Design for intersecting tunnels
Hybrid metro stations
RETC returns to in-person meeting
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The city of Charleston’s Spring/Fishburne US17 Drainage Improvements Project is a five-phase program designed to alleviate flooding in two drainage basins covering approximately 202 ha (500 acres), or about 20 percent of the Charleston peninsula. This project has several objectives: to improve the mobility, efficiency, emergency preparedness and community livability; and, most importantly, to alleviate many of the flooding problems by reinvesting in the infrastructure. See the article on page 16.

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Margo Ellis

tucmagazine.com
Looking back and looking ahead as term comes to an close

This is my last column in this magazine as the Chair of the UCA Executive Committee, so it is somewhat inevitable for this column to have a look back and look forward. As the Chair of UCA, you take on the role of a steward, building on the achievements and leadership of those that have gone before and trying to push forward some key objectives into the future. I hope to leave some fertile ground on which future leadership can continue to build.

Looking back, I said this in my first column two years ago:

In addition to continuing the great work of the UCA, I have three areas of focus for my two-year tenure in the chair:

1. A focus on listening to what the industry needs and wants from the UCA and setting out a clear pathway of action items to achieve those goals.
2. A focus on getting more volunteers engaged in UCA activities so we can achieve our goals in a reasonable and practical timeframe.
3. Provide clear and transparent feedback to the industry about what the UCA is doing on behalf of the members.

After multiple member engagement surveys and an industry leadership survey ahead of the strategic planning exercise, it appears that we have achieved success for the first objective. This regular column has been my attempt to meet the goals of the third objective. I have always tried to be clear on the inner workings and developing news from the UCA initiatives and report where you, as members, can get more involved.

Engaging more volunteers in objective two provides so many benefits both for the individuals and for the UCA. This is something I have seen help my own career tremendously, so encouraging participation is a particular passion of mine. We have worked as a group at UCA to expand the number of volunteers and there are many ongoing and new opportunities, such as:

• An increase in the number and quality of guideline publications (e.g., we now have several in the pipeline — risk management, TBM selection, alternative delivery, backfill grouting and others).
• We have created a website and expanded the Down for That initiative to engage young members and students, bringing new blood into the industry.
• We have expanded our outreach to colleges and even high schools, encouraging presentations and preparing materials for presenters.
• We have encouraged and further empowered the Young Members and Women in Tunneling groups, with conferences and other events for networking and advancement. Representation of UCA at the newly formed SME Inclusion and Diversity committee will drive our passion to increase the number and influence of these important groups for the future of our industry.
• We have continued our contact with and education of elected officials and are creating a “top underground projects” list to enhance these education efforts ahead of anticipated federal infrastructure investment.
• We have created a dozen new committees with more than 100 new UCA volunteers by forming...

(continued on page 12)
BANGKOK METRO

Bangkok’s Mass Rapid Transit network is quickly expanding to meet the needs of this growing Asian Mega-City. For the 3.3km Orange Line Project, TERRATEC has delivered a complete tunnelling solution to contractor, Italian-Thai Development PCL.

Having the final breakthrough completed a full month ahead of schedule, TERRATEC’s continuing success is a result of robust custom-made TBM designs, a readily available stock of TBM spares and consumables, and a highly-skilled team offering specialised TBM support and prompt onsite assistance throughout tunnelling operations.
The U.S. Senate confirmed Polly Trottenberg, by a vote of 82-15, to the No. 2 spot at the U.S. Transportation Department. Trottenberg is a New York Policy veteran who will be deputy to Secretary Pete Buttigieg. She will bring more than 30 years of experience to helping President Joe Biden sell his $2.25 trillion infrastructure package.

Bloomberg Government reported that Biden’s $2 trillion infrastructure plan faces pushback from Republicans and corporations opposed to the tax increases proposed to pay for the plan. Trottenberg, whose nomination was opposed by 15 Republicans, drew criticism over her whose nomination was opposed by 15 years of experience to helping President Joe Biden sell his $2.25 trillion infrastructure package.

Democrats lauded her support of the long-delayed Gateway rail project to alleviate congestion between New York and New Jersey, as well her focus on clean transportation technologies and making streets safer for multimodal users, like cyclists and pedestrians.

Trottenberg’s most recent post was New York Mayor Bill de Blasio’s Department of Transportation commissioner. She has promised to seek bipartisan solutions for the nation’s transportation needs.

“Throughout my career, I always valued the ability to work with colleagues across the aisle,” she said at her nomination hearing on March 3.

“Her understanding of transportation issues will help the administration work to get a package across the finish line, said Greg Regan, president of the Transportation Trades Department, AFL-CIO.

Trottenberg served on Biden’s transition team, worked in the Obama-era Transportation Department as assistant secretary and under secretary for policy, and spent 12 years working on legislation as a Senate aide for Democrats including Charles Schumer (NY), the current majority leader.

Schumer said on the Senate floor that he talked with Trottenberg “regularly” about Gateway. During her confirmation hearing, Trottenberg agreed to prioritize the rail and tunnel project, calling it a “project of national significance.”

The Biden infrastructure package would double transit spending, according to the White House, providing $85 billion to modernize public transportation.

**Tunnel connecting Northern Ireland and Scotland proposed**

High Speed Rail Group (HSRG) a group of rail industry experts has created a proposal for a tunnel under the Irish Sea that would link Northern Ireland to Scotland and create better connectivity between the four constituent parts of the United Kingdom.

The Guardian reported that the submission from HSRG is expected to be reviewed by Sir Peter Hendy, who is expected to publish his interim report within weeks.

The proposed tunnel would link the towns of Stranraer and Larne, which are 50 km (31 miles) apart but a preferred route for the tunnel, based on 120-year-old research by the Victorian engineer James Barton, would be diverted to avoid Beaufort’s Dyke, a 305-m (1,000-ft) deep trench in the Irish Sea.

According to the HSRG, the tunnel would bind Northern Ireland closer to Great Britain and would “address problems in economic status of Northern Ireland post-Brexit.”

Jim Steer, an HSRG board member, said, “There is an urgent need for both new and improved transport links between the four nations of the United Kingdom, which have been systematically neglected for too long.

“Cross-border travel markets for rail were growing strongly over the period to 2019. Travel generates economic value, but the opportunity for further economic stimulus from this source will be lost if transport network capacity constraints are not addressed.

“Building on the transformative impact of HS2, HSRG are calling for these cross-border rail links to be addressed as a matter of urgency, safeguarding the strength of the whole of the UK economy in the years ahead.”

The pitch submitted to the review claims the proposal has the backing of Northern Ireland post-Brexit.”

Experts raised concerns about the practicality of constructing a bridge across the stormy stretch of water, which is more than 305-m (1,000-ft) deep in places, and said would require dozens of support towers at heights “never achieved anywhere in the world.”
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U.S. Transportation Secretary Pete Buttigieg told lawmakers that the Gateway rail tunnel linking New York and New Jersey is of national significance and as such, the Biden administration is prioritizing the project.

“This is a regional issue, but one of national significance because if there were a failure in one of those tunnels, the entire U.S. economy would feel it,” Buttigieg told members of the House Transportation and Infrastructure Committee.

Crains New York Business reported that Buttigieg provided lawmakers with his first update of the project. The project was stalled by former President Donald Trump who in 2018 threatened to shut down the government if a spending bill directed federal funding for the tunnel. Gateway was ineligible for federal taxpayer money, the Trump administration said, because New York and New Jersey hadn’t pledged enough cash.

Buttigieg said the Federal Rail Administration and Federal Transit Administration (FTA) are working with New Jersey Transit and the Port Authority of New York and New Jersey, as well as with Amtrak and the Gateway Development Commission, on updates to a draft environmental impact statement issued in 2017.

The impact statement is “a big part of what needs to be completed in order to get there,” Buttigieg said. The process involves reviewing anything that might have changed since the draft was issued, and coordinating with other federal agencies like the U.S. Army Corps of Engineers, as well as state agencies that might have jurisdiction, he said.

Angelo Roefaro, a spokesman for Senate Majority Leader Chuck Schumer, said Buttigieg has indicated to the New York Democrat that the environmental review will be approved in May.

“I’ve said that the new administration could break Trump’s petty Gateway roadblock with the

(continued on page 8)
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Sydney Metro West receives major planning approvals

The Sydney Metro West project has received two major planning approvals in readiness for the tunnel boring machines to start working by the end of 2022.

The planning approvals for the project are being done in stages because of the project size.

First, the Sydney Metro West Project Concept has received planning approval from Westmead to Sydney’s central business district and for the station excavation and tunneling between Westmead and The Bays.

Second, Sydney Metro has received planning approval for two planned precast facilities at Eastern Creek, which are to contribute to the construction of Sydney Metro West. The two facilities will manufacture 148,000 precast concrete segments for the 24-km (15-miles) twin tunnels between Westmead and Sydney CBD. Once built, it is estimated that it will take passengers 20 minutes to travel from Parramatta to Sydney CBD.

Stations have been confirmed at Westmead, Parramatta, Sydney Olympic Park, North Strathfield, Burwood North, Five Dock, The Bays, Pyrmont and Sydney CBD.

Future planning stages are required for major civil construction works such as station excavation and tunneling between The Bays and Sydney CBD, for tunnel fitout, station building and operation of the line between Westmead and the central business district.

Construction on the Sydney Metro West project started in late 2020. The first tunneling contracts are likely to be issued in mid-2021.

Gateway: Project would repair tunnels under Hudson

(continued from page 6)

‘flick of a pen,’” Schumer said in a statement. “The Biden administration and Secretary Buttigieg have picked up that pen and heeded the call to free the ‘hostage’ that is Gateway.”

The tunnel would carry Amtrak and New Jersey Transit commuter trains under the Hudson River. Amtrak said it will allow for twice as many trains to run under the Hudson River, including those that are part of its Northeast Corridor service that connects Boston, New York and Washington.

“The FTA is working closely with project sponsors as it advances through the capital investment grant process prescribed in law, which is obviously an important part of the picture when it comes to funding,” Buttigieg said.

The Gateway Development Commission said in a statement after the hearing that “we applaud Secretary Buttigieg’s public commitment to the Gateway Program, particularly confirming that the Hudson Tunnel Project is a project ‘of national significance’ and setting a rapid timeline for completing the project’s environmental review.”

The commission said it’s working with local and federal partners to complete the environmental review and improve the project’s grant rating, “so we can start full construction and finally replace a 110-year-old one-track-in, one-track-out delay-prone tunnel with a 21st Century rail link between New York, New Jersey and the rest of the Northeast Corridor.”

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First tunnel boring machine reaches future Wilshire/LA Cienega subway station

The first of two tunnel boring machines (TBM) working on the D Line (Purple) Extension project in Los Angeles, CA broke through to the Wilshire/La Cienega subway station in Beverly Hills.

Metro announced that tunneling for the first 6.4-km (4-mile) section of the subway project is now two-thirds complete. More than 90 percent of the tunnels have been mined safely and Metro anticipates completing tunnel mining in summer 2021.

Excavation for all three subway station boxes beneath Wilshire Boulevard has been completed.

Elsie, the 910-t (1,000-st), 122-m (400-ft) long TBM, started west at the Wilshire/Fairfax station on May 29, 2020, and broke through to the Wilshire/La Cienega station site about 1.6 km (1 mile) away on Feb. 25, 2021.

Reaching this milestone is a significant win for Metro. Section 1 of project tunneling has presented challenges that have been successfully overcome by the project. En route to Wilshire/La Cienega, the agency’s modern, high-tech TBMs have mined through a unique combination of soils and geologic conditions, including tar sands and methane gas.

Metro’s TBMs were first lowered into the ground at Metro’s Wilshire/La Brea station site in the Miracle Mile area of Wilshire in October 2018. While advancing, the TBM tunneled about 18 m/d (60 ftpd). They worked five days a week, 20 hours a day.

Metro’s TBMs are pressurized, closed-face machines that minimize ground settlement during excavation. The tunnel is lined with precast concrete segments that are bolted together to form a ring. Segments are also gasketed to make the joints between segments water- and gas-tight.

When tunneling is finished for this project section, both of Metro’s TBMs will have mined nearly half a million cubic yards of earth. The TBMs were manufactured in Germany by Herrenknecht AG. Metro has contracted with Skanska Traylor Shea (STS), a joint venture to design and build the first section of the project.

The $9.3-billion Metro Purple Line Extension is a 14-km (9-mile) underground subway project that will extend the Metro Purple Line from its terminus in Koreatown to Westwood/VA Hospital in West Los Angeles. Section 1 is expected to be completed in 2023, Section 2 in 2025 and Section 3 in 2027.
Canada to invest nearly $15 billion for transit projects

The Canadian government announced plans to invest $14.9 billion for public transit project over the next eight years. The plans include permanent funding of $3 billion per year for Canadian communities beginning in 2026-27.

According to a government news release, “This commitment provides cities and communities the predictable transit funding they need to plan for the future, and is part of our plan to create one million jobs, fight climate change and rebuild a more sustainable and resilient economy.”

“When we invest in public transit infrastructure, we are supporting good middle-class jobs, creating better commutes, fighting climate change and helping make life easier and more affordable for Canadians,” said Prime Minister Justin Trudeau. “We will continue to do what it takes to ensure our economic recovery from COVID-19 and build back a more resilient country for everyone.”

Reaction from local municipal leaders was swift. “This is great news for Toronto and our transit system,” Toronto Mayor John Tory said. “Over the coming days and weeks, we expect that the details of this commitment will show the tremendous impact on Toronto transit that will be achieved with this investment. I am confident that Toronto will receive its fair share of funding from this initiative and that it will make a significant contribution to our economic recovery in the wake of COVID-19. Our share of this investment will mean transit expansion, transit vehicles and other system upgrades, jobs and a greener city.”

Markham mayor Frank Scarpitti stated, “This is a positive sign for the Yonge North Subway Extension, York Region’s top transit infrastructure project. It is one of the most studied and justified transit projects in the country and we cannot wait any longer to get shovels in the ground. By earmarking these infrastructure dollars, the federal government is confirming its commitment to making public transit investment a high priority.”

Ontario’s transportation minister, Caroline Mulroney, announced that Ontario had selected five priority projects that it hoped the federal government would fund. Four of those projects are in Toronto, part of the transit expansion plan that Premier Doug Ford announced in April 2019. Those four projects include:

- Building the Ontario Line Subway between Don Mills Road / Eglinton Avenue East and Exhibition Place.
- Extending the TTC’s Line 2 Bloor – Danforth subway to McCowan Road / Sheppard Avenue East.
- Extending the Line 1 Yonge – University subway to Highway 7 / Yonge Street.
- Extending the Line 5 Eglinton light rail transit line to Toronto Pearson International Airport.

In a surprise part of the announcement, Mulroney identified a light rail transit line in Hamilton as Ontario’s fifth priority project for federal funding. The Ontario government controversially canceled the project in December, 2019 after previously committing $1 billion toward building the line.

The renewed support for the project may, however, result in a shorter line than Ontario and the City of Hamilton had earlier planned.
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King County Ship Canal Water Quality Project TBM launched

The 6.6-m (21.8-ft) diameter earth pressure balance tunnel boring machine (TBM) named Mudhoney launched in Seattle, WA to begin creation of the 4.3-km (2.7-mile) long tunnel that will store combined sewer overflow as part of the city’s consent decree with the U.S. Environmental Protection Agency.

The $225-million underground storage tunnel is part of the larger $570 million King County Ship Canal Water Quality Project.

Lane Construction, contractor on the tunnel portion of the project, launched the TBM on April 19 and plans to have the overflow tunnel ready by 2025. When completed, the tunnel can, on average, prevent 75 million gallons of polluted stormwater and sewage from entering the neighboring waterways. The tunnel will capture and temporarily hold more than 29.6 million gallons during heavy rains.

Engineering News Record reported the storage tunnel is part of the larger Ship Canal project from Seattle Public Utilities and the King County wastewater treatment division. Along the tunnel path, five vertical shafts in Ballard, East Ballard, Fremont, Queen Anne and Wallingford can collect stormwater and sewage flows from each basin and send them 64 m to 128 m (40 to 80 ft) below ground to the tunnel. To bring flows from Queen Anne into the storage tunnel, an additional 12-m (8-ft) diameter conveyance tunnel underneath the Ship Canal connects the vertical shafts in Queen Anne and Fremont. New pipes will connect the existing sewer system to the shafts.

In some parts of Seattle, sewage and stormwater share a set of pipes in a combined sewer and stormwater overflow system that can send untreated co-mingled water into the environment. The region is under federal order to prevent the sewage releases.

Parts for the TBM were shipped to Seattle from Germany and assembled in Ballard.

The machine, which requires 10 to 15 operators, was built new in 2020 and is more than 4,300 m (14,200 ft) long. The machine includes 18 double-disc cutters, 48 scrapers and 16 bucket cutters, with the ability to remove about 360 kt (400,000 st) of dirt during the dig, including 32 m (105 ft) under the Aurora Bridge.

Smaller tunneling machines will create conveyance tunnels under the Ship Canal between Fremont and Queen Anne and in Ballard.

Chairman’s Column: It has been a privilege

(continued from page 2)

• more than a dozen U.S. sub-committees, each to support one ITA Working Group.

Looming over the past two years has been COVID-19. The impact on our businesses and professional association has been challenging. UCA and SME both still exist — quite an achievement given the many casualties among professional associations. We have run virtual events with some success and kept up with industry. I would characterize this period by the many long phone calls and difficult decisions that had to be made.

We now look forward with a revitalized desire to get out and meet again in person, a refreshed and expanded pool of active industry volunteers and we have a new strategic plan to capture this enthusiasm and turn it purposely to the benefit of the tunnel industry.

Finally, but most important, it has been my privilege to serve you as the Chair of UCA. The Executive Committee has put in a huge amount of work on your behalf over the past two years and I hope that we have pushed the ball down the field in a positive way. The staff at SME have been fantastic and supportive, as always, and deserve more thanks than I can adequately give. I look forward to supporting Mike Rispin as he takes over in the chair and as I slide into the past-chair role of being one of the old guys complaining from the balcony in the Muppet Show!

It has been fun. Thanks very much everybody.

Robert Goodfellow
UCA of SME Chair
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Record advances at the Brenner Base Tunnel by double-shield tunnel boring machines

Miners in the Brenner Base Tunnel are pushing ahead rapidly with the major rail project. On March 31, 2021, they achieved a new record while excavating the main tubes in South Tyrol — 860 m (2,821 ft) of tunnel bored and lined in one month.

On the Italian construction lot “Mauls 2-3” of the Brenner Base Tunnel, three Herrenknecht tunnel boring machines (TBMs) are boring from south to north. They are excavating the two main tubes as well as an exploratory and later service tunnel 12 m (39 ft) below. In March 2021, a new record was set by one of these three machines: the double-shield TBM (Ø 10.65 m or 35 ft) named “Virginia” covered 860 m (2,821 ft) in one month. The contracting joint venture BTC S.c.a.r.l. (Astaldi S.p.A., Ghella S.p.A., P.A.C. S.p.A. and Cogeis S.p.A.) thus achieved a peak advance rate at the Mauls jobsite. For March 2021, the Brenner Base Tunnel project owner, Austrian-Italian BBT SE, announced an average daily advance rate of 27.7 m (91 ft) for Virginia. The daily best performance was 36.75 m (120.6 ft).

Matthias Flora, sales and project manager at Herrenknecht, congratulated the team on the jobsite, “Our customer BTC’s crews are absolute top professionals in their field. Congratulations and our utmost respect for this achievement.”

By early April 2021, the two machines in the Brenner main tunnels had already covered more than 50 percent of the total distance toward their lot boundary. In stable geologies, double-shield TBMs are predestined for good tunneling performance. As the TBM bores, the excavated tunnel is concurrently lined with concrete segments.

At a total length of 64 km (40 miles), the Brenner Base Tunnel being built under the direction of Austrian-Italian BBT SE will be the longest underground rail link in the world. It crosses beneath the Alps between Innsbruck in Austria and Franzensfeste (Forteza) in South Tyrol/Italy as a particularly efficient flat trajectory, that is, with very low gradients.

ITA accepting award nominations

The 7th edition of the International Tunnelling Association’s (ITA) International Tunnelling and Underground Space awards welcomes new applications.

ITA Awards 2021 will be a digital event. For this edition, a small change is proposed in the categories notably to better specify what is expected in the category “Beyond Engineering - Making Underground Works Projects Even Better” replacing “Overcoming the challenges.”

This year the entries can be submitted in eight categories:

- Major Project of the Year - More than €500 million; Project of the Year - between €50 million and €500 million; Project of the Year including Renovation - up to €50 million; Technical Innovation of the Year; Beyond Engineering - making underground works projects even better; Oddities of the Underground; Innovative and contributing Underground spaces; Young Tunneller of the Year.

Entries can be submitted until June 30, 2021. The submission requirements and selection process are stated in the ITA Tunnelling Awards website: https://awards.ita-aites.org/account-creation. More information can be found at https://awards.ita-aites.org.
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Design and construction considerations for intersecting tunnels — Charleston, SC

Founded in 1670, Charleston, SC is one of oldest cities in the nation. Since its inception, the city of Charleston has experienced difficulties with stormwater management. With rising tidal waters and stronger storms, stormwater management has only become more difficult. Tunnels and trenchless technology have roots in Charleston dating back to 1928 when a system of water supply tunnels was constructed to bring a new water supply from the Edisto River and Foster Creek to the Hanahan Water Treatment Plant to supplement ground water sources. Today nearly 80 km (50 miles) of tunnels have been constructed or designed in and around Charleston for water, waste water and storm water conveyance.

The city of Charleston first utilized tunnels to address storm water in 1999 for their Meeting Street/Calhoun tunnel. The city selected tunneling to minimize utility impacts and public disruption. Two additional storm water tunnels have been completed since the Meeting Street/Calhoun tunnel. The Market Street Drainage Improvements Project tunnel was completed in 2013 and the final phase of the project is pending construction. The US17 Spring/Fishburne Drainage Improvements Project tunnel system was completed in summer 2020. Additional basins in the Charleston peninsula also have conceptual tunnel systems that may be implemented in the future.

The city of Charleston’s Spring/Fishburne US17 Drainage Improvements Project is a five-phase program designed to alleviate flooding in two drainage basins covering approximately 202 ha (500 acres), or about 20-percent of the Charleston peninsula. This project has several objectives: to improve the mobility, efficiency, emergency preparedness and community livability; and, most importantly, to alleviate many of the flooding problems by reinvesting in the infrastructure.

The transportation advancements (Phases 1 and 2) incorporated safer travel lanes for vehicles; improved intersections for pedestrian safety and vehicle efficiency; Intelligent Transportation Systems (ITS); and new, energy-efficient traffic signals. The infrastructure reinvestment (Phases 2 and 3) will consist of constructing improved and additional surface collection systems throughout parts of the basins, drilling and sinking several shafts, boring a deep tunnel system to connect the shafts, (Phase 4) constructing an outfall from the pump station to the Ashley River and (Phase 5) constructing a new pump station adjacent to the Ashley River. Phase 3 was designed by Black & Veatch and Davis & Floyd Inc.; the contractor was Jay Dee Contractors Inc.; and the support of excavation design was completed by FK Engineering.

Geological conditions and concerns

The geology of the Charleston peninsula is that of an estuary, and as such, the shallow deposits (surficial soils) are influenced by a combination of marine and continental processes. The surficial soils were deposited in a range of sedimentary facies including fluvial, overbank, tidal marsh, tidal channel, tidal flat, lagoon, beach, barrier island and shallow marine. Characterized by its extremely low shear strength and high clay content, the surficial soils are susceptible to significant consolidation and settlement over time. As a result, large portions of the peninsula, including city streets, are slowly subsiding. However, 15 to 21 m (50 to 70 ft) below these surficial soils is a geologic formation locally referred to as the Cooper Marl. The Cooper Marl is a relatively thick layer 45 to 60 m (150 to 200 ft) of olive-green, calcareous, medium-to-stiff, sandy/clayey silt. It is an excellent engineering medium used extensively for its load-bearing and self-supporting attributes. Large buildings are almost exclusively founded on pile supports that extend into the Cooper Marl. The Cooper Marl’s strength and standup time can primarily be attributed to the calcareous bonds, as depicted in Fig. 1. However, these bonds are easily broken by traditional and modern mechanical tunneling methods.

Design

The tunnel system was designed to capture the storm water flows from select low points within the Spring and Fishburne basins via drop shafts and transport the storm water through the tunnel system via a pump station and outfall to the Ashley River. The tunnel was designed to a depth of 37 to 46 m (120 to 150 ft) below the ground surface to ensure adequate clearance was maintained from the surficial soils and existing/future building piles, bridge piers and existing waste water tunnels in the project vicinity. The system is comprised of approximately 2,566 m (8,420 ft) of cast-in-place 2.4 to 3.6 m (8 to 12 ft) finished internal diameter (ID) tunnels, four large-diameter access shafts 6 to 9 m (20 to 30 ft ID) and eight drop shafts 122 to 137 cm (48 and 54 in. ID).
The system design includes four access shafts and two intersecting tunnels. The access shafts were generally referred to as follows: Lockwood Drive, Harmon Field, Cannon Street and Coming Street. The two tunnels were the Main Line Tunnel and the President Street Branch Tunnel. The Main Line Tunnel extended about 680 m (2,225 LF) from the Lockwood Drive Access Shaft approximately 0.3 percent upgrade to the Intersection, and then 895 m (2,935 LF) approximately 1.0 percent upgrade to the Coming Street Access Shaft. The President Street Branch Tunnel runs about 396 m (1,300 LF) from the Harmon Field Access Shaft 0.3 percent downgrade to the intersection, then about 680 LF 0.3 percent upgrade to the Cannon Street Access Shafts. This “V” shaped alignment serves to ensure that any entrained air can travel back to either the Harmon Field Access Shaft or Cannon Street Access Shaft and that storm water flows to the Lockwood Drive Access Shaft, where a wetwell, pump station and outfall will be constructed in future phases.

The intersection location and geometry was a result of construction easements and hydraulic boundary conditions. Figure 2 provides an aerial view of the surface above the intersection. The President Street Branch Tunnel was designed to run directly beneath President Street in downtown Charleston. The Main Line Tunnel alignment generally follows the Septima P. Clark Parkway (US17), locally referred to as the “Crosstown,” which cuts across the Charleston peninsula. Stakeholders along President Street and the Septima P. Clark Parkway include utilities, schools, homes and local businesses. The resulting Intersection design helped minimize impact to these stakeholders.

Support of excavation for the tunnels was designed for a two-pass installation method. The cast-in-place concrete final lining for the tunnel system used polypropylene fibers to reduce crack frequency and width. Steel reinforcement was only used at tunnel-adit junctions, tunnel-shaft junctions and at the Main Line Tunnel-President Street Branch Tunnel intersection (the Intersection). The typical minimum thickness of the concrete lining was 31 cm (12 in.). The Intersection concrete minimum thickness was 51 cm (20 in.).

Three of the four access shafts (Coming, Cannon and Harmon Field) were constructed using the caisson-sinking method. A cast-in-place circular reinforced concrete caisson could sink under its own weight as the native material in the center of the structure was excavated. Excavation was stopped at regular intervals to allow casting of the subsequent portions of the caisson. The process was repeated until the caisson was extended through the surficial soils and Cooper Marl to the full depth of the caissons. The shafts were excavated within the surficial soils with a clamshell-type bucket mounted on a crane, and within the Cooper Marl using a small mechanical excavator and muck box for spoil removal. This excavation and support methodology allows for the initial support to act as the final shaft lining. Wall thickness design required a minimum of 46 cm (18 in.) of reinforced concrete. This thickness applied for both 6-m and 9-m (20-ft and 30-ft) shafts. An approximately 1.5 m (5 ft) 6 m (20 ft shafts) or 2.5 m (8.5 ft) 9 m (30 ft shafts) thick concrete invert plug was designed to account for buoyancy forces.

The Lockwood Drive Access Shaft design consisted of a two-pass construction method. Initial support through the surficial soils, and a minimum of 3 m (10 ft) into the Cooper Marl, was to be constructed of concrete caisson, sheet piling, secant piles or slurry wall through the surficial soils. Following support 3 m (10 ft) into the Cooper Marl, initial support consisted of ribs and lagging, liner plate or other contractor-selected support through the Cooper Marl. The final lining design consisted of 45-cm (18-in.) minimum reinforced cast-in-place concrete.

Project construction

Lockwood Drive Access Shaft. The first shaft constructed was the Lockwood Drive Access Shaft (LDAS). The LDAS acted as the primary support shaft for the Main Line Tunnel construction and is the future location of the tunnel system pump station. The Main Line Tunnel invert meets the LDAS about 10 m (35 ft) above the base slab invert. This 10 m (35 ft) sump will be used for future tunnel dewatering pump installation and act as a sediment basin for the tunnel system.

The LDAS is situated on a marsh adjacent to the...
Ashley River. To account for flooding from extreme high-tide events and tropical storms, the shaft area was built up from EL 0.5 m (1.5 ft) to about EL 3 m (10 ft) with clean sand, general fill and a stoned surface.

Support of excavation in the surficial soils utilized steel sheet piles supported internally with steel ribs. The sheet piles were socketed approximately 3 m (10 ft) in the Cooper Marl. Excavation was accomplished with a clamshell bucket and a small mechanical excavator. The contractor installed a 1.5-m (5-ft) tall concrete collar which transitioned the support of excavation from the sheet piles to a ribs and lagging system. The ribs and lagging extended through the Cooper Marl to the invert of the shaft excavation.

The LDAS used a 9-m (30-ft) internal diameter cast-in-place concrete final lining. The concrete final lining was a minimum of 45 cm (18 in.) thick and reinforced with steel rebar. The shaft used a 2.5-m (8.5-ft) thick base slab with the top of slab at approximately EL -52 m (-170 ft). Shaft concrete final lining was installed from EL -52 m (-170 ft) to EL -9 m (-30 ft). The final lining terminates at EL -9 m (-30 ft) where it will connect to future wet well and outfall construction.

Caissons. The Coming Street, Cannon Street and Harmon Field Access Shafts were constructed using the caisson sinking method. In order to facilitate sinking, the contractor used a “cutting shoe.” The cutting shoe was a tapered cylindrical steel structure built with a larger outside diameter than the typical caisson cross-section. The cutting shoe aided sinking by reducing the bearing surface of caisson and creating a shear plane to loosen excavatable material and direct soils to the interior of the caisson as the shaft was sunk. In addition to the cutting shoe, the contractor pumped bentonite slurry into the annulus through a series of 5-cm (2-in.) PVC piping running vertically through the shaft walls, reducing the skin friction that could otherwise cause the caisson to “hang-up” in the Cooper Marl. The pipes expelled the bentonite to the outside of the caisson walls. Following excavation and sinking, the annulus space outside of the caissons was grouted to fill the voids prior to excavating for the tunnel eyes.

The contractor and its design engineer elected to increase the caisson wall thickness as an additional measure to facilitate sinking in the Cooper Marl formation. The 6-m (20-ft) ID shafts (Coming Street and Cannon Street) were 0.7 m (2.5 ft) thick. The Harmon Field Access Shaft 9 m (30 ft ID) was 1 m (3 ft) thick. The depths of the shafts ranged from 37 to 46 m (120 to 150 ft).

The contractor was required to prevent uncontrollable sinking, which is more typical and problematic in the weaker surficial soils above the Cooper Marl. In order to prevent uncontrollable sinking, the contractor preloaded the shaft with hydraulic jacks. The hydraulic jacks were anchored to a concrete counterweight with steel threaded rods and applied force to a steel frame that was placed on the shaft. As a result, the hydraulic force was exerted onto the shaft. The pressure applied was generally representative of the next concrete lift, or approximately 145 to 163 t (160 to 180 st). If sinking was noted while the hydraulic jacks were active, force would continue to be applied until no additional sinking was noted. The hydraulic jacks were applied to the shafts in order to prevent uncontrollable sinking during concrete placement. The hydraulic jacks were also utilized during the excavation process in order to encourage incrementally controlled sinking versus unexpected and uncontrollable sinking.

The caissons were constructed in 3.6-m (12-ft) lifts with a modular set of 4.2-m (14-ft) tall internal and external concrete forms. The additional height was used for 0.3 m (1 ft) of overlap at the bottom and 0.3 m (1 ft) of gap at the top for water-stop installation. These forms were only tied together at the top of the forms; wall-penetrating form ties were not used. The shafts were maintained in a flooded state while excavation progressed through the surficial soils. The flooded state prevented the surficial soils from running into the interior of the shaft during excavation and sinking activities. Once the caisson reached 3 to 6 m (10 to 20 ft) of embedment...
into the Cooper Marl, the interior could be dewatered.

**Tunnel and adit initial support.** The Main Line Tunnel (approximately 1,650 m (5,400 LF)) was excavated upgrade from the Lockwood Drive Access Shaft to the Coming Street Access Shaft. Means of excavation included a refurbished open-face soft-ground tunnel boring machine (TBM). The TBM bore was approximately 4.5 m (15 ft) and utilized a ribs-and-lagging initial support system. The initial support consisted of steel ribs (W4x13) on approximately 1.5-m (5-ft) centers with mixed hardwood lagging between the sets. The ribs were assembled within the tail shield of the TBM and expanded tightly against the ground after the machine had moved forward. Muck was removed from the heading using rail-mounted muck cars.

The first 67 m (220 ft) of the Main Line Tunnel was converted to a 4.5 m by 4.5 m (15 ft by 15 ft) horseshoe. This horseshoe section of the tunnel allowed for the installation of a rail switch for expediting the tunnel excavation. Two muck car trains were utilized during excavation. While one train was being loaded with excavated material, the other train would be unloaded into a muck area on the surface. Each train generally consisted of four 15 cy muck cars, a diesel-powered locomotive, and a flat car for supplying the initial support system to the TBM. A tail tunnel was also utilized to facilitate unloading muck trains. The tail tunnel was constructed with ribs & lagging initial support and ultimately abandoned with flowable fill grout.

The President Street Branch Tunnel (approximately 610 m (2,000 LF)) was excavated downgrade from the Harmon Field Access Shaft to the Main Line Tunnel Intersection, then upgrade to the Cannon Street Access Shaft. Means of excavation included a refurbished open-face soft-ground TBM. The TBM bore was approximately 3.3 m (11 ft) and utilized a ribs and lagging initial support system. The initial support consisted of steel ribs (W4x13) on approximately 1.2-m (4-ft) centers with mixed hardwood lagging between the sets. The ribs were assembled within the tail shield of the TBM and expanded tightly against the ground after the machine had moved forward. Muck was removed from the heading utilizing rail mounted muck cars. The President Street Branch Tunnel did not utilize a tail tunnel or switch during the excavation process.

There were eight adit tunnels extending from the primary tunnels to the previously installed drop shafts. Along the Main Line Tunnel were seven adits with the remaining adit extending off the President Street Branch Tunnel. Adit tunnel excavation ranged from approximately 1.5 m (5 LF) to 163 m (535 LF) along the alignment. The longest adit, extending to the Cherry Street Drop Shaft, was excavated with a combination of mechanical (roadheader) and hand-mining techniques. Muck was removed from the Cherry Street Adit with a pair of skid steers traversing through the adit as the excavation progressed. Voids behind the initial support were filled with grout. The remaining adits were excavated via hand-mining techniques.

Excavation advancement in the adit tunnels was generally consistent throughout the project. Following initial support and breakout from either of the primary tunnels, the contractor would “bench” the excavation so that the crown of the excavation was one-to-two initial support sets ahead of the spring-line and invert support. Initial support consisted of rolled steel ribs (W4x13) for the crown and steel beams (W4x13) supporting the ribs. The steel was typically installed on 1.5-m (5-ft) centers with mixed hardwood lagging. Voids behind the initial support were filled with grout.

**Tunnel and adit final lining.** The tunnel and adits used a cast-in-place concrete final lining. The concrete was reinforced with polypropylene fibers. Steel reinforcement was only used at tunnel-adit junctions, tunnel-shaft junctions, and at the Intersection. The tunnel concrete forms were reusable, collapsible steel forms. A keyway was installed at the face of each concrete segment/placement. The pumping location moved as needed to facilitate the concrete pump capabilities. Concrete was pumped through a steel slickline with pumping distances reaching 610 m (2,000 ft).

The Main Line Tunnel finished internal diameter was 3.6 m (12 ft). The concrete was placed in a series of segments ranging in length, typically 24 to 37 m (80 to 120 LF). Concrete segment lengths would generally vary to account for tunnel alignment curvature or planning around junctions. Concrete for the Main Line Tunnel was pumped from the surface from the Lockwood Drive Access Shaft the Courtenay Drop Shaft, the Cannon Street Access Shaft and the Ashe Drop Shaft. The formwork was advanced mechanically with an electric-powered hydraulic form carrier. Concrete was placed at an approximate 0.3 percent grade from the Lockwood Drive Access Shaft to the Intersection and approximately 1.0 percent grade from the Intersection to the Coming Street Access Shaft.

The President Street Branch Tunnel finished internal diameter was 2.4 m (8 ft). The concrete was placed in a series of segments ranging in length, typically 27 to 38 m (90 to 125 LF). Concrete segment lengths would generally vary to account for tunnel alignment curvature or planning around junctions. Concrete for the President Street Branch Tunnel was pumped from the surface from the Harmon Field Access Shaft and the Cannon Street Access Shaft. The formwork was advanced mechanically with an electric-powered hydraulic form carrier. The concrete was placed approximately 0.3 percent downgrade from the access shafts to the Intersection, creating a “v” shape from the Intersection up to both access shafts (Harmon Field and Cannon Street).

The finished internal diameter for the eight adits was 2.4 m (8 ft). The concrete was placed in a series of
segments ranging in length, typically 3 to 15 m (10 to 50 LF). Seven of the eight adits were completed with one to three segments. The Cherry Street Adit, approximately 163 m (535 LF), required a series of segments to complete. Typical segments length was 15 m (50 LF), varying as needed around curves or at the Main Line Tunnel junction. Concrete final lining for the adits was designed and installed with a flat (0 percent) grade.

**Intersection construction**

**Intersection initial support.** The proposed junction design needed to address a series of challenges. One of the primary challenges was maintaining the minimum design wall thickness in the Intersection. The designed wall thickness in the intersection was 20 cm (8 in.) larger than the typical tunnel section (50 cm (20 in.) instead of 31 cm (12 in.)).

The Main Line Tunnel TBM bored an approximate 15-ft (180-in.) diameter tunnel. When accounting for the initial support, approximately four inches thick, or 20 cm (8 in.) impacting the diameter, the resulting initial support diameter was approximately 437 cm (172 in.). The designed final internal diameter was 3.7 m (12 ft) along the Main Line Tunnel 365 cm (144 in.). With the initial support, this resulted in an approximate 36-cm (14-in.) projected wall thickness. In order to achieve the required 50 cm (20 in.) minimum, the contractor proposed reducing the Intersection opening to 3.3 m (11 ft) along the Main Line Tunnel. This design would align inverts at the Intersection, but the crown would drop down about one foot along the Main Line Tunnel.

The primary concern regarding reducing the Main Street Branch Tunnel TBM. The TBM would then “walk” through the intersecting Main Line Tunnel and relaunch through the opposite adit. The completed initial support system is displayed in Fig. 3.

**Intersection final lining.** The Intersection was the final concrete placed for the tunnel system. The contractor was elected to complete the Main Line Tunnel, President Street Branch Tunnel and adit final lining concrete prior to forming and placing concrete in the intersection. The concrete in the Intersection was formed with a combination of custom-built formwork along with repurposed 2.4-m (8-ft) ID formwork used for the President Street Branch Tunnel final lining, referred by the contractor as “fish mouth” forms.

The concrete along the Main Line Tunnel used custom-built forms constructed out of steel ribs, timber, plywood and mixed hardwood lagging. The steel ribs were rolled to an approximate diameter of 3.3 m (11 ft). Between two steel ribs was plywood reinforced with 1.5-m (5-ft) long two-by timber, resulting in 1.5-m (5-ft) long “quadrant” pieces. Two quadrants bolted together resulted in one 1.5-m (5-ft) long invert section piece. The preassembled quadrant pieces were mobilized to the Intersection via locomotive along the President Street Branch Tunnel. The quadrants were hoisted with a previously installed steel monorail, assembled into 1.5-m (5-ft) invert section pieces, and stored in the Main Line Tunnel for future installation. The concrete along the President Street Branch Tunnel utilized repurposed 2.4-m (8-ft) steel formwork previously used for the President Street Branch Tunnel concrete lining. The
forms were torch-cut offsite to configure the unique Intersection geometry. Steel spuds were installed along the invert and spring-line in order to hold the custom forms during install and prevent shifting during concrete placement. Steel bracing was also installed to prevent form movement during placement.

The first concrete placement was about 180 cu yd. Concrete was pumped from the Courtenay Drop Shaft through about 305 m (1,000 LF) of steel slick line. The concrete was distributed throughout the forms using a series of valves and hoses. The valves were connected to additional slick line which extended out from the Main Line Tunnel centerline to the forms. The concrete was adequately vibrated to ensure proper consolidation and flow around the forms. Following completion of the first concrete placement, a PVC waterstop was installed, along with a keyway, at the interface between the first and second placements.

The crown used similar custom formwork as the invert placement. However, the timber-reinforced plywood was replaced with 0.6-cm (0.25-in.) thick by 1.5 m (5 ft) steel plates reinforced with mixed hardwood lagging. Initially the contractor had planned to strip the Main Line Tunnel invert forms and reuse for the second concrete placement for the crown. The contractor elected to construct additional custom forms on top of the installed invert forms. This new approach allowed for the structural benefit of circular forms.

Concrete for the second placement was pumped from the Courtenay Drop Shaft through about 305 m (1,000 LF) of slick line. About 110 cu yd of concrete was needed to complete the second placement. Concrete was pumped through a series of ports installed at the crown in the Main Line Tunnel custom forms and President Street Branch Tunnel fish-mouth forms. Form vibrators were used to properly consolidate the concrete. The contractor installed temporary PVC pipes at both crown ends of the Main Line Tunnel forms to expel air as the forms were filled. The Intersection final lining was successfully completed in March 2020 and can be seen in Fig. 4.

**Conclusion**

Successful completion of this unique and complex project required coordination and communication between the project team. The US17 Spring/Fishburne Drainage Improvements Project tunnel system was completed in summer 2020. The fourth phase is currently under construction which includes construction of the wet well and outfall. The drainage system will be fully operational after the completion of the final fifth phase.

The authors would like to thank the city of Charleston for their permission to publish this paper and whose work provided the basis for this paper. Charleston is a showcase for the increasing viability of underground construction techniques and other communities can benefit from the city’s foresight and ingenuity. Charleston has demonstrated that determination and strong leadership do eventually pay off.

The authors would also like to thank the project team: Black & Veatch, Davis & Floyd, Jay Dee Contractors Inc., and FK Engineering for their considerable contributions for the completion of this project. Black & Veatch and Davis & Floyd Inc. acted as the owner’s engineer for the project. Jay Dee Contractors Inc. was the contractor for this third phase of the drainage system and provided unyielding expertise and craftsmanship. FK Engineering was the design engineer for the contractor. FK Engineering produced initial support of excavation design and contributed to the final support design.
Capital cities of the world have made a common observation that large population increases have led to traffic congestion, unpleasant conditions of life, downgraded economy and unsustainable development. They have invested in public transport systems constructed under tight urban constraints in order to maintain activity and mobility. The so-called quality of life has been exacerbated by competition and rankings by various journals and organization such as *The Economist*.

This article presents the concept of hybrid stations as developed or constructed in large cities to keep mobility and business unaffected during construction works. Large bored tunnels, large rock excavations, under-river construction provide interesting alternatives to traditional open-air construction. This article reviews a 20-year experience at Bouygues Travaux Publics of alternative station concepts to minimize construction disturbance and loss of mobility and economy during construction.

**City competition**

*The Economist* ranked 140 major cities on a global liveability index based on five criteria:

- **Stability** — In relation to crime, threat and conflict.
- **Healthcare** — Availability and quality.
- **Culture and environment** — Climate, corruption, censorship and sporting.
- **Education** — Availability and quality.
- **Infrastructure** — Quality of road and public transport, telecommunication and water.

In the world, Australia, Central Europe, Japan and Canada take the prime positions. In the United States, Honolulu takes the lead, followed by Atlanta, GA; Pittsburgh, PA; Seattle, WA and Washington, D.C.

Public mobility creates comfort and quietness for inhabitants, provides free time and opportunities for culture and education, and reduces stress and pollution in relation to healthcare. It is a prerequisite for liveability and many cities invest massively in public transport to provide superior conditions for business, communication, research and innovation and finally leadership.

Hybrid station concept has come from a mix of cavern and open-air excavation to minimize surface footprint and keep city activity unaffected.

Many interesting examples can be found in New York City, NY (USA), Barcelona (Spain), Stockholm (Sweden), and Hong Kong (China). As a leader in large bored tunnel and complex underground construction, our company has promoted such schemes in tender and development phases to provide better value for money for the inhabitants.

**Amsterdam Metro, initial concept (2002)**

Amsterdam is the capital city of the Netherlands with a population of 1.5 million. The city lays on a vast sedimentary plain filled with a series of loose sandy soils and soft clays. The majority of the country is near sea level and protected from flooding by a long sea defense line along the shore. The North-South metro line was launched in 2001 on strict requirements for no road closure and no impact on buildings. As a consequence, the program of works was extended and a new concept tested with large tunnels housing train platforms and requiring mini access boxes as a substitute for large stations.

Figure 1 compares three alternatives:

1. Single-track tunnel and central platform with TBM near 6.5 m (21 ft) in diameter and street more than 20 m (65 ft) wide.
2. Double-track tunnel and side platform with TBM near 10.45 m (34 ft) diameter and street more than 22 m (72 ft) width.
3. Stacked-track tunnel and integrated platforms with TBM near 13.6 m (45 ft) diameter and same street width.

Stations built around traditional single-track or double-track tunnels have their surface dimensions governed by length and width of platform. Surface dimensions of modern stations built around superposed track tunnels are governed by vertical circulation and ventilation box but not any more by platform sizes (Fig. 2). Passenger access shaft can be limited to 50 m (160 ft) in length and 12 m (50 ft) in width and located in side streets keeping traffic in the central artery with minimum impact. The surface area reduces from 4,650 m² (50,000 sq ft) down to 1,100 m² (12,000 sq ft) or a ratio nearly 4 to 1.

At that time, the world’s largest TBM was 14.9 m (49 ft) as developed by Bouygues for the construction of the Groene Hart tunnel in the Netherlands and superposed...
track tunnel was at the edge of knowledge. Today, the world's largest TBM is 17.7 m (58 ft) as constructed also by Bouygues for the recent Tuen Mun Check Lap Kok tunnel in Hong Kong. Superposed track is no longer near the edge of knowledge and technology. It is open to almost all soft soil conditions.

**Sandton Station Gautrain (2006-2010)**

Johannesburg is the financial capital of South Africa with a population of more than 4 million. In 2005, Bouygues Travaux Publics was awarded the Gautrain rapid rail link project on a concession basis with geological risk to the contractor. The project was a stand-alone 75-km (46-mile) long, 10 stations and one depot international gauge project with a 15-km (9-mile) long underground section from the center of Johannesburg to the city of Marlboro on its outskirts. Located in the business district, Sandton station was the masterpiece of the project with highest passenger exchange and specific service direct to the airport terminal. Gautrain project was presented at conferences in Chicago, IL in 2008 and Moscow in 2013 for its interest in both structural and architectural expression.

The station was located in fresh granite with faulted areas either side of the station and variable topography. The detailed design and risk analysis concluded in deepening the excavation level of the station to 42 m (140 ft) below ground, drastically increasing rock excavation and adversely delaying the construction program. A review of cavern alternatives was introduced to minimize rock excavation and keep program within contract.

Six cavern options were developed in parallel from a single large double-floor cavern with span of 25 m (82 ft) in length, to a dual medium size-double floor cavern with unit span of 15 m (49 ft) in length and a triple narrow single-floor cavern with unit span of 9 m (30 ft) in length. Option six, shown in Fig. 3, consisting of a dual cavern with single and stacked-track cavern configurations together with central platform access. It was considered most appropriate in keeping cavern dimensions reasonable, rock excavation minimum and easy access to platforms.

It was further developed and constructed. Surface works were reduced from a traditional 165 m (540 ft)
width by 30 m (100 ft) box down to two access shafts of 56 m (220 ft) length, 17 m (56 ft) width and 20 m (65 ft) length, 15 m (50 ft) reducing the surface area from 4,950 m² (53,000 sq ft) down to 1,440 m² (15,000 sq ft) or a ratio of 3.5 to 1. The program was met and Sandton station opened for the Soccer World Cup in June 2010.

Aerial photos in Fig. 4 provide an overall impression of the station in the city and traffic. The two side-platforms are distance of 14 m (46 ft) and the dedicated airport service on the lower deck is only separated by 4.25 m (14 ft) height difference with the other platforms from which means that rapid interconnection between the lines is achieved. It is a great functional design and a popular success.

Doha West Bay people mover concept
Doha is the capital city of Qatar with a population of around one million and West Bay is its financial and business district. The city lays on a series of surficial fill, dolomitic limestone, shale and chalky limestone. It is proper for traditional and mechanised construction.

In 2012, options were developed for connecting West Bay and compared for construction volumes and impact to the city. The project was 9.6-km (6-mile) long and included 19 stations in three consecutive loops. Due to the extreme heat during the day, the surface project became underground and located under the main roads of the district. The construction of the stations impacted both utilities and road traffic.

Four tunnel options, (Fig. 5), were compared in terms of construction, surface impact, program and cost:

1. A traditional single tunnel including side-to-side tracks.
2. A traditional double tunnel including single track in each.
3. A vertically stacked double tunnel with single track in each.
4. A single tunnel with stacked track inside. The later tunnel is big enough to incorporate the station platforms.

The comparison is summarized in Table 1 in terms of quantities, surface impact, program and final estimate.
Option four, single stacked-track tunnel with integrated platform was ranked highest with economies in excavation and concrete volume of 20 to 40 percent, in construction program of 8 to 12 months and cost of 20 percent. Surface impacts were divided by a ratio of four with respect to base single tunnel.

On the particular configuration of Doha, the comparison of data was clear because the 500-m (1,640-ft) spacing between stations was short and the increase in tunnel diameter did not over pass the reduction in station volume. Figure 6 gives architectural views and shows the interest in terms of sustainability with direct sun access and natural ventilation and also in terms of passenger experience with a through view inside the stations.

**Cairo Metro Alternative Station (Concept 2016)**

Cairo is the largest and busiest city in Africa with more than 10 million inhabitants. Its metro was initiated in the early 1970s, its development has been uninterrupted since and construction of line 3 phase 3 and line 4 is ongoing. The city is located around the Nile River in a deep alluvial basin principally sandy layers with impervious clay layers around 100-m (330-ft) depth. A smaller derivation of the river has created Zamalek Island.
Two stations were located either side of the secondary Nile River bed and an alternative proposal was made to relocate one station under the Nile River with passenger accesses from both sides as shown in Fig. 7. Marine access, site installation on river banks, distance from sensitive receivers and limited utility and traffic disruptions were of significant interest.

The alternative involved the construction of an artificial island and closure of secondary Nile River bed with precautions to ensure water overpass in case of flooding, and soil treatment to allow excavation of diaphragm walls. Construction was intended to proceed on shore with diaphragm wall sealed into watertight clay layers and excavation down to tunnel level to let the TBM pass through. The platform was incorporated into the underwater trench in such a way that permanent configuration of the secondary river bed could be re-established at the end of construction. The under-river box was terminated on the banks with access boxes running along the shore and letting people go in and out from either side of the river.

Melbourne Metro CBD Stations (2017-2022)

Melbourne is the second largest city in Australia and houses the largest universities of the country. Its population exceeds four million and the city anticipates a major growth due to immigration. The historic public transport combines a traditional tram service in the city and a train network extending far outside the city. Melbourne has been named the most liveable city in the world for several years in a row and the standard of living is clearly a priority.

In 2016, the city launched a modern underground metro concept in increasing capacity in the North-South corridor and relieving stress on the other lines as well. The project includes 6 miles (9 km) of dual single-track tunnel and accommodates five stations of which two are built in the city center with severe constraints and three are built in the student districts with traditional open excavation under the major artery roads (Fig. 8).

State Library and Town Hall stations are the two central stations, they are built under Flinders street with underground side access from shafts located under future development. The architectural style is green and generous.

The stations are built in sedimentary rock called Melbourne formation. The cavern is excavated with rock support and shotcrete from three shafts located two on one side and the third on the other side of the road. The caverns houses the concourse and central platform and offers 20 m (66 ft) width between platform screen doors. Passengers exit from the platform up then sideline to
The cavern is 29 m (95 ft) wide and 14 m (46 ft) high. It is supported by two rows of columns either side of the vertical circulation. It is constructed in three temporary stages namely a central excavation, central temporary support and side excavation (Fig. 9) and three permanent stages namely concreting of the base slab and permanent columns followed by the transfer beams and central roof and then side walls and roof.

The connection between cavern and shaft, shown in Fig. 10, is the key element that governs the whole design and construction methodology. Its space is split into passenger access and dedicated fire brigade intervention, into fresh-air supply and smoke extraction ducts, into corridors for HV feed and LV distribution cables and into any other services required in the cavern. The cross-adits are 17 m (56 ft) wide and 24 m (78 ft) high, they are larger than the platform cavern and also more critical for rock stress during construction. They extend 6 m (20 ft) above cavern top which reduces rock cover and also 4 m (13 ft) below the track that increases vertical span.

**Conclusions**

The global demand for mass transit projects in large cities has affected both historic and business centers. Elevated stations are complicated and underground alternatives have become the norm where space is constrained. Keeping major roads unaffected and local business alive have become common and have promoted the development of alternative station concepts departing from traditional braced and open-air excavation.

Hybrid stations have benefited from the ongoing development of large bored tunnels in soft soil and large caverns in rock. Both provide interesting options to adjust to available land and necessary continuity of the city during the construction stage.

Large tunnels with stacked tracks and integrated platforms have been tested successfully and have provided acceptable solutions for railway systems and for public building safety. Under-waterway stations are interesting options. Large caverns accessed by side shafts are valid alternatives for station in rock. Anticipation and care is required on the functionality and construction of adits.

Construction technology and numerical simulations have allowed to go further into friendly construction, minimizing impact during construction while enhancing safety during operation.

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UCA returns to in-person meetings with RETC in Las Vegas, NV

by Margo Ellis, Associate Editor

Get ready to turn off the Zoom conference calls, and prepare to return to in-person meetings at the RETC conference from June 13-16, 2021 in Las Vegas, NV.

RETC marks the first in-person meeting for the UCA, a Division of SME, in more than a year. There will be some modifications to comply with COVID-19 pandemic protocols, but RETC 2021 will include a full technical program, exhibit hall and networking opportunities — all held face-to-face with appropriate health and safety measures.

Attendees will have the opportunity to learn about top-of-mind industry issues, trends and innovations to help their career trajectories.

There will be no onsite registration available due to COVID-19 protocols. However, the conference will feature the same level or technical content attendees have come to expect from previous meetings.

"We really looked at previous conferences to see what they had, we tweaked it a little bit and I think we came up with a good program," said Greg Davidson, co-chair of RETC 2021. "People want to hear about future projects, TBMs and innovation so we have two sessions on innovation which is good, we want to encourage innovation. People want to see new ideas and we should be looking for new ideas."

Technical sessions at RETC 2021 include 106 papers in sessions on contract practices, design, difficult ground, hard-rock TBMs and tunnels, design build, ground control approaches and methods, health and safety and sustainability, shafts and mining, ground support and final lining, international projects, large span tunnels and caverns, new and innovative technologies 1 and 2, future projects, pressurized face tunneling, SEM applications and projects, geotechnical considerations, microtunneling and trenchless tunneling, project planning and risk management and tunnel rehabilitation.

"It’s a very good forum for the sharing of knowledge. The presentations are very good and are a snapshot into the paper," said Davidson. "You can look at the program and decided what to listen to and dig into the proceedings in more depth."

RETC 2021: Health and safety precautions and procedures

Additional health and safety protocols will be implemented during RETC.

All attendees are expected to comply with COVID-19 protocols during the conference.

AECOM expands tunneling expertise in Canada

AECOM announced the addition of two international tunnel experts to its Canadian tunneling practice. Roberto deMoraes, director of tunnels, and Mike Mains, senior tunnel design lead, have joined AECOM in the Metro Vancouver Regional District of British Columbia.

"The addition of Roberto and Mike to our tunneling practice strengthens our team’s ability to meet the growing demand for innovative solutions and the latest technologies for tunneling and underground structures in cities across Canada," said Nasri Munfah, AECOM’s director of tunneling and underground engineering in the Americas. "In addition to their skills, each brings broad international expertise and best practices gained from working on major projects across the globe."

deMoraes is a geotechnical and tunneling engineer with more than 10 years of international experience. He has worked in the United Kingdom, Australia, New Zealand, Brazil, Norway, Sweden, Switzerland, Portugal, Turkey and many other parts of the world. His portfolio includes major projects such as the Metro Manila in the Philippines, the Dubai Storm Water Tunnel in the United Arab Emirates, the Folio Line Railway Tunnel in Norway and the Devoll Hydropower in Albania.

Mains is a licensed engineer in British Columbia and California. He is a member of the French Tunnelling and Underground Space Association’s Underground Construction and Sustainable Development work group and has presented on the use of mechanized tunnel boring machines at several conferences and events, including the International Tunnelling and Underground Space Association World Congress.
Edited by Jarrett E. Carlson and Gregg W. Davidson 2021, 1248 pages
Print or eBook Hardcover, 4 lbs $149
Member ISBN 978-0-87335-492-9
$129 Student Member Book Order No. 492-9 $219 Nonmember/List
Save 25 percent on print and eBook bundle.

Every two years, industry leaders and practitioners from around the world gather at the Rapid Excavation and Tunneling Conference (RETC), the authoritative program for the tunneling profession, to learn about the most recent advances and breakthroughs in this unique field. The information presented helps professionals keep pace with the ever-changing and growing tunneling industry.

This book includes the full text of 106 papers presented at the 2021 conference.

Though the tunneling industry continues to develop both technically and contractually, one notable adaptation of the last two years has been the onset and management of COVID-19. The hallmarks of tunneling professionals include adaptability, resiliency, optimism and management of change. These are traits that have been recently put to an entirely new challenge over the last year or so. We have truly witnessed why what we do is deemed “essential” infrastructure.

The COVID-19 pandemic has impacted each of us, personally and professionally, and while times have been hard, we are fortunate to work in a field that is able to meet the challenge and thrive thereafter. Congratulations are in order to everyone in our industry for keeping the planning and development of projects moving forward and for maintaining safe and productive worksites in these challenging times.

The Proceedings include chapters on: Contract practices, design, design/build projects, difficult ground, future projects, geotechnical considerations, ground control approaches and methods, ground support and final lining, hard rock TBM and tunnels, health and safety & sustainability, international projects, large span tunnels and caverns, microtunneling and trenchless, tunneling, new and innovative technologies, pressure face tunneling, project planning and risk management, SEM applications and projects, shafts and mining and tunnel rehabilitation.

Kimberly Martin joins Keller

Keller has announced the hire of Kimberly Martin, Ph.D., P.E., as senior engineer – innovation and sustainability. Martin will focus on Keller’s initiatives toward environmental and societal sustainability in North America and provide high-level innovative efforts within our engineering function.

With more than 13 years in the geotechnical industry, Martin previously worked at ExxonMobil as a lead geotechnical engineer on development projects across the globe. She is the past chair of the Arizona Geo-Institute and is the Region 8 representative for the Geo-Institute’s Local Involvement Committee. Martin also serves on the sustainability committees of the Geo-Institute and the Deep Foundations Institute. She is a member of the editorial panel for Engineering Sustainability, a journal published by the Institute of Civil Engineers. Martin holds a B.S. in civil engineering from the University of Arizona, and an M.S. in geotechnical and geoenvironmental engineering from the University of Texas at Austin. She recently completed her Ph.D. at Arizona State University with a focus on bio-inspired geotechnics and lifecycle sustainability within geotechnical engineering. In addition, Martin has devoted much of her career to improving diversity and inclusion within the engineering community.

“The construction industry is well-positioned to benefit from infrastructure renewal, urbanization and expanding cities. As the global climate crisis worsens, we face the challenges of cutting carbon emissions, limiting waste, and using more environmentally friendly materials and processes,” said Martin. “By offering innovative products and solutions for a sustainable future, Keller is proactively leading the geotechnical sector. For these reasons, I am excited and proud to join the Keller team.”

Kimberly Martin
K.N. Murthy, April 4, 1943 - Feb. 21, 2021

In memoriam

On Feb. 21, 2021, the tunneling industry lost K.N. Murthy, a well-known transportation professional who had a pivotal role in Los Angeles, CA tunneling. “Murthy,” as he was universally known, was not a pick-and-shovel tunneler, rather he was one whose career made Los Angeles tunnels possible.

Murthy was born April 4, 1943, one of six children in a small town near Bangalore, India. Even after his father’s death when he was 15, Murthy, through his perseverance, graduated from college with a Bachelor’s Degree in civil engineering. He obtained his first job with a Bangalore engineering firm the day after his graduation and later joined a contractor near Kolkata. When his friend Vijay Chandra moved to New York to work in 1970 Murthy moved to New York to look for work. He joined a small engineering firm, Bunny and Associates, before joining Parsons Brinkerhoff Quade & Douglas in 1973. In 1974, he moved to Atlanta, GA for the firm to work on the new heavy rail transit system for the Metropolitan Area Regional Transit Authority (MARTA). He worked on projects in the Atlanta area for 10 years.

In 1983, Murthy began work on the new rail system for one of the predecessor agencies to the Los Angeles County Metropolitan Transportation Authority (LA Metro). This project was the heavy rail subway in Los Angeles, then known as the Metro Red Line.

After the non-tunneling-related methane gas explosion and fire that occurred during construction of the Red Line in 1985 and the subsequent freeze on federal funding for the tunneling project along the planned alignment, Murthy worked with Metro to revise the Red Line alignment to avoid the risk areas, completing the work in 1993 to define the approximately 29 km (18 miles) of subway.

Tunneling technology and political acceptance of tunneling in Los Angeles — including the gassy geologic conditions had to mature before the Metro tunnels could be constructed in the high-risk areas of Los Angeles. In response to ground conditions and other tunneling problems, Metro engaged a three-member geotechnical/tunneling panel to evaluate the feasibility of tunneling in Los Angeles. The 1995 report of this panel (the “Eisenstein Panel”) concluded that with modern tunneling technology, it was reasonable to undertake tunneling in Los Angeles and recommended the use of pressurized-face TBMs. Subsequently, in 2005 an APTA peer review indicated it was safe to tunnel in the high-risk area. Ultimately, the federal ban on funding the tunneling project was repealed and work continues today on this much-anticipated mobility solution. Murthy advised key decision-makers throughout this effort.

Murthy, working with the PB team, was also involved in the City of Los Angeles East Central Interceptor Sewer (ECIS) and North East Interceptor Sewer (NEIS).

Murthy left Parsons Brinkerhoff in 2007 after 34 years to join the Los Angeles Metro as the executive director of transit project delivery. In that position, he oversaw all of Metro’s construction projects, including the environmental clearance and preliminary engineering for the next wave of major tunnel projects in Los Angeles: light rail Crenshaw and Regional Connector projects and the heavy rail Purple Line Extension project on Wilshire Blvd. As an indicator of his role in the underground industry’s greatest issues, Murthy presented “Managing Risk on LA Metro’s Megaprojects” at the UCA of SME 2013 Cutting Edge Conference in Seattle, WA. Murthy retired from Metro in 2014 as those major tunnel projects in Los Angeles were just starting construction.

Murthy’s expertise led him to yet another challenge when the Honolulu Authority for Rapid Transit (HART) sought his help to serve as the interim chief executive officer (CEO) and subsequently as an advisor to Mayor Caldwell overseeing a 32-km (20-mile), $12 billion elevated transit system, the largest public infrastructure program in the history of Hawaii. Murthy held this role for over two years and afterward he assisted the new CEO and the mayor’s office for another year prior to retiring in 2019.

Former Los Angeles Deputy Mayor for Transportation, Jaime de la Vega, shared upon learning of Murthy’s death:

“K.N. Murthy was an instrumental partner and leader in advancing Los Angeles Mayor Antonio R. Villaraigosa’s ambitious transit expansion agenda that began in 2005. Murthy’s management and technical expertise helped restore public confidence in Los Angeles Metro and he led a resurgence of rail construction that continues to this day. Murthy will be missed by all who knew and loved him, but his legacy as one of the fathers of the Los Angeles’ modern rail network will live on forever.”

In addition to his stellar career, K.N. Murthy is remembered for his love of his family, his enjoyment of good food and drink, his great knowledge of music — from the Indian music of his youth, to Beethoven to jazz — and, his penchant for old movies, including “It’s A Wonderful Life” every December. Murthy is survived by Padmini, his wife of 44 years, two sons and three grandchildren.
The UCA has launched 15 working groups on key technical focus areas. These subcommittees mirror the subject areas established by the International Tunnelling Association (ITA) and aim to maximize benefit for UCA members by providing clear input on U.S. needs and perspectives. In this issue, and future issues of T&UC, ITA and UCA Working Groups will be featured.

**Working Group 9:**
Working Group 9, Seismic Design and Construction for Tunnels and Underground Structures, was established in the fall of 2020, and the group is meeting quarterly. Currently, there are 12 active members and one ad hoc member in the group representing the public sector, engineering, consulting and academic communities. The working group’s scope includes seismic planning, design, construction, performance, maintenance and operation of tunnels and underground structures, supporting sub-systems, and interactions with surrounding infrastructure. The consensus of the group members was to focus on three initial activities.

1. Develop a synthesis of current seismic practice and guidelines.
2. Prepare a document on performance-based seismic design for tunnels and underground structures.
3. Identify and create a list of knowledge gaps/emerging technologies specific to seismic performance.

The synthesis document was selected as the highest priority and is currently under development, with Prof. Youssef Hashash and Carlos Jaramillo leading the effort. This synthesis aims to present an overview of the current state of practice for the seismic design and construction of tunnels and underground structures.

The information is intended to provide owners, designers and contractors with a resource to develop guidance and methods for new projects and retrofit existing underground systems. The synthesis will draw information from literature, personal experiences and a survey of current public agencies’ practices within the United States and other countries. Past and current design approaches, analysis tools and practice will be documented and critically analyzed, and knowledge gaps will be identified to provide future research directions.

Design case histories where seismic evaluations and designs have been employed on projects will be documented and supplemented from interviews with knowledgeable individuals from both the public and private sectors. A summary of selected performance case histories of underground structures that experienced seismic shaking will be included. Publication of the document is targeted for June 2020.

If you would like additional information on the working group or would like to become a member, please contact Conrad Felice at conrad.felice@cwelicellc.com.

**ITA Working Group 14**
The goal of the UCA of SME Working Group 14 – Mechanized Tunnelling, is to further develop an intensive knowledge base for planners, designers, contractors and equipment and service providers. Mechanized tunneling in this context generally includes all forms of machine excavated and supported tunnels and caverns with the exclusion of...
UCA Working Groups

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the drill and blast and SEM tunneling (UCA WG 19 – Conventional Tunneling). Based on the ITA charter for WG 14:

“WG14 is to promote mechanized tunneling and to inform about the current state of development in this flexible technology. It shall support public and private clients, planners and contractors with general and technical information during the preparation for tunnelling projects.”

ITA Working Group participation. UCA WG 14 supports the ITA WG 14 – Mechanized Tunnelling. Our group (both ITA and UCA affiliates) is composed of representatives from owners, designers, contractors, subcontractors as well as equipment and material manufacturers and, therefore, represent a highly diverse cross-section from the global tunnelling industry. All group participants are volunteers and share a common goal of making contributions and seeking betterments to the tunneling and underground construction industry. Over the past several years this Working Group has developed collaborative relationships with other established Working Groups and has placed a special emphasis (dedication) on the engagement of young members. Accordingly, all current and future activities and publications will have substantial involvement (and ownership) from young members.

ITA Working Group Leadership. Within the ITA organization, Working Group 14 is under the leadership of Brian Fulcher, Animateur; Karin Bäppler, Vice Animateur and Soren Eskesen, Tutor.

Recent Working Group Publications. The ITA Working Group has been active in recent years in completing several comprehensive publications intended for the global tunneling industry. These documents have also been very well received in the U.S. tunneling industry and are frequently referenced in tunneling journals and technical publications. Quick access to these publications can be achieved through:

Handling, Treatment and Disposal of Tunnel Spoil Materials, 2019, Author Working Group 14 and 15
Recommendations on the Development Process for Mined Tunnels, 2016, Author Working Group 14 and 19

WG 14 has been active in developing two concurrent publications with input from volunteers from around the globe including the United States. It is intended that these publications will be completed at the end of 2021 in advance of WTC 2022 in April in Copenhagen.

TBM Guide Specifications
• Preparing a guideline for the development of TBM specifications in soft ground and hard rock. The work is progressing under an expanded participant base.
• Complete current narrative and data summaries.
• Publish target date – late 2021.

TBM Tunnel Spoil Processing, Treatment and Disposal
• Expanding on a prior completed major work product (2019 by WG 14+15) related to the handling, treatment and disposal options of tunnel spoil material. This is an important global topic needing considerably more attention and solutions.
• Further develop narrative and data summaries (linked to 2019 publication).
• Publish target date – late 2021.

Additional attention and specialized focus have commenced on future publications dedicated to specific mechanized tunnelling technologies related to improvement in efficiencies, safety, communications and wear detection issues.

Summary
UCA WG 14 involvement with the ITA and the global tunneling industry provides a unique portal to access developments and technological improvements that also makes sure that information flows from the U.S. to other countries. Current membership in the UCA Working Group includes persons working in the design, contracting and equipment manufacturing sectors. Additional members are actively being sought to expand the UCA WG to contribute to present and future publications.

Working Group 22
The goal of the UCA of SME Working Group 22 “Information Modeling in Tunneling” is to develop and support best Building Information Modeling (BIM) practices within the tunneling industry. As the name indicates, the UCA WG 22 supports the ITA WG 22 “Information Modeling in Tunneling” in achieving this goal. We are composed of representatives from both designers and contractors and therefore represent a diverse view of how BIM is used in the modern tunneling industry.

Our close relationship with the ITA allows information and knowledge to flow in two directions. In one direction, our WG aims to benefit from international experience in using methods or technology that have not yet become widespread in the U.S. tunneling industry. In doing so, our WG specifically focuses (continued on page 33)
DFI announces new chair and scholarships


Sinnreich earned a bachelor’s degree in civil engineering and a master’s degree in structural engineering at the University of Florida (UF), and previously worked for Fugro Loadtest. He has participated in hundreds of international bi-directional test projects and led R&D efforts on various technologies, including ultrasonic shaft profiling. While coordinating UF research at the Powell Structures and Materials Lab, he oversaw projects dealing with wind engineering and natural hazards. Sinnreich is a registered professional engineer in Florida and current chair of ASTM Subcommittee D18.23 (Field Instrumentation Subcommittee under D18 Soil and Rock). He is also active in DFI as an editorial board member for DFI Journal, and serves on multiple technical committees.

The DFI Seismic and Lateral Loads Committee focuses on the unique issues of seismic design and construction as well as related concerns of other lateral load issues that apply in marine applications, ice and permafrost regions.

UCA Working Groups

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on the development of new project organization methods that employ novel software to increase project efficiency and to improve information exchange within a tunneling project. Several countries already require, as a standard, that BIM methodologies are used within the tunneling industry. The UCA of SME WG 22 aims to learn from these regulations to bring the best BIM practices back to the United States and to our diverse assortment of owners, contractors, and consultants.

Our involvement with the ITA also makes sure that information flows from the U.S. to other countries. Our group members are currently actively engaged in the development of BIM guidelines for bored tunneling projects within the ITA, and we actively work to promote U.S. interests in their development. For example, in the United States we employ several different contracting techniques (design-build, progressive design build, contract management at risk, etc.) that may not be widely adopted in all countries. Such contracting techniques intrinsically affect information flow within a project, and who is responsible for what information at what stage. Our group therefore aims to ensure that any attempt at international standardization of information flows allows enough flexibility to account for unique U.S. contracting practices or other aspects of the U.S. industry. In this way we are not only making sure that our national industry is internationally heard but are doing our part to introduce unique viewpoints and approaches to the international tunneling community.

Whichever way the information flows, we at the UCA WG 22 look forward to continued work with our international colleagues to promote BIM and its continued adoption within our industry.

RETC: UCA returns to in person conferences

(continued from page 28)
ply with current venue, local, county, state and federal guidelines. Complete and updated health and safety measures can be found online.

Before arriving at Caesars Palace in Las Vegas, attendees should review terms and conditions that must be accepted during registration.

To avoid congestion, please register in advance. RETC will offer only badge changes at registration. All attendees must be registered in advance and will have their name badge delivered to their hotel room or will be mailed their name badge. The venue is adhering to strict protocols to clean and sanitize the property. For details, visit: https://www.caesars.com/health-and-safety.

During RETC, all attendees must wear a face covering regardless of vaccination status.

Health self-assessments will be required to enter the meeting space. You may be subject to a temperature screening and may be required to scan your badge upon entry to assist with contact tracing. While networking is highly encouraged, social distancing guidelines will be followed in session rooms, at meal functions and in the Exhibit Hall.

The venue will not provide pens and pads in session rooms and RETC will limit the distribution of printed materials. Please plan to bring your own pen and notebook and download the conference app.

If you are not feeling well while attending RETC, medical personnel will be available for assistance.
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*To have your major tunnel project added to the Tunnel Demand Forecast, or to update information on a listed project, please contact Jonathan Klug at jklug@drklug.com.*
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<td>18</td>
<td>2024</td>
<td>Under design</td>
</tr>
<tr>
<td>LA Metro Speulvada Pass Corridor</td>
<td>Los Angeles MTA</td>
<td>Los Angeles</td>
<td>CA</td>
<td>High/Trans.</td>
<td>55,500</td>
<td>60</td>
<td>2020</td>
<td>LOI received</td>
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<td>Folsom Area Storm Water Improvement</td>
<td>SFPUC</td>
<td>San Francisco</td>
<td>CA</td>
<td>CSO</td>
<td>4,000</td>
<td>12</td>
<td>2022</td>
<td>Under design</td>
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<tr>
<td>BART Silicon Valley Phase 2 Tunnel</td>
<td>Santa Clara Valley Transit Authority</td>
<td>San Jose</td>
<td>CA</td>
<td>Subway</td>
<td>26,400</td>
<td>56</td>
<td>2021</td>
<td>Under design</td>
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<tr>
<td>California Waterfix 1</td>
<td>Delta Conveyance Design and Const.</td>
<td>Sacramento</td>
<td>CA</td>
<td>Water</td>
<td>39,905</td>
<td>28</td>
<td>2020</td>
<td>Delayed</td>
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<td>California Waterfix 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>403,400</td>
<td>40</td>
<td></td>
<td>2020 Delayed</td>
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<tr>
<td>Yonge St. Extension</td>
<td>Toronto Transit</td>
<td>Toronto</td>
<td>ON</td>
<td>Subway</td>
<td>15,000</td>
<td>18</td>
<td>2022</td>
<td>Under design</td>
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<tr>
<td>Massey Tunnel</td>
<td>City of Toronto</td>
<td>Toronto</td>
<td>ON</td>
<td>CSO</td>
<td>20,000</td>
<td>18</td>
<td>2022</td>
<td>Under design</td>
</tr>
<tr>
<td>Inner Harbour West</td>
<td>City of Toronto</td>
<td>Toronto</td>
<td>ON</td>
<td>CSO</td>
<td>18,400</td>
<td>19</td>
<td>2022</td>
<td>Under design</td>
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<tr>
<td>Scarborough Rapid Transit Extension</td>
<td>Toronto Transit Commission</td>
<td>Toronto</td>
<td>ON</td>
<td>Subway</td>
<td>25,000</td>
<td>18</td>
<td>2018</td>
<td>Strabag low bidder</td>
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<td>Elington Crosstown West Extension</td>
<td>Toronto Transit Commission</td>
<td>Toronto</td>
<td>ON</td>
<td>Subway</td>
<td>40,000</td>
<td>18</td>
<td>2020</td>
<td>West End Contractors low bid</td>
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<td>Ontario Line North Extension</td>
<td>Toronto Transit Commission</td>
<td>Toronto</td>
<td>ON</td>
<td>Subway</td>
<td>29,500</td>
<td>20</td>
<td>2022</td>
<td>Under design</td>
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<td>Ontario Line South Extension</td>
<td>Toronto Transit Commission</td>
<td>Toronto</td>
<td>ON</td>
<td>Subway</td>
<td>29,500</td>
<td>20</td>
<td>2021</td>
<td>Shortlist announced</td>
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<tr>
<td>Blue Line Extension</td>
<td>Societe de transport de Montreal</td>
<td>Montreal</td>
<td>QC</td>
<td>Subway</td>
<td>19,000</td>
<td>20</td>
<td>2021</td>
<td>Under design</td>
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<td>Green Line LRT</td>
<td>City of Calgary</td>
<td>Calgary</td>
<td>AB</td>
<td>Transit</td>
<td>26,250</td>
<td>20</td>
<td>2021</td>
<td>RFQ submitted</td>
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<td>Nose Hill Project</td>
<td>City of Calgary</td>
<td>Calgary</td>
<td>AB</td>
<td>CSO</td>
<td>10,800</td>
<td>10</td>
<td>2020</td>
<td>Under design</td>
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<td>Annacis Water Supply Tunnel</td>
<td>City of Vancouver</td>
<td>Vancouver</td>
<td>BC</td>
<td>Water</td>
<td>7,500</td>
<td>15</td>
<td>2021</td>
<td>RFQ requested</td>
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<td>Millennium Line Broadway Extension</td>
<td>Metro Vancouver</td>
<td>Vancouver</td>
<td>BC</td>
<td>Subway</td>
<td>18,700</td>
<td>18</td>
<td>2020</td>
<td>Acciona/Ghella JV awarded</td>
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<td>Eagle Mt. Pipeline</td>
<td>Fortis BC Woodfine</td>
<td>Vancouver</td>
<td>BC</td>
<td>Oil</td>
<td>29,500</td>
<td>13</td>
<td>2020</td>
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<td>Stanley Park Water Supply Tunnel</td>
<td>City of Vancouver</td>
<td>Vancouver</td>
<td>BC</td>
<td>Water</td>
<td>5,000</td>
<td>15</td>
<td>2021</td>
<td>Under design</td>
</tr>
</tbody>
</table>
Get ready to **RECONNECT**
with tunneling professionals at the first tunneling event of 2021, RETC!

**RE-FOCUS**
Find solutions to common project challenges and case studies presented only at RETC.

**RE-CHARGE**
Break away from the Zoom fatigue of the last year to network, engage and re-ignite your passion for tunneling.

**RE-EMERGE**
Find fresh ideas and strategies to implement that will positively affect your bottom line, and your perspective!

Register and book your room at [retc.org](http://retc.org)

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**TECHNICAL PROGRAM**

**SUNDAY, JUNE 13**

- **8:00 – 11:00 am**
  - Short Course: DRB Training: Dispute Boards for Projects Using Alternative Delivery Methods
    - $150 Member
    - $250 Nonmember
- **1:00 pm**
  - The State of Dispute Resolution Boards in the Tunnel Industry (The Good, the Bad and the Ugly)

**MONDAY, JUNE 14**

- **8:30 am**
  - Contract Practices
  - Design
  - Difficult Ground
  - Hard Rock TBM and Tunnels
- **1:30 pm**
  - Design Build Projects
  - Ground Control Approaches and Methods
  - Health & Safety and Sustainability
  - Shafts and Mining

**TUESDAY, JUNE 15**

- **8:30 am**
  - Ground Support and Final Lining
  - International Projects
  - Large Span Tunnels and Caverns
  - New and Innovative Technologies I
- **1:30 pm**
  - Future Projects
  - New and Innovative Technologies II
  - Pressurized Face Tunneling
  - SEM Applications and Projects

**WEDNESDAY, JUNE 16**

- **8:30 am**
  - Geotechnical Considerations
  - Microtunneling & Trenchless Tunneling
  - Project Planning and Risk Management
  - Tunnel Rehabilitation

Learn more about the program and speakers at [retc.org](http://retc.org)
## SCHEDULE-AT-A-GLANCE

**SUNDAY, JUNE 13**
- 8:00 am - 11:00 am: Short Course | DRB Training: Dispute Boards for Projects Using Alternative Delivery Methods (ticketed)
- 10:00 am - 11:00 am: RETC Executive Committee Meeting
- 11:00 am - 12:00 pm: RETC International Committee Meeting
- 1:00 pm - 4:00 pm: Workshop | Panel Session: The State of the Dispute Resolution Boards in the Tunnel Industry (The Good, the Bad and the Ugly)
- 3:00 pm - 4:30 pm: Cutting Edge 2021 Organizing Committee Meeting
- 5:00 pm - 6:30 pm: UCA Corporate/Sustaining Members Reception (by invitation only)
- 6:00 pm - 8:00 pm: Women in Tunneling Reception
- 7:00 pm - 7:30 pm: UCA Mentor Orientation
- 7:30 pm - 8:00 pm: UCA Mentor/Mentee Meeting Place
- 8:00 pm - 9:00 pm: UCA Young Members Scholarship Orientation

**MONDAY, JUNE 14**
- 7:00 am - 8:30 am: RETC Scholarship Recipients Breakfast
- 7:30 am - 5:00 pm: RETC Information Desk Open
- 7:30 am - 3:00 pm: Speaker Ready Room
- 7:30 am - 8:30 am: Authors’ Coffee
- 8:00 am - 3:00 pm: Exhibitor Move-in
- 8:30 am - 11:30 am: Technical Sessions
- 11:30 am - 1:00 pm: Welcoming Luncheon (ticketed)
- 1:30 pm - 5:00 pm: Technical Sessions
- 4:00 pm - 5:00 pm: George Fox Committee Meeting
- 5:00 pm - 7:00 pm: Exhibit Hall Hosted Reception
- 8:00 pm - 10:30 pm: UCAA/Y Networking Event (offsite location)

**TUESDAY, JUNE 15**
- 7:00 am - 8:30 am: UCA Breakfast (ticketed)
- 7:30 am - 5:00 pm: RETC Information Desk Open
- 7:30 am - 3:00 pm: Speaker Ready Room
- 7:30 am - 8:30 am: Authors’ Coffee
- 8:30 am - 11:30 am: Technical Sessions
- 11:00 am - 2:00 pm: Exhibit Hall Open
- 11:30 am - 1:00 pm: Luncheon in Exhibit Hall
- 1:30 pm - 5:00 pm: Technical Sessions
- 4:00 pm - 7:00 pm: Exhibit Hall Hosted Reception

**WEDNESDAY, JUNE 16**
- 7:30 am - 12:00 pm: RETC Information Desk Open
- 7:30 am - 10:30 am: Speaker Ready Room
- 7:30 am - 8:30 am: Authors’ Coffee
- 8:30 am - 11:30 am: Technical Sessions
- 9:00 am - 12:00 pm: Exhibit Hall Open
- 9:00 am - 11:00 am: UCA Executive Committee Orientation
- 9:30 am - 11:30 am: NAT 2022 Organizing Committee Meeting
- 11:30 am - 2:00 pm: UCA Executive Committee Meeting

**SUNDAY, JUNE 13**
- 8:00 am: Short Course | DRB Training: Dispute Boards for Projects Using Alternative Delivery Methods (ticketed)
- 1:00 pm: Workshop | The State of Dispute Resolution Boards in the Tunnel Industry (The Good, the Bad and the Ugly)

**MONDAY, JUNE 14**
- 8:30 am
  - Contract Practices
  - Design
  - Difficult Ground
  - Hard Rock TBMs and Tunnels
- 1:30 pm
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  - Pressurized Face Tunneling
  - SEM Applications and Projects

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- 8:30 am
  - Geotechnical Considerations
  - Microtunneling & Trenchless Tunneling
  - Project Planning and Risk Management
  - Tunnel Rehabilitation

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Entrance

FLOORPLAN - OCTAVIUS
Herrenknecht
Gold Sponsor

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 transport tunnels (Traffic Tunnelling) and supply and disposal tunnels (Utility Tunnelling). 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.

Jacobs
RETC Mobile App

Jacobs brings extensive design and construction management experience to all types of tunnels projects, including highways, transit/railroad, water and wastewater systems. We have successfully delivered the design of some of the most challenging recent design-build/P3 tunnel projects in the U.S., such as the Port of Miami Tunnel project in Florida, the Blue Plains Tunnel in Washington D.C. and the Ohio River Bridge East End Crossing Tunnel in Louisville, Kentucky.

With a talent force of more than 50,000, Jacobs provides a full spectrum of services including technical, professional and construction/program-management for business, industrial, commercial, government and infrastructure sectors. For more information, please visit www.jacobs.com.

JENNMAR Civil
WiFi

JENNMAR has been an innovative leader in ground control for the mining industry for more than forty years. Over the past decade, the success of our products and engineering solutions has led us, quite naturally, into tunneling applications as well. We’ve made key acquisitions of people and equipment to further enhance our deep commitment to serve the tunneling industry.

Our primary product roster includes M3® expandable rock bolts, FRICTION-LOK® stabilizer systems, Fast Anchors™ DCP Bolts, steel sets, steel tunnel ribs & shaft rings, lattice girders, rail ties, resins and with our alliance partners, Contech, we also provide 2-flange liner plate.

Traylor Bros., Inc.
Lanyards

Traylor Bros., Inc. (TBI) is a family-owned corporation founded in 1946. For more than 75 years, TBI has provided single-source, comprehensive, cutting-edge construction and design-build services to public works agencies throughout North America. The tremendous depth of experience in our engineering and management staff, together with our highly experienced field personnel, has allowed TBI to develop some of the most innovative construction solutions in the industry. Our array of services includes tunnels and other underground structures, bridges, locks and dams, ports and wharfs, and mine development, as well as equipment support. Visit us at www.traylor.com.

Skanska
RETC Proceedings Sponsor

Skanska USA is one of the largest, most financially sound construction and development companies in the U.S., serving a broad range of clients including those in transportation, power, industrial, water/wastewater, healthcare, education, sports, data centers, government, aviation, life sciences and commercial. Throughout the 31 metropolitan areas where it works, Skanska has extensive tunneling and complex underground experience and expertise in support of a variety of infrastructure sectors.

Jay Dee Contractors, Inc.
Monday Exhibit Hall Hosted Reception
Exclusive Sponsor

Jay Dee Contractors, Inc. has been delivering quality and innovative underground construction since 1965. Our team is comprised of experienced and dedicated industry professionals, and our commitment to quality is evident in everything we do. We continue to build upon our reputation of excellence by delivering innovative, quality and reliable underground tunneling projects including: Soft Ground, Hard Rock and Pressurized Face Tunneling, Tunnel Rehabilitation, Shaft Excavations, and Concrete Structures. Our work underground makes the surface world more livable.
Keller Company
Silver Sponsor
Facing challenging subsurface conditions is a familiar scenario for tunneling contractors, and as the leading geotechnical specialty contractor, Keller has provided solutions to these challenges for almost 100 years. Our solutions for tunneling include diaphragm walls, ground freezing, secant piles, dewatering, jet, permeation and compensation grouting, and instrumentation and monitoring.

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

Barnard Construction
Coffee Break Sponsor
People building for People. That’s what we do at Barnard. Whether we’re raising a dam in Alaska, constructing a reservoir in Florida, tunneling under downtown San Francisco, redirecting a river while building a complex hydropower plant in northern Manitoba, or strengthening and improving the integrity of a natural gas pipeline in a Sacramento suburb, our people arrive at our projects with a determination to do the best for their communities and be the best in the industry. Our work also encompasses power transmission, marine, water and sewer pipeline, and environmental construction. Most often our projects include several of these elements. They always present a challenge. They affect our neighbors as well as our families. We live where we work, so we come to know our projects personally. We build for People.

HNTB
Technical Presentations Sponsor
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.

Kiewit
Coffee Break Sponsor
For more than 60 years, Kiewit has built some of the most complex tunneling and underground projects in North America. We have the capabilities to self-perform soft ground and hard rock TBM tunneling, along with conventional tunneling techniques such as Drill and Blast, and SEM. At the heart of these projects is a workforce dedicated to industry-leading safety performance and unmatched quality excellence. From the unique, complex projects we build, to the committed professionals who design, engineer and construct them, Kiewit ensures the ordinary is always extraordinary.

Kiewit Infrastructure Co.
Underground District
1550 Mike Fahey St, 3rd Floor
Omaha, NE 68102
402-342-2052

MAPEI Corp
Coffee Break Sponsor
MAPei’s Underground Tunneling Technology (UTT) category offers a complete line of products and associated technologies for use in and on underground construction projects, including shotcrete accelerators and admixtures for concrete, as well as products for injection and consolidation, mechanized tunneling (TBM), engineering and soil stabilization, coating and protection, maintenance, repair and waterproofing.

The Walsh Group
Technical Program Sponsor
Founded in 1898, The Walsh Group is a fourth-generation family-owned business providing design, build, finance and operation for a wide variety of construction projects. We are consistently listed among the largest contractors in the United States, operating out of 21 strategically located regional offices across North America. Our three companies are united by a shared dedication to exceptional customer service, while upholding the highest standards of ethics, quality and safety.

IPC – Bothar Group of Companies
Silver Sponsor
IPC is an industry leader in trenchless underground construction with over 50 years of international experience.

With focus on safety and quality, we are BUILDING THE WORLD BENEATH YOU while taking care of our people and providing exceptional service to our clients and the public. Our commitment to the environment ensures a maximum reduction in environmental footprint. IPC provides a wide range of cutting-edge technology and underground construction solutions from Micro-tunneling, to complete trenchless installation in urban and environmentally sensitive areas. Our solutions and technologies are adaptive to complex geological conditions providing superior value and services to our clients across various industries.
BabEng, LLC
Women in Tunneling Reception

BabEng specializes in mechanized tunneling and underground storage construction. The world-wide services range from project development and design to construction management and practical work process optimization. Another successful service being offered is hands-on troubleshooting on-site for TBMs in difficult situations. For water and gas storage, BabEng joins forces with project developers and construction companies. TPC Tunnelsoft, the software branch, supports the tunneling industry with specialized software for technical data management and visualization on tunnel projects. Its unique flexibility, combined with powerful automatic reporting and notification tools, makes it one of the leading solutions in the market.

Gall Zeidler Consultants
Bronze Sponsor

Gall Zeidler Consultants is an international engineering consultancy specialized in solutions for tunnel and underground schemes. We provide geotechnical and tunnel engineering services along with consultancy in tunnel construction as well as program and construction management. We use our wide range of expertise in mining, transportation, infrastructure and water conveyance, projects to help our clients overcome difficult ground conditions and to provide a superior product from its first conceptual phases to its turn-key completion. With decades of international experience in all areas of underground construction, we are a global leader in our field and have successfully completed over 300 miles of tunnels worldwide.

McMillen Jacobs Associates
Women in Tunneling Reception

McMillen Jacobs Associates specializes in delivering underground and water resources infrastructure and providing technical engineering design and construction expertise in the water, wastewater, transportation, transit, and energy/power industries. Offering a full range of design, design-build, self-performing construction and construction management services, we work closely with our clients at every stage of a project, assisting them with planning, design expertise, project management, construction, start-up, and dispute resolution. McMillen Jacobs is also committed to the principles of sustainability in its design and construction practices. Our 21 offices in North America and Australasia and more than 500 staff, serve clients locally and worldwide.

SAK Construction
UCA of SME Young Members Reception

SAK Construction, LLC (SAK), a national pipeline rehabilitation and tunneling services contractor is a leading provider of pipeline rehabilitation services. The company solves the challenge of maintaining and restoring aging water and sanitary infrastructure for the municipal, energy and industrial markets.

Founded in 2006, SAK Construction has built a reputation as an industry leader and is recognized as one of the nation’s most respected pipeline rehabilitation contractors. Led by industry pioneers, Bob Affholter, Jerry Shaw and Tom Kalishman, SAK has become one of the fastest growing privately owned construction companies in the United States.

AMIX Systems Ltd.
Bronze Sponsor

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 systems, which simplify the grout mixing process. If you are retrofitting existing plants, we’re your solution. Our team has 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, buyback and OEM valve sales programs available for all your grouting applications!

Contact us for more information
Dennis Arbour
AMIX Systems, Founding Partner & CTO
dennis@amixsystems.com

AZTEC-TYPSA
Bronze Sponsor

AZTEC is a full-service engineering and environmental consulting firm and is consistently recognized by Engineering News-Record. AZTEC is a wholly-owned subsidiary of the TYPSA Group in the United States. TYPSA is global engineering, environmental and architectural firm with revenues of more than $250M annually, and more than 2,800 staff in 50 offices worldwide.

AZTEC-TYPSA is a leader in the field of underground and geotechnical engineering with successfully delivering these services for projects that involved tunnels for metros, railways, roadways and hydraulic systems. On average, the AZTEC-TYPSA geotechnical and tunneling group is involved in more than 60 miles of tunnel-related projects every year.
ABC Industries, Inc

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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- Dust and Fume Control Technology
- Mining Equipment
- Tunnel Lining and Support Materials
- Ventilation Systems, Materials and Equipment

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301 Kings Hwy
Winona Lake, IN 46590 United States of America
Phone: (574) 267-5166
www.abc-industries.net

ABC Ventilation Systems

ABC Ventilation Systems is one of the world’s leading companies in underground ventilation. ABC Ventilation Systems provides complete turn-key tunnel ventilation design and systems from fan to face. ABC Hardline Ducting is a highly efficient, low resistance, high pressure, flat shipped hard line ducting for positive and negative pressure applications. Hardline is now approved for use in California. ABC Ventilation Systems high pressure Zipper Coupling has one of the lowest resistance and leakage profiles available.

Products & Services
- Ventilation Systems, Materials and Equipment

Main Office
1802 Quebec Ave
Saskatoon, SK S7K 1W2 Canada
Phone: (306) 653-4303
www.abcventilation.com

AECOM

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 around the world. AECOM understands that specialized services are vital to a successful project. That’s why our tunnel practice experts are recognized for their work on the world’s landmark tunnels. We bring extensive design and construction management expertise, including experience with alternative delivery projects.

Products & Services
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- Engineering Design and Services for Tunnels
- Geological, Geotechnical Services and Equipment

Main Office
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Los Angeles, CA 90067 United States of America
Phone: (843) 743-8355
www.aecom.com

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Aerix Industries
Aerix Industries (formerly Cellular Concrete Solutions), manufactures and supplies a dynamic product line of integrated engineered foam liquid concentrates, enabling its customers to produce and install high quality lightweight cellular concretes, 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 70 years.

Products & Services
- Grouting Services, Equipment and Materials

Main Office
5902 McIntyre St
Golden, CO 80403 United States of America
Phone: (303) 271-1773
Email: info@aerixindustries.com

AESTUVER - ECO Tunneling

Main Office
704 Baker Ln, Ste 5
Winston-Salem, NC 27105 United States of America
Phone: (336) 740-4183
Email: info@ecotunneling.com

AGRU America, Inc
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
- Precast Concrete Linings
- Tunnel Lining and Support Materials
- Water Treatment Plant and Materials

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

Antraquip Corp
Antraquip continues its reputation as the leading supplier of rock and concrete cutting attachments for excavators which are commonly used for scaling, profiling, mixing/remediation and tunnel enlargement projects, as well as roadheaders for tunnel and mining applications. In the field of tunnel support, Antraquip offers lattice girders, steel ribs and complete casing systems for pipe roofing, anchoring and drainage. Other products offered include self-drilling rock bolts, steel fibers, rock saw attachments and custom engineered shaft sinking equipment.

Products & Services
- Tunnel Boring Equipment
- Underground Excavation Services and Equipment

Main Office
758 Bowman Ave
Hagerstown, MD 21740 United States of America
Phone: (301) 665-1165
Email: info@antraquip.net
www.antraquip.net

Avanti International
Avanti International is a producer of high-quality injection grouts in the U.S. For decades, Avanti’s injection grouts have been used in geotechnical applications to stabilize soils and control groundwater before, during, and after construction. Injection grouts can be used: 1) Before tunnel break-ins/outs to stabilize surrounding soils, control groundwater inflow, and improve project productivity; 2) During tunnel construction to stabilize weak soils, control groundwater ahead of and behind TBMs, and create a safer work environment; and 3) After project completion to create an impermeable watertight barrier. For more information on Avanti’s injection grouts, visit our website.

Products & Services
- Ground Improvement Equipment and Services
- Grouting Services, Equipment and Materials
- Pumps and Pumping Equipment
- Underground Utility Materials and Operations

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822 Bay Star Blvd
Webster, TX 77598 United States of America
Phone: (281) 486-5600
Email: info@avantigrout.com
www.avantigrout.com

Ballard Marine Construction
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).

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Bauer Foundation Corporation (BFC), the US subsidiary of Bauer Spezialtiefbau of Germany, is a deep foundation and ground improvement contractor. BFC provides ground improvement and support of excavation services to the tunneling industry including slurry/diaphragm walls, secant walls, grouting, drilled shafts and ground freezing.

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Products & Services
Ground Improvement Equipment and Services
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Colorado School of Mines - Underground Construction and Tunnel Engineering
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Crux is a leader in geotechnical construction and exploration. With more than 20 years’ experience in the tunneling industry, the company has provided solutions to some of the most difficult-access and geologically challenging projects in North America. Crux specializes in long range horizontal coring, borehole surveying, optical and acoustical televsion services, high-quality sampling, and instrumentation installation. Pre-exavation stabilization services include dewatering, permeation and compaction grouting, tube arch canopies, and cased horizontal boreholes. Crux provides design-build services and a fleet of custom designed equipment to ensure unique project needs can be met.

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Ground Improvement Equipment and Services
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Instrumentation Equipment and Services

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Phone: (509) 892-9409
Email:info@cruxsub.com
www.cruxsub.com

Crux Subsurface, Inc
Crux Measuring Technique USA, Inc
Dibit Measuring Technique USA, Inc. is a worldwide operating engineering office specialized in tunnel surveying and tunnel scanning. Through decades of experience, hardware and software technologies have evolved steadily, enabling Dibit to provide high-skilled surveying services and sophisticated scanning solutions. Each scanning system and solution is specialized for different tasks, such as excavation scanning, as-built documentation, or inspections. Independently of the various scanning systems, the result is a high-resolution, true-color 3D-model. This 3D-model builds the basis for any further analysis like volume and thickness calculations, or geometry and clearance checks as well as mapping geological and geotechnical information.

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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 innovative design solutions and high quality field supervision has led to the successful completion of numerous transportation and utility tunnels.

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EC Applications - Tunnel Lining
EC Applications supplies and installs protective tunnel liner systems combining the advantages of thermoplastics (HDPE and LLDPE) with associated materials (geotextile, waterbar, injectable grout hose and components) required for a turnkey tunnel lining system. ECA’s qualified installation technicians, project experience and Los Angeles based fabrication facility provide a cost effective solution for geomembrane tunnel lining on any project.

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- Rotary Drum Cutters
- Tunnel Boring Equipment
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**GeoStructural Engineering Inc**

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- Geotechnical, Geotechnical Services and Equipment Instrumentation Equipment and Services
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**Geokon, Inc**

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**Products & Services**
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Grouting Services, Equipment and Materials
Lubricants for TBM
Shotcrete Equipment, Supplies, and Services
Slurry Services and Machines
Soil Conditioning Equipment and Materials

Master Builders Solutions
Through its Master Builders Solutions brand, BASF is a leading supplier of underground construction solutions that help tunneling customers to become more successful, even in highly challenging ground conditions. BASF 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.

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Grouting Services, Equipment and Materials
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    - 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.
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      - Phone: (215) 824-4987
      - www.messingerbearings.com
  - **MILLER**
    - **Main Office**
      - 5905 Walnut Grove Rd
      - Carrier Mills, IL 62917 United States of America
      - Phone: (618) 994-4616
      - Email:miller@millercontracting.us
      - miller@millercontracting.us
  - **Mining Equipment Ltd**
    - 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.
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      - Phone: (970) 259-0412
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      - Georgetown, KY 40324 United States of America
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      - Email:americas@mottmac.com
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Sandvik Mining and Rock Solutions is a business area within the Sandvik Group and a global leading supplier of equipment and tools, parts, service and technical solutions for the mining and construction industries. Application areas include rock drilling, rock cutting, loading and hauling, tunneling and quarrying. In 2020, sales were approximately 37 billion SEK with about 12,500 employees within continuing operations.
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SEALABLE Solutions GmbH previously DATWYLER Sealing Technologies is the world leading provider of tunneling gaskets. Datwyler will no longer sell tunnel gasket and SEALABLE took over this business by management-by-out. SEALABLE will continue business as we did with PHOENIX PDT Profiles. SEALABLE has more than 750 successful references on five continents and offers a full range of gasket profiles and material options for your tunnel project. SEALABLE manufacture all types of gaskets to meet all segmental tunnel specifications: mono EPDM, hydrophilic, Co-ex Swell/Composite Black Swell and anchored gasket. SEALABLE known for their support and experience for segmental lining gasket projects.

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Crux Subsurface, Inc
DSI Tunneling LLC
Keller
Master Builders Solutions
Shannon & Wilson, Inc
Simem Underground Solutions, Inc
Williams Form Engineering Corp

Grouting Services, Equipment and Materials
Aerix Industries
Avanti International
Bauer Foundation Corporation
ChemGrout, Inc
CJGeo
Crux Subsurface, Inc
DSI Tunneling LLC
Keller
MAPEI Corp
Master Builders Solutions
Nicholson Construction Co
Normet Americas, Inc
Renesco Inc
Richway Industries
Sika Corporation
Simem Underground Solutions, Inc

Hoists and Headframes
Carroll Technologies Group

Hydraulic Hammers and Drills
Epiroc

Instrumentation Equipment and Services
Carroll Technologies Group
Crux Subsurface, Inc
Dibit Measuring Technique USA, Inc
GeoComp Corp/GeoTesting Express, Inc
Geo-Instruments
Geokon, Inc
Measurand Inc
RST Instruments Ltd.
Senceive Ltd
Shannon & Wilson, Inc
SISGEO SRL
VMT USA
Worldsensing

Jet Grouting Equipment and Services
Keller

Laser Guidance Systems
VMT USA

Lighting Systems
IoT Automation
Nightstick

Lubricants for TBM
MAPEI Corp
Master Builders Solutions
Sika Corporation

Microtunneling Equipment, Tools, and Supplies
Herrenknecht Tunnelling Systems USA, Inc
HyperSciences, Inc
Pipe Me In
Terratec
VMT USA

Mining Equipment
ABC Industries, Inc
Brookville Equipment Corp
CAB
Dräger

Epiroc
J.H. Fletcher & Co
Line Power
Measurand Inc
Robbins
Sandvik Mining and Rock Solutions
Terratec
Worldsensing

Precast Concrete Linings
AGRU America, Inc
Master Builders Solutions
MSP Structures Inc
SEALABLE Solutions GmbH
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Sika Corporation
Simem Underground Solutions, Inc

Publishers
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Tunnels & Tunnelling
TunnelTalk

Pumps and Pumping Equipment
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ChemGrout, Inc
Gomez International, Inc
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Robbins

Rotary Drum Cutters
Antraquip Corp
Epiroc

Safety Products
CAB
Carroll Technologies Group
Dräger
HYTORC, Division of Unex Corp
Innovative Wireless Technologies
IoT Automation
Nightstick
Strata Worldwide
Tunnel Radio of America, Inc
Worldsensing

Scaling
Antraquip Corp
J.H. Fletcher & Co

Segment Accessories
MSP Structures Inc
SEALABLE Solutions GmbH
(formerly Datwyler Sealing Technology)

Shaft Drilling and Raiseboring Equipment
Herrenknecht Tunnelling Systems USA, Inc
JENNMAR Civil
Keller

Shotcrete Equipment, Supplies, and Services
Bekaert
MAPEI Corp
Master Builders Solutions
Sika Corporation
Simem Underground Solutions, Inc
SISGEO SRL
Strata Worldwide

Slurry Services and Machines
Keller
MAPEI Corp

Soft Ground Shields
Herrenknecht Tunnelling Systems USA, Inc
Robbins

Soil Conditioning Equipment and Materials
Geocomp Corp/GeoTesting Express, Inc
MAPEI Corp
Sika Corporation
Williams Form Engineering Corp

Steel Pipe
JENNMAR Civil
Naylor Pipe Co
TBM Supply
Williams Form Engineering Corp

Survey Equipment and Lasers
Dibit Measuring Technique USA, Inc
Senceive Ltd
VMT USA
Worldsensing

Tunnel Boring Equipment
Antraquip Corp
Ballard Marine Construction
Bessac
Epiroc
Gomez International, Inc
Herrenknecht Tunnelling Systems USA, Inc
HNTB Corp
HyperSciences, Inc
Messinger Bearings
Richway Industries
Robbins
Spendrup Fan Co
Terratec
VMT USA

Tunnel Communication Systems and Equipment
Carroll Technologies Group
HNTB Corp
Innovative Wireless Technologies
IoT Automation
Measurand Inc
RST Instruments Ltd.
Strata Worldwide
Tunnel Radio of America, Inc

Tunnel Haulage Systems
HNTB Corp

Tunnel Lining and Support Materials
ABC Industries, Inc
AGRU America, Inc
Antraquip Corp
Bekaert
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DSI Tunneling LLC
EC Applications - Tunnel Lining
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Services and Equipment
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Bekaert
Englo, Inc, DBA Engart, Inc
Richway Industries
Schnabel - SWS

Underground Locomotives and
Rail Haulage Equipment
Brookville Equipment Corp

Underground Utility Materials
and Operations
Avanti International
CAB
HOBAS Pipe USA
Pipe Me In

Ventilation Systems, Materials
and Equipment
ABC Industries, Inc
ABC Ventilation Systems
CAB
Englo, Inc, DBA Engart, Inc
Epiroc
Grydale USA
HNTB Corp
JENNMAR Civil
Mining Equipment Ltd
Mobile Air
Rocvent Inc
Spendrup Fan Co
TLT-Turbo

Wastewater Management
Products
HOBAS Pipe USA

Water Treatment Plant and
Materials
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HOBAS Pipe USA
## EXHIBITOR LISTING
### & BOOTH NUMBER

**Thank you to our 2021 RETC Exhibitors**

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- Small Diameter Tunneling
- Shaft Construction
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- Risk Management
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