sauer & Partners Corp-Booth 317
Fugro-Booth 730
Gall Zeidler Consultants-Booth 711
Geocomp Corp/GeoTesting Express, Inc-Booth 611
Gomez International, Inc-Booth 617
GZA GeoEnvironmental, Inc-Booth 114
Hager-Richter Geoscience, Inc-Booth 610
Hatch-Booth 107
ILF Consultants, Inc.-Booth 934
JCK Underground, Inc-Booth 331
Mott MacDonald-Booth 509
MSP Structures Inc-Booth 926
Nexans AmerCable-Booth 911
Parsons-Booth 918
Pini Group USA Inc.-Booth 832
Schauenburg Maschinen- und Anlagen-Bau GmbH-Booth 833
Schnabel Engineering-Booth 806
Shannon & Wilson, Inc-Booth 612
Stantec-Booth 212
STV Inc-Booth 1010
Towill, Inc.-Booth 217
TRE ALTAMIRA Inc-Booth 731
WSP-Booth 807

Consulting Environmental

ENVECO ENVIRONMENTAL SOLUTIONS, LLC-Booth 530
GZA GeoEnvironmental, Inc-Booth 114
Hager-Richter Geoscience, Inc-Booth 610

Hatch-Booth 107
Pini Group USA Inc.-Booth 832
Schauenburg Maschinen- und Anlagen-Bau GmbH-Booth 833
Schnabel Engineering-Booth 806
Shannon & Wilson, Inc-Booth 612
SIXENSE-Booth 315
Stantec-Booth 212
TRE ALTAMIRA Inc-Booth 731

Control Systems

Control International-Booth 625
IoT Automation-Booth 512
Watson Bowman Acme-Booth 124
x-Glo North America Inc-Booth 310
Zitron USA-Booth 329

Conveyor Equipment and Systems

E-BERK-Booth 118
H+E Logistics USA, Inc-Booth 211
MCT Group Inc-Booth 834
Moldequipo Internacional-Booth 737
Robbins-Booth 409
Terratec / Kelley Engineered Equipment-Booth 526

Drilling Services and Equipment

Crux Subsurface, Inc-Booth 519
Derrick Corporation-Booth 427
ENVECO ENVIRONMENTAL SOLUTIONS, LLC-Booth 530
J.H. Fletcher & Co-Booth 930
Kayden Environmental Services-Booth 109
Malcolm Drilling Co Inc-Booth 425
McDowell Equipment Ltd-Booth 718
Palmieri S.p.A.-Booth 314
Ruen Drilling, Inc-Booth 322
Sandvik Mining and Rock Solutions-Booth 412
Treviicos-Booth 111

Dust and Fume Control Technology

ABC Industries, Inc-Booth 415
Geo-Instruments-Booth 909
Grydale USA-Booth 910
Rocvent Inc-Booth 815
Spendrup Fan Co/CFT-Booth 715
Zitron USA-Booth 329

Earth Pressure Balance Machines

ASI Marine-Booth 831
Herrenknecht Tunnelling Systems USA, Inc-Booth 206
Master Builders Solutions-Booth 607
MTS /Polaris Underground Solutions-Booth 1007



Robbins-Booth 409
Terratec / Kelley Engineered Equipment-Booth 526

Educational

Colorado School of Mines-Booth 725
Deep Foundations Institute-Booth 900
Northwest Laborers-Employers Training Trust-Booth 817
Tunnel Business Magazine (TBM)-Booth 513
Tunneling Journal-Booth 413
Tunnels & Tunnelling-Booth 1006
TunnelTalk-Booth 325

Electrical - Generator-Motor, Wire-Cable

CAB-Booth 818
Carroll Technologies Group-Booth 808
Gomez International, Inc-Booth 617
Line Power-Booth 622
Nexans AmerCable-Booth 911

Engineering Design and Services for Tunnels

AECOM-Booth 223
Arup-Booth 126
BabEng, LLC-Booth 219
Bekaert-Booth 411
CBE GROUP-Booth 627
CREG TBM Germany GmbH-Booth 830
Delve Underground-Booth 522
Dibit Measuring Technique USA, Inc.-Booth 716
Dr. Sauer & Partners Corp-Booth 317
Gall Zeidler Consultants-Booth 711
Geocomp Corp/GeoTesting Express, Inc-Booth 611
GeoSonics/Vibra-Tech-Booth 925
Gomez International, Inc-Booth 617
Hatch-Booth 107
HNTB Corp-Booth 216
JCK Underground, Inc-Booth 331
Matrix Design Group-Booth 1022
Mott MacDonald-Booth 509
MSP Structures Inc-Booth 926
MTS /Polaris Underground Solutions-Booth 1007
Parsons-Booth 918
Promat International NV-Booth 117
PSC Crane and Rigging-Booth 826
Schnabel Engineering-Booth 806
Shannon & Wilson, Inc-Booth 612
SIXENSE-Booth 315
Stantec-Booth 212
STV Inc-Booth 1010
Terra Insights-Booth 719

Terratec / Kelley Engineered Equipment-Booth 526
Towill, Inc.-Booth 217
TRE ALTAMIRA Inc-Booth 731
United Rentals Trench Safety-Booth 110
WSP-Booth 807

Environmental Control Equipment and Supplies

AMR PEMCO, Inc-Booth 1011
ENVECO ENVIRONMENTAL SOLUTIONS, LLC-Booth 530
Innovative Wireless Technologies-Booth 922
IoT Automation-Booth 512

Explosive Materials and Services

Daigh Company, Inc-Booth 733
GeoSonics/Vibra-Tech-Booth 925

Fabrication Materials

Gomez International, Inc-Booth 617
JADCO Manufacturing Inc-Booth 726

Geological, Geotechnical Services and Equipment

Ackcio-Booth 1027
AECOM-Booth 223
Amberg Technologies Ltd-Booth 430
Collier Geophysics-Booth 1008
Crux Subsurface, Inc-Booth 519
Delve Underground-Booth 522
Dibit Measuring Technique USA, Inc.-Booth 716
FPT Infrastructure-Booth 431
Geocomp Corp/GeoTesting Express, Inc-Booth 611
Geo-Instruments-Booth 909
GEOKON-Booth 423
Geosense Ltd-Booth 626
GeoSonics/Vibra-Tech-Booth 925
GZA GeoEnvironmental, Inc-Booth 114
Hager-Richter Geoscience, Inc-Booth 610
IoT Automation-Booth 512
JENNMAR Civil-Booth 123
Mott MacDonald-Booth 509
North American Drillers LLC, a Shaft Drillers International Company-Booth 724
Parsons-Booth 918
Schnabel Engineering-Booth 806
Sequent-Booth 308
Senceive Corp-Booth 811
Shannon & Wilson, Inc-Booth 612

SIXENSE-Booth 315
Stage 3 Separation-Booth 630
STV Inc-Booth 1010
Terra Insights-Booth 719
TRE ALTAMIRA Inc-Booth 731
Williams Form Engineering Corp-Booth 418
Worldsensing SL-Booth 623
WSP-Booth 807

Ground Freezing

Bauer Foundation Corporation-Booth 524
CDM Smith-Booth 608
Keller-Booth 907
SoilFreeze Inc-Booth 727
TPH & GEOFORM North America-Booth 629

Ground Improvement Equipment and Services

Alpine Equipment-Booth 615
Avanti International-Booth 618
CJGeo-Booth 809
Crux Subsurface, Inc-Booth 519
DSI Tunneling LLC-Booth 408
Inflatable Packers International LLC-Booth 914
Keller-Booth 907
Malcolm Drilling Co Inc-Booth 425
Master Builders Solutions-Booth 607
North American Drillers LLC, a Shaft Drillers International Company-Booth 724
Shannon & Wilson, Inc-Booth 612
Simem Underground Solutions, Inc-Booth 723
Stage 3 Separation-Booth 630
TPH & GEOFORM North America-Booth 629
Williams Form Engineering Corp-Booth 418

Grouting Services, Equipment and Materials

Aerix Industries-Booth 319
AMIX Systems Ltd-Booth 1023
Avanti International-Booth 618
Bauer Foundation Corporation-Booth 524
ChemGrout, Inc-Booth 422
CJGeo-Booth 809
Crux Subsurface, Inc-Booth 519
DSI Tunneling LLC-Booth 408
Fiori Group S.p.A-Booth 614
FPT Infrastructure-Booth 431
GCP Applied Technologies-Booth 324

PRODUCTS & SERVICES

Inflatable Packers Internaional LLC–Booth 914
Keller–Booth 907
Malcolm Drilling Co Inc–Booth 425
MAPEI Corp–Booth 106
Master Builders Solutions–Booth 607
Minova–Booth 714
MixOnSite USA, Inc–Booth 837
Nicholson Construction Co–Booth 311
QSP Packers, LLC–Booth 728
Renesco Inc–Booth 327
Richard Goettle, Inc–Booth 936
Richway Industries–Booth 823
Sika Corporation–Booth 316
Simem Underground Solutions, Inc–Booth 723
Stage 3 Separation–Booth 630
Technical Tunnelling Components LTD (TTC)–Booth 309
TPH & GEOFORM North America–Booth 629
Treviicos–Booth 111

Hoists and Headframes

Carroll Technologies Group–Booth 808
MILLER–Booth 814
PSC Crane and Rigging–Booth 826
Treviicos–Booth 111

Hydraulic Hammers and Drills

Epiroc–Booth 508
Treviicos–Booth 111
Yamamoto Rock Splitter–Booth 628

Instrumentation Equipment and Services

Ackcio–Booth 1027
AMR PEMCO, Inc–Booth 1011
Carroll Technologies Group–Booth 808
Crux Subsurface, Inc–Booth 519
Dibit Measuring Technique USA, Inc.–Booth 716
Duham Geo Slope Indicator–Booth 702
Geocomp Corp/GeoTesting Express, Inc–Booth 611
Geo-Instruments–Booth 909
GEOKON–Booth 423
Geosense Ltd–Booth 626
GeoSonics/Vibra-Tech–Booth 925
GZA GeoEnvironmental, Inc–Booth 114
Inzwa Technologies–Booth 1009
Poltinger Precision Systems GmbH–Booth 116
Schnabel Engineering–Booth 806
Senceive Corp–Booth 811
Shannon & Wilson, Inc–Booth 612
Sigicom Inc–Booth 906

SIXENSE–Booth 315
Terra Insights–Booth 719
Trimble Inc–Booth 624
VMT USA–Booth 209
Worldsensing SL–Booth 623

Jet Grouting Equipment and Services

Keller–Booth 907
Malcolm Drilling Co Inc–Booth 425
TPH & GEOFORM North America–Booth 629

Laser Guidance Systems

Amberg Technologies Ltd–Booth 430
Poltinger Precision Systems GmbH–Booth 116
Tunnel24 GmbH–Booth 122
VMT USA–Booth 209

Lighting Systems

Carroll Technologies Group–Booth 808
IoT Automation–Booth 512
x-Glo North America Inc–Booth 310

Lubricants for TBM

MAPEI Corp–Booth 106
Master Builders Solutions–Booth 607
Sika Corporation–Booth 316

Microtunneling Equipment, Tools, and Supplies

AGRU America, Inc–Booth 214
ASI Marine–Booth 831
Derrick Corporation–Booth 427
E-BERK–Booth 118
FPT Infrastructure–Booth 431
Herrenknecht Tunnelling Systems USA, Inc–Booth 206
Kayden Environmental Services–Booth 109
McDowell Equipment Ltd–Booth 718
MTS /Polaris Underground Solutions–Booth 1007
Palmieri S.p.A.–Booth 314
Poltinger Precision Systems GmbH–Booth 116
Schauenburg Maschinen- und Anlagen-Bau GmbH–Booth 833
Sentinel Solutions LLC–Booth 525
Terratec / Kelley Engineered Equipment–Booth 526
Tunnel24 GmbH–Booth 122
VMT USA–Booth 209

Mining Equipment

ABC Industries, Inc–Booth 415
Ackcio–Booth 1027
Alpine Equipment–Booth 615

AMR PEMCO, Inc–Booth 1011
Brookville Equipment Corp–Booth 518
CAB–Booth 818
Chengdu Foresight–Booth 932
Epiroc–Booth 508
H+E Logistics USA, Inc–Booth 211
J.H. Fletcher & Co–Booth 930
JADCO Manufacturing Inc–Booth 726
Line Power–Booth 622
Matrix Design Group–Booth 1022
McDowell Equipment Ltd–Booth 718
MineARC Systems–Booth 916
Minova–Booth 714
QSP Packers, LLC–Booth 728
Robbins–Booth 409
Sandvik Mining and Rock Solutions–Booth 412
Terra Insights–Booth 719
Terratec / Kelley Engineered Equipment–Booth 526
Tsurumi Pump–Booth 822

Precast Concrete Linings

AGRU America, Inc–Booth 214
CBE GROUP–Booth 627
Master Builders Solutions–Booth 607
MSP Structures Inc–Booth 926
SEALABLE Solutions GmbH (formerly Datwyler Sealing Technology)–Booth 323
Sika Corporation–Booth 316
Simem Underground Solutions, Inc–Booth 723
Technical Tunnelling Components LTD (TTC)–Booth 309

Publishers

Deep Foundations Institute–Booth 900
Tunnel Business Magazine (TBM)–Booth 513
Tunneling Journal–Booth 413
Tunnels & Tunnelling–Booth 1006
TunnelTalk–Booth 325

Pumps and Pumping Equipment

Avanti International–Booth 618
ChemGrout, Inc–Booth 422
Gomez International, Inc–Booth 617
HYTORC–Booth 706
McDowell Equipment Ltd–Booth 718
Miller Sales and Engineering–Booth 824
Minova–Booth 714
Sentinel Solutions LLC–Booth 525
Simem Underground Solutions, Inc–Booth 723
Tsurumi Pump–Booth 822
Tunnel24 GmbH–Booth 122



Rail Products

Brookville Equipment Corp–Booth 518
JENNMAR Civil–Booth 123
SEALABLE Solutions GmbH (formerly Datwyler Sealing Technology)–Booth 323

Roadheaders

Antraquip Corp–Booth 523
CREG TBM Germany GmbH–Booth 830
Poltinger Precision Systems GmbH–Booth 116
Sandvik Mining and Rock Solutions–Booth 412
VMT USA–Booth 209

Rock Drills

Epiroc–Booth 508
J.H. Fletcher & Co–Booth 930
McDowell Equipment Ltd–Booth 718
Palmieri S.p.A.–Booth 314
ROBODRILL S.A.–Booth 527
Sandvik Mining and Rock Solutions–Booth 412

Rock TBM's

CREG TBM Germany GmbH–Booth 830
Herrenknecht Tunnelling Systems USA, Inc–Booth 206
MTS /Polaris Underground Solutions–Booth 1007
Palmieri S.p.A.–Booth 314
Robbins–Booth 409

Rotary Drum Cutters

Alpine Equipment–Booth 615
Antraquip Corp–Booth 523
Epiroc–Booth 508

Safety Products

AMR PEMCO, Inc–Booth 1011
CAB–Booth 818
Carroll Technologies Group–Booth 808
Control International–Booth 625
HYTORC–Booth 706
Innovative Wireless Technologies–Booth 922
IoT Automation–Booth 512
Matrix Design Group–Booth 1022
MineARC Systems–Booth 916
Strata Worldwide | Tunneling–Booth 827
United Rentals Trench Safety–Booth 110
x-Glo North America Inc–Booth 310

Scaling

Antraquip Corp–Booth 523
J.H. Fletcher & Co–Booth 930

Segment Accessories

Algaher S.A.–Booth 927
CBE GROUP–Booth 627
FAMA Srl–Booth 836
MSP Structures Inc–Booth 926
SEALABLE Solutions GmbH (formerly Datwyler Sealing Technology)–Booth 323
Technical Tunnelling Components LTD (TTC)–Booth 309

Shaft Drilling and Raiseboring Equipment

Herrenknecht Tunnelling Systems USA, Inc–Booth 206
JENNMAR Civil–Booth 123
Keller–Booth 907
MILLER–Booth 814
North American Drillers LLC, a Shaft Drillers International Company–Booth 724
Palmieri S.p.A.–Booth 314
Yamamoto Rock Splitter–Booth 628

Shotcrete Equipment, Supplies, and Services

Bekaert–Booth 411
Continental Building Materials–Booth 112
GCP Applied Technologies–Booth 324
Malcolm Drilling Co Inc–Booth 425
MAPEI Corp–Booth 106
Master Builders Solutions–Booth 607
McDowell Equipment Ltd–Booth 718
Minova–Booth 714
North American Drillers LLC, a Shaft Drillers International Company–Booth 724
Putzmeister America, Inc–Booth 529
Sika Corporation–Booth 316
Simem Underground Solutions, Inc–Booth 723
Strata Worldwide | Tunneling–Booth 827

Slurry Services and Machines

Derrick Corporation–Booth 427
ENVECO ENVIRONMENTAL SOLUTIONS, LLC–Booth 530
Kayden Environmental Services–Booth 109
Keller–Booth 907
Malcolm Drilling Co Inc–Booth 425

MAPEI Corp–Booth 106
MTS /Polaris Underground Solutions–Booth 1007
Schauenburg Maschinen- und Anlagen-Bau GmbH–Booth 833
Sentinel Solutions LLC–Booth 525
Stage 3 Separation–Booth 630
Treviicos–Booth 111
Tunnel24 GmbH–Booth 122

Soft Ground Shields

Herrenknecht Tunnelling Systems USA, Inc–Booth 206
Robbins–Booth 409
TPH & GEOFORM North America–Booth 629

Soil Conditioning Equipment and Materials

FPT Infrastructure–Booth 431
Geocomp Corp/GeoTesting Express, Inc–Booth 611
MAPEI Corp–Booth 106
Minova–Booth 714
Sika Corporation–Booth 316
TNL18–Booth 1026
TPH & GEOFORM North America–Booth 629
Williams Form Engineering Corp–Booth 418

Steel Pipe

JENNMAR Civil–Booth 123
Naylor Pipe Co–Booth 707
TBM Supply–Booth 616

Survey Equipment and Lasers

Amberg Technologies Ltd–Booth 430
ASI Marine–Booth 831
Dibit Measuring Technique USA, Inc.–Booth 716
GZA GeoEnvironmental, Inc–Booth 114
Poltinger Precision Systems GmbH–Booth 116
Senceive Corp–Booth 811
Trimble Inc–Booth 624
VMT USA–Booth 209
Worldsensing SL–Booth 623

Tunnel Boring Equipment

Antraquip Corp–Booth 523
ASI Marine–Booth 831
Ballard Marine Construction–Booth 312
Bessac–Booth 313
Chengdu Foresight–Booth 932

PRODUCTS & SERVICES

CREG TBM Germany GmbH–Booth 830
E-BERK–Booth 118
Epiroc–Booth 508
Gomez International, Inc–Booth 617
Herrenknecht Tunneling Systems USA, Inc–Booth 206
HNTB Corp–Booth 216
Messinger Bearings–Booth 416
MTS /Polaris Underground Solutions–Booth 1007
Palmieri S.p.A.–Booth 314
Poltinger Precision Systems GmbH–Booth 116
Richway Industries–Booth 823
Robbins–Booth 409
Roxard Industries–Booth 528
Sentinel Solutions LLC–Booth 525
Spendrup Fan Co/CFT–Booth 715
Terratec / Kelley Engineered Equipment–Booth 526
VMT USA–Booth 209
Yamamoto Rock Splitter–Booth 628

Tunnel Communication Systems and Equipment

Ackcio–Booth 1027
AMR PEMCO, Inc–Booth 1011
Carroll Technologies Group–Booth 808
Control International–Booth 625
HNTB Corp–Booth 216
Innovative Wireless Technologies–Booth 922
IoT Automation–Booth 512
MineARC Systems–Booth 916
Strata Worldwide | Tunneling–Booth 827
Terra Insights–Booth 719
Tunnel Radio of America, Inc–Booth 531
x-Glo North America Inc–Booth 310

Tunnel Haulage Systems

E-BERK–Booth 118
HNTB Corp–Booth 216
Matrix Design Group–Booth 1022
McDowell Equipment Ltd–Booth 718

Tunnel Lining and Support Materials

ABC Industries, Inc–Booth 415
AGRU America, Inc–Booth 214
Antraquip Corp–Booth 523
Bekaert–Booth 411
Bessac–Booth 313
CAB–Booth 818
CBE GROUP–Booth 627
Chengdu Foresight–Booth 932

Continental Building Materials–Booth 112
David R. Klug & Associates, Inc–Booth 213
DSI Tunneling LLC–Booth 408
EC Applications - Tunnel Lining–Booth 115
Everest Equipment Co–Booth 516
FPT Infrastructure–Booth 431
GCP Applied Technologies–Booth 324
HNTB Corp–Booth 216
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Fiori Group S.p.A–Booth 614
Kayden Environmental Services–Booth 109
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Parsons–Booth 918
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Yamamoto Rock Splitter–Booth 628

Underground Locomotives and Rail Haulage Equipment

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PSC Crane and Rigging–Booth 826

Underground Utility Materials and

Operations

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Avanti International–Booth 618
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TBM Supply–Booth 616

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ABC Industries, Inc–Booth 415
ABC Ventilation Systems–Booth 120
AMR PEMCO, Inc–Booth 1011
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Stage 3 Separation–Booth 630
Tsurumi Pump–Booth 822

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