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## TUNNELING & UNDERGROUND CONSTRUCTION

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A wide-angle photograph of a large tunnel under construction. The tunnel's interior is lined with a corrugated metal structure. On the left, a large circular opening is filled with wooden planks. Several workers in orange safety vests and hard hats are visible. In the center, a large piece of machinery, possibly a conveyor or pump, is labeled with the number '2919'. The tunnel extends into the distance, illuminated by bright lights at the far end.

**Ventilating Gotthard Base Tunnel  
Sound Transit Link Light Rail System  
Cutting Edge: Tunneling in nation's hotbed**

Special Editorial Supplement from the publisher of Mining Engineering



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**In this issue —**  
The Sound Transit Link Light Rail project in Seattle is part of the city's \$1.9-billion Northgate project. Some of the innovative technologies used are examined on page 14. More than 200 professionals attended the Cutting Edge conference last month, page 10. Cover photo is of the Sound Transit Link system, courtesy of Brokk.

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## CHAIRMAN'S COLUMN

# ITA hosts spectacular awards, another successful Cutting Edge

First and foremost, I hope you and your family had a wonderful Thanksgiving and are readying for a wonderful, safe and very rewarding holiday season and a prosperous New Year.

I recently returned from the 2016 International Tunnelling Association's (ITA) awards event in Singapore. It was the ITA's second annual awards event. The 2017 event is planned for Paris, France.

The event was quite spectacular. Many fascinating projects and new technologies were presented on day one of the two-day event. One of the most notable items at the event for me was the lack of American submissions for consideration in any of the categories. We did, though, have one finalist in the Young Engineer of the Year category. I hope the American Association can and will step up next year and compete for some or all of the award categories.

I also want to report on the Underground Construction Association of SME's (UCA) most recent Cutting Edge Conference, held in Los Angeles, CA in November. The presentations were top notch and proved to be very interesting to all of the attendees. The paid attendance of 227 people exceeded our budgeted estimate, and our sponsorships were more than double our estimated revenue. I opine this success was due in large part to the many hours of early planning and the early release of the topics to be presented and discussed. My thanks to the committee and all of those who worked hard to turn the conference into a complete success.

As for the *History of Tunneling* book, many of our members have spent many hours, weeks and months working on this project. My thanks to you, too. I am happy to report that the work is nearing

completion. It is scheduled to have the final edits completed and sent to the printer prior to the end of the calendar year. Each World Tunnel Congress 2016 (WTC) attendee will be mailed a complimentary copy of the book when the printing has been completed.

The Rapid Excavation and Tunneling Conference is scheduled for June 4-7, 2017, and should be very successful given all of the work and planning going into the event. I am also happy to report that the 2017 UCA budget includes funding to support the attendance of many Young Tunnelers through grants like we provided last year for the WTC. Details and applications will be provided soon. The evaluation and recommendation committee will consist of those within the Young Tunnelers group. The group will make recommendations to the Executive Committee for review and approval. I am looking forward to many applications and a large attendance by young and other tunnelers. We, as a group, must continue to support and provide outreach to the Young Tunnelers and to the Women Tunnelers group to better our Association and engage new members.

Lastly, the George A. Fox Conference is scheduled for Jan. 24, 2017 in New York City. The one-day conference will provide attendees the opportunity to meet industry leaders, attend technical sessions, interact with other professionals and catch up on some professional networking. Please register soon, as the available seats fill quickly and the event is usually sold out early.

Again, I wish everyone a happy, safe and healthy holiday season and a safe and prosperous New Year. ■

**Artie Silber,**  
**UCA of SME Chairman**

A construction worker wearing an orange high-visibility safety vest with reflective stripes and a hard hat with a headlamp is working on a large, complex industrial machine, likely part of a tunnel boring or ground treatment system. The worker is positioned in the foreground, facing away from the camera, looking down at the machinery. The background shows a long, dimly lit tunnel with a series of lights receding into the distance, creating a sense of depth. The overall scene is industrial and underground.

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### Tunneling to begin on downtown Los Angeles regional connector rail line

The tunnel boring machine (TBM), named Angeli, that will be used for the regional connector transit project in Los Angeles was lowered into place in October to be assembled to dig 1.7-km (1.1-mile) twin tunnels as part of the \$1.55-million regional connector project that is scheduled to be completed in 2021.

Angeli, a 6.5-m (21.5-ft) diameter TBM, will create the path for a rail line to connect three currently disconnected light rail lines.

When the project is completed passengers will have a one-seat ride from Long Beach to Azusa along the

Blue and Gold Lines and from East L.A. to Santa Monica along the Gold Eastside Extension and Expo Lines. Los Angeles County Metro estimates the connector will reduce travel times by as much as 20 minutes.

The regional connector will span 3 km (1.9 miles) through downtown adding three new stations.

"This is a major milestone toward the completion of a vital project that truly connects the region by providing a one-seat ride to downtown Los Angeles for users of the Blue, Gold and Expo lines," said John Fasana, Metro board chair and Duarte City Council member.

Tunnel digging begins in January and will advance at a rate of about 18 m/d (60 ft/day).

The project has already hit cost overruns and delays due to unexpected underground utility lines discovered during early phases of construction. Because downtown L.A. is one of the oldest and densest areas of the city, many existing utilities have never been mapped.

Metro relocated the utility lines and extended its timeline for the project at a cost of an extra \$130 million. The anticipated opening date for the line has been shifted from 2020 to 2021. ■

### Governor pledges support for tunnel expansion

Maryland Gov. Larry Hogan pledged to find a way to expand the Howard Street Tunnel underneath Baltimore. It is a project that Hogan said would spur production at the port.

The Howard Street Tunnel is more than 100 years old and has become a bottleneck for freight coming out of the Port of Baltimore. To expand the tunnel, Hogan predicted the federal government would help pay the \$425 million price tag to make it deeper, *The Baltimore Sun* reported.

"This is something that we're going to make sure gets done," Hogan told reporters at the Seagirt Marine Terminal. "It's critically important, not only to the Port of Baltimore and the city of Baltimore, but the entire state of Maryland. It really could be transformative to our economy."

Hogan emphasized the state's plans to reapply for \$155 million in federal FASTLANE funding, a new federal grant program that last year doled out \$800 million to 18 projects. Neither of Maryland's applications received any money last year.

But Hogan said he's confident the

project will be funded in the second year of the grant program, citing the application's high ranking and his personal appeals to President Barack Obama and Vice President Joe Biden.

The port of Baltimore was recently deepened to accommodate large ships bringing in freight. But Howard Street Tunnel is not large enough to accommodate double-stacked freight containers, so there is a bottleneck there.

If the tunnel were expanded, 178,000 containers that now leave the port on tractor-trailers each year could be moved by rail.

Previous estimates put at more than \$1 billion the cost of creating two feet more clearance in the tunnel.

Rail giant CSX Corp., which owns the tunnel and the track, thought the entire roof of the tunnel would have to be removed and rebuilt. But new construction and engineering techniques used by CSX to expand other aging tunnels dramatically brought down the cost for Howard Street, CSX spokesman Rob Doolittle said.

The new plan calls for dropping

the floor of the tunnel, notching archways to allow the rectangular shipping containers to pass through, trimming back ceilings and using lower-profile metal crossties instead of wooden ones. The existing ceiling would be reinforced.

CSX and Maryland transportation officials pitched this cheaper plan to the federal government earlier this year. The state promised to cover \$145 million of the project and CSX would pay for \$125 million. They are hoping the federal government will cover the remaining \$155 million.

Construction work on the tunnel project would generate about 500 jobs, Maryland and CSX officials said. The additional capacity to move cargo would generate about 3,000 jobs in and around the port, Hogan said.

It would take up to five years to construct the tunnel once funding is approved. CSX would need to expand several other bridges between Baltimore and Philadelphia for double-stacked shipping containers to travel unimpeded along the entire East Coast, Doolittle said. ■

### Bertha passes halfway point on SR-99 project

The Washington Department of Transportation (WSDOT) announced that Seattle's massive tunneling machine was roughly halfway through her nearly 3.2-km (2-mile) dig to replace the Alaskan Way Viaduct at the end of September and the tunnel boring machine (TBM) is expected to break through the tunnel's northern end by May 2017.

As far as WSDOT and Seattle Tunnel Partners are concerned, all is going well now as the TBM, named Bertha, paused at the 1,400-m (4,635-ft) mark of the tunnel.

"Everything's going according to plan," said Chris Dixon, project manager for Seattle Tunnel Partners, the contractor digging the tunnel.

Seattle PI reported that the TBM machine would be halting again in

early October for a maintenance stop, likely to last several weeks, Dixon said.

WSDOT's administrator for the tunnel project, Joe Hedges, hailed the day as something of a milestone from the bottom of the extraction pit just north of Thomas Street and Sixth Avenue.

A 27-m (90-ft) pit that was built as an extraction point when the TBM breaks through at the end of the line will also be the last resting place of Bertha, the world's largest tunneling machine, where a cradle is built that will hold the machine while it is dismantled after tunneling finishes.

But Hedges also suggested cautious optimism, clearly not forgetting the more than two-year breakdown of the machine only 304

m (1,000 ft) into the 2,962-m (9,720-ft) tunnel.

"Be optimistic, but understand what's in front of us," Hedges said.

Most of the boulders that have come out of the tunnel are around 0.6 m (2 ft) in diameter, Dixon.

Despite healthy progress — Bertha has mined about 914 m (3,000 ft) since April — the tunnel is still years behind schedule. At latest count, the tunnel is set to open sometime in early 2019. It was originally set to open by the end of 2016.

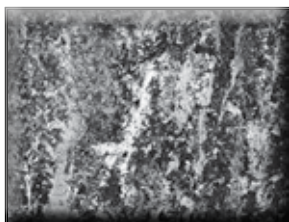
This summer, WSDOT reported to Olympia to tell lawmakers the state would need another \$224 million to finish the project, and that's if Seattle Tunnel Partners doesn't win its lawsuits seeking more money. ■



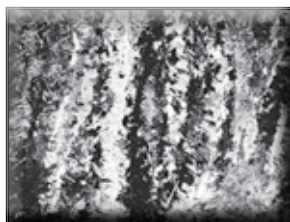
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### Norris Cut project completed through complex conditions in South Florida

In February 2016, construction company Bessac completed work on a protection tunnel in extremely difficult geology in South Florida.

The Norris Cut project used a custom Herrenknecht combined shield tunnel boring machine (TBM) with a diameter of 3.14 m (10.6 ft) to tunnel 1,613 m (5,290 ft) and add a new sewer line in the finished tunnel in just 10 months.

The ground conditions and project circumstances of the mission at Norris Cut were anything but standard. Not only did the karstified, permeable geology pose the risk of flooding the machine, the complex Fort Thompson Formation that was tunneled through was also full of sand-filled cavities. The tunnel face was therefore prone to instability.

For this reason, the construction of the protection tunnel for a new sewer line between Virginia Key and Fisher Island required a special and highly flexible machine with exceptional safety features. The Herrenknecht combined shield (HCS), called Dorsey, offered the necessary adaptability — available in slurry mode as well as in earth pressure balance (EPB) mode depending on the requirements. The HCS machine is optimally prepared for changeable ground conditions.

Additionally, the front area of the machine had to be accessible at all times during the job to allow for tool changes. For maximum safety, a bulkhead with a dive pit was developed especially for the project. Thanks to the bulkhead between the front two machine parts and the overpressure thus enabled, muck and water cannot penetrate into the machine at the tunnel face. Should high water pressures, nevertheless, lead to flooding, the dive pit allows safe locking into the flooded area.

In the end, the safety reserves

were not needed. Neither the sophisticated lock system nor the EPB mode of the HCS machine were used. The ground was highly permeable, as expected. However, the proper design of the cutterhead and the appropriate disc cutters enabled the customer to perform only one maintenance stop, performed under compressed air after a novative ground treatment from the TBM.

Dorsey began the drive near the treatment plant on Virginia Key in April 2015. From the first meter, the project was characterized by its special requirements to save space. With a diameter of 12 m (39 ft), the launch shaft was rather small. At the beginning, there was no room for the HSC machine's backups and they were only able to be used one by one after 70 m (230 ft) of tunneling. For the first section, the TBM was therefore pushed forward in pipe jacking mode using a jacking frame adapter developed by the customer, the rest of the tunnel was then lined with concrete segments.

At a depth of up to 21 m (68 ft) below sea level, the 3.13-m (10.6-ft) diameter Dorsey dug its way forward in the months that followed. After 227 working days came the breakthrough on Fisher Island on Feb. 16, 2016 — top performances of up to 24 m/d (79 ft/day) and about 300 m/month (984 ft/month) confirmed the optimum configuration of the TBM. By the end of the year, the new 152-cm (60-in.) discharge pipeline is due to be installed in the finished protection tunnel and put into operation.

The successful drive on the Norris Cut project has pushed the boundaries of what is possible in Florida's tunneling industry and contributed to its further

**In February 2016, "Dorsey" reached the target shaft on Fisher Island. In late 2016, a new segmentally lined protection tunnel will replace the old line and transport wastewater from Fisher Island to the treatment plant on Virginia Key.**



development. "The project has set standards for work in Florida's underground and showed solutions for deep sewer lines in the porous Fort Thompson Formation," said Bernard Theron, president of Bessac.

With the previous construction of the Port Miami Tunnel, machine technology from Herrenknecht had demonstrated that even the most complex ground conditions, such as the Fort Thompson Formation, can be safely mastered with optimally adapted technology. Despite its huge diameter of nearly 13 m (43 ft), in 2013 the EPB Shield S-600 reached its target reliably thanks to an additionally installed slurry circuit. According to the internationally renowned accounting and consulting firm KPMG, in 2012 the Miami Port Tunnel was one of the 10 most innovative transport projects in the world. ■

## FEATURE ARTICLE

# Oversized fans ventilate the world's largest and longest railway tunnel

**W**ith up to 2,300 m (7,545 ft) of rock on top of it, the Gotthard Base Tunnel, which is scheduled to go into regular operation in December 2016 in the Swiss Alps, is not only the world's longest, but also the deepest railway tunnel ever built. Accordingly, the temperatures in the tunnel are very high, with the surrounding rock expected to reach 45° C (113° F) once the tunnel is fully operational. Since unrestricted rail operations are only permitted in temperatures of 40° C (104° F) or less, the heat has to be controlled with suitable equipment. Large fans developed and built especially for this application by TLT-Turbo GmbH provide fresh air for regular operations as well as during maintenance and repair work. Separate fans ensure that the emergency exits are properly ventilated in case of fire. In addition to coming up with a technical solution that could handle the special challenges of this project, the engineers and planners had to develop detailed preliminary plans as well as a sophisticated logistics and installation concept.

The Gotthard Base Tunnel consists of two 57-km (35-mile) long tubes, one in each direction. Including all connecting and access tunnels, the entire underground system measures 152 km (95 miles). At Faido and Sedrun, at approximately 16 and 36 km (9 and 23 miles) respectively, two multifunction stations were built that cut each of the two tubes into three sections of roughly equal length. Here, trains can make emergency stops and change tracks, if necessary. This is also where eight large axial fans made by TLT were installed that exchange the air, i.e. they extract a certain amount of heated air and inject the same amount of cool fresh air a few hundred meters further down the train tracks. In addition to the four exhaust and four supply fans, 24 so-called jet fans were installed along with associated components like silencers, shut-off dampers, drives and lubrication systems from TLT.

In addition to exchanging the air, these fans are used to enable maintenance and repair operations in the tunnel. Current plans call for blocking each tunnel tube for one night per week in order to perform preventive maintenance work, thus enhancing the tunnel's overall functionality and

**In the two multifunction stations in Faido and Sedrun (approximately at km markers 18 and 36), eight large axial fans from TLT were installed.**



availability. During these hours, many people will be in the tunnel who require fresh air. "One of the major criteria for winning this bid was the fans' ability to quickly switch between a wide-range of modes. TLT fans are among the best in the world in this regard," said Andreas Kuhn, TLT's project manager for the Gotthard Base Tunnel, about the selection of his company's fans for this project.

### Power of four Formula 1 cars

In the third potential operating mode, the so-called event case (i.e. a fire), four exhaust fans with a power rating of 2.4 mW (3,263 hp) each extract smoke from the emergency stop. The fans were designed to handle gases with temperatures of up to 400° C (752° F) for two hours. To put this in perspective, Kuhn explained that 2.4 MW correspond to 3,263 hp, which means that each exhaust fan has the power of four Formula 1 race cars. If a train reports a fire, from sensors that are mounted on the train or in the tunnel, it is routed to the nearest multifunction station and instructed to make an emergency stop. Following a sophisticated evacuation system, passengers can exit the train at the emergency stop and escape to secure areas. To keep the emergency stations from filling with smoke and enable passengers to take refuge in separately ventilated, secure tunnel areas, the four supply fans with ratings of 1.5

**The Sedrun multifunction station is linked to the ventilation center via two 800-m (2,625-ft) tall air shafts. One of these includes a large freight elevator. While the elevator is moving, no fan may operate. If a 'Start' command is issued, the controller must first check whether the elevator is either at the top or the bottom of the shaft. If it is not, the controller must move it to one or the other. Source: AlpTransit Gotthard AG.**



MW (2,011 hp) each are used, each of which can inject 275 m<sup>3</sup> (359 cu yd) of fresh air per second into the protected areas.

During normal operations, the system controls only the temperature in the tunnel. During maintenance operations, the system controls what is called the dry temperature, i.e. the combination of temperature and relative humidity. The exhaust fans must run at top speed if a fire breaks out so that they can extract as much smoke as possible. The supply fans, on the other hand, must run at top speed in a specific maintenance scenario when many people are present in the tunnel. In this mode, the supply fans are operated in parallel to inject 420 m<sup>3</sup> (550 cu yd) of air per second. The

amount of air being moved by the fans is adjusted in two ways, using a speed controller with frequency converters and using the blade controller, which uses hydraulic pressure to adjust the fans' blade angles while they are rotating.

## Innovative prototype developments

The special aerodynamic conditions of the 57-km (35-mile) tunnel deep under the mountain posed complex technical challenges. Since the trains can run at speeds of up to 250 km/h (155 mph), they generate a pressure shock in front of them and a vacuum behind them, which can cause serious problems for the giant fans. To come up with a solution, the research and development department of TLT conducted special tests early on. As a result, each fan is now being permanently monitored by a stall warning unit. Stalls must be prevented at all cost. Equally dangerous is excessive impeller acceleration, the so-called windmill effect, because it may cause mechanical damage. The stall warning unit, an innovative development of the TLT engineers, measures any changes in the tunnel's air pressure 10 times per second and uses the fan controller to prevent stalls by hydraulically adjusting the fan blade angles.

The logistics of moving very large and heavy components onto and into the mountain and assembling them in extremely tight spaces posed major challenges as well. In addition, schedule changes made it necessary to deliver four of the large fans to the Sedrun ventilation station in the High Alps in deepest winter. "As a rule, we had to expect snow at any time during this period in the High Alps. Fortunately, we were lucky, because we had a mild winter and almost no snow," said Kuhn. The problem was that the roads in this region are designed for passenger cars, small vans and trucks with weights of no more than 25 t (28 st). The heavy trucks needed to ship the fans, however, weighed roughly 63 t (70 st). After making sure that the bridges could accommodate them, Swiss police escorted the fans to the mountain without any problems.

## Coordinating more than a thousand technical interfaces

Since the tunnel shell was completed earlier than planned, its opening was pushed up by one year. As a result, all the shell equipment contractors, which included the consortium of TLT and Swiss company ABB Schweiz AG, had to perform much of their work side-by-side instead of sequentially, as had been originally planned. "The corresponding coordination and schedule management turned out to be a real challenge. Because of the complexity of the project, we had to coordinate over 1,000 technical interfaces in order to ensure a smooth execution," said the project manager.

After the components had been successfully installed

and tested, the actual commissioning could commence. To start the process, the engineers checked and documented the interaction of the system's components and their safety compliance by conducting extensive tests, which included sending a specially rented German Rail ICE through the tunnel at a speed of 275 km/h (170 mph). "We use extensive scripts for this purpose in which virtually each action and desired reaction are described in detail. We also tested failure scenarios — automated ones and those where the operator must step in," said Kuhn.

The special challenge facing the consortium was the fact that the fan controls are the lead controls for all components. Accordingly, each scenario has to be initiated and controlled through the TLT master computer. This means the Sedrun multifunction station is linked to the ventilation center through two 800-m (2,642-ft) tall air shafts. One of these includes a large freight elevator. While this elevator moves, no fan may be in operation. This means that the controller must check whether the elevator is in its final position — top or bottom — when a "Start" command is issued for a fan. If it is not, the controller must move the elevator into this position before the fan can actually commence operation.

## Regular rail operations commence in late 2016

TLT initially became involved in the project as early as 2007, when a feasibility study was conducted to explore whether it is even possible to install fans with this level of performance into such small spaces. The pressure and vacuum problem caused by fast-moving trains was discussed as well. The actual bid was developed between late 2009 and August 2010. TLT won the contract in early 2011. Unlike in other tunnel projects, no standard fans could be used, but the engineers had to develop, test, install and commission prototypes. "This was a very exciting time for us in terms of the contract size as well as the related

**The project's complexity required not only a solution that would meet the special requirements, but also a sophisticated concept for moving the very large and heavy components into the mountain and installing them in very tight spaces.**



delivery and performance parameters," said Kuhn.

The tunnel opened on June 1, 2016, and SBB, as the future operator of the Gotthard Base Tunnel, commenced test operations to demonstrate that passenger and freight trains can traverse the tunnel without problems and that maintenance and event management would work without a hitch. If everything works as planned, the tunnel will be taken into account for the regular rail schedule starting in December 2016. For TLT, however, the project will not be over at that time. The manufacturer has already received an order for spare parts and expects to sign a five-year maintenance contract. ■

## Coming Events

### 2017 George A. Fox Conference

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## FEATURE ARTICLE

# More than 200 attend Cutting Edge 2016 in nation's tunneling hotbed

Speakers and attendees of the 2016 Cutting Edge Conference could not be faulted for keeping one eye on the presentations taking place at the Hyatt Regency at LAX in Los Angeles, CA on Nov. 7 and 8 and another on the results of the historic election in the United States that took place on Nov. 8. While there was certainly interest in the presidential campaign, there was also a great deal of interest in Measure M on the California ballot. Measure M, which passed easily, is a half-cent sales tax increase that will fund the most ambitious transit expansion in Los Angeles County history.

In the coming years, the ballot measure will transform a traffic-choked region by funding the construction of nearly a dozen new rail lines with an estimated \$120 billion raised in four decades. Among the projects that could come to fruition are a twin-rail tunnels project through the Sepulveda Pass and new connections in the city.

During the update on West Coast projects, Bill Hansmire summed things up with a slide asking “How much work is there on the West Coast,” and his answer was “Billions.”

From Seattle, WA south to Los Angeles, there is already a lot of work for tunneling and underground construction experts, and Measure M ensures that there will be plenty of work for decades to come.

Currently, The Los Angeles County Metropolitan Transportation Authority (Metro) has three rail projects underway that were funded by Measure R in 2008 — the Regional Connector, the Purple Line subway extension and the Crenshaw/LAX Line that are designed to alleviate the traffic pressure with an eye to more solutions.

Measure M is the fourth sales tax increase to fund transportation in L.A. County, bringing the base sales tax rate to 9.25 percent. In some cities, which already levy their own sales tax, the rate would be higher, *The Los Angeles Times* reported.

About 35 percent of the revenue will fund major new transit projects, such as the subway under the Sepulveda Pass, extension of the Gold Line to Claremont, extension of the Crenshaw Line to West Hollywood and acceleration of the Purple Line Subway construction along Wilshire

Boulevard to finish in 2024, 10 years earlier than scheduled.

About 17 percent would fund a dozen highway

improvement projects, such as widening parts of I-5 in the Antelope Valley and southeastern county, adding bus lanes to the Sepulveda Pass section of the 405 freeway and adding truck-only lanes to a section of the 710 freeway.

Another two percent would cover bike and pedestrian projects and 17 percent would be returned to the 88 cities of L.A. County for local transportation projects, including repairs to streets and sidewalks.

The rest of the revenue would fund ongoing bus and rail operations and infrastructure maintenance.

The ongoing projects — the Regional Connector, Purple Line and Crenshaw/LAX projects — will soon help remove some traffic from the congested streets, and the projects that become possible from the passage of Measure M will provide more relief. But city planners will still need to find more solutions for the future, and some of those solutions will surely come from the Metro's Office of Extraordinary of Innovation (OEI), an office that was established to explore new ways to move Los Angeles forward by finding and testing leading-edge ideas that have potential to improve mobility for the people in the region. From public-private capital partnerships to cutting-edge new technologies, OEI is tasked with identifying, evaluating, developing and implementing these new approaches. These efforts may be undertaken by Metro on its own or jointly in collaboration with private sector firms through public-private partnership agreements.

Joshua Schank, chief innovation officer for LA Metro's OEI, was one of the keynote speakers at the Cutting Edge Conference and spoke about how and why LA Metro created the office of innovation.

According to Schank, one of the primary reasons the office is needed is to bridge the gap between the private construction sector and the government entities that are in charge of transportation projects.

“We need the innovation office because politicians are, by nature, risk-adverse and focused on the short-term solutions. Our office looks for innovation on a longer term basis,” said Schank.

In addition to the massive amount of work that is headed to Los Angeles County in the form of transportation projects is a massive water project that could keep the work flowing in on the west coast. The project is the California WaterFix Project

California's WaterFix Tunnels will be another massive tunneling project on the West Coast of the United States.

“We are still in the planning phase of this and we feel

By William Gleason,  
Senior Editor



NATIONAL RECORD OF  
**57 METERS**  
IN A SINGLE DAY

TÚNEL EMISOR PONIENTE II, MEXICO CITY



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Right now on Mexico City's TEP II project, a Robbins Crossover machine is excavating at record-breaking speed through varying geology. Since the beginning, we have been on a relentless pursuit to find innovative solutions to the tunneling challenges our partners face. We don't innovate for innovation's sake. We innovate to break records on your next project.



we are reaching the light at the end of the tunnel on the environmental impact statement,” said John Bednarski who spoke about rural enabling works for the program. “We are optimistic that we will be able to begin preliminary design work early next year.”

The \$15-billion project is an update to the state’s gaining water delivery system that will tap into the water supply the California Delta and supply water to the southern part of the state via two tunnels.

The project would require 10 to 12 tunnel boring machines (TBM) working to build one 14-km (9-mile) long north tunnel that is expected to be 8.5-m to 12-m (28-ft to 40-ft) inside diameter and a pair of 48-km (30-mile) tunnels in the south with 12-m (40-ft) diameter. There will be about 700,000 segments needed for the project.

## Cutting Edge technical sessions

At its core, the Cutting Edge Conference is a place to share ideas and best practices in the industry, and this year’s conference was no different for the 200-plus attendees. A real world example of extraordinary innovation in the tunneling industry was given by Bruno Combe, technical director of Bouygues, who completed the keynote session with his presentation about large diameter tunnel boring machine (TBM) innovation for Hong Kong’s Tuen Mun–Chek Lap Kok Highway Link.

The Tuen Mun–Chek Lap Kok Link will provide a strategic road link between North West New Territories (NWNT), North Lantau, the Hong Kong–Zhuhai–Macao Bridge Hong Kong Boundary Crossing Facilities (HKBCF) and the Hong Kong International Airport (HKIA) at Chek Lap Kok with a twin tunnel under the sea.

The total length of the twin tunnels is about 42 km (26 miles) and the project includes many unique features. The HZMB will be the longest bridge-cum-tunnel sea-crossing with dual three-lane carriageway, which is about 35.6 km (22 miles) in length from the shore of northern Lantau to the western shore of Pearl River Estuary. The HZMB is to be built with 120 years design life.

The keynote session kicked off the two-day conference that included sessions on the advancement in the use of building information modeling and data analysis in underground construction; developments in tunneling, materials, equipment and safety; innovations in deep tunnels and shafts through mountain ranges; tunnel construction enabling works as well as look at West Coast projects and discussions about face loss and settlement. The conference also included an owners roundtable discussion that gave all attendees a chance to have a dialogue about some of the biggest issues in the industry

**About 50 people from the Cutting Edge Conference attended the field trip to LA Metro’s Crenshaw LAX/Project on Nov. 9.**



with a selection of local clients with major underground projects.

## Field Trip

One of the projects that is currently underway in Los Angeles is the LA Metro Crenshaw/LAX Transit project. A group of about 50 people toured the project on Wednesday, Nov. 9.

The LA Metro Crenshaw/LAX Transit project is an 13.8 km (8.5 mile) extension from the Metro Exposition Line at Crenshaw and Exposition to the Metro Green Line Aviation LAX Station that will include six new stations. It is part of a \$2.058-billion project that is funded largely by Measure R that was approved by Los Angeles County voters in 2008. The light rail line will include eight new stations.

The Crenshaw/LAX Transit project will include three stops between LAX and the existing Expo Line.

The TBM on the project, “Harriet,” completed the southbound tunnel on Oct. 20, was removed and put back into the starter shaft where it was rebuilt and was expected to begin boring again by the end of 2016. The project is expected to be completed by 2019.

“For decades, the thought of a rail stop at the center of African–American culture in Los Angeles was no more than a dream,” said Mark Ridley-Thomas, L.A. County supervisor and Metro Board member.

The TBM weighs 862 t (950 st), has a diameter of 6.5 m (21.5 ft) and is 121 m (400 ft) long. Harriet advanced about 18 m/d (60 ftd) through soil and rock under Crenshaw Boulevard.

Excavation of the three underground stations is completed. Construction of the six bridges is underway. ■



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## FEATURE ARTICLE

# Contractor uses innovative techniques on Seattle project

There is no fast way to add more than 6.4 km (4 miles) of track, most of it underground, to the Sound Transit Link Light Rail system in the Seattle, WA area. But increasingly busy traffic through a number of neighborhoods made it necessary. That's the challenge a joint venture of several tunneling contractors faced when starting its portion of the \$1.9-billion Northgate Link Extension in 2013, and the project is still keeping it busy three years later. Completion will mean just a 14-minute ride from Northgate to downtown for an extra 60,000 passengers by 2030. The transit lines will join 57 km (36 miles) of new and under-construction light rail lines running north, east and south from Seattle.

Voters tired of long commute times approved the project, a key part of Seattle's regional mass transit system, in 2008. The extension is part of a plan adopted by the Sound Transit board in 1996 to connect the region's major activity centers. The Northgate project is meant to relieve one of the area's most congested traffic areas by connecting the Northgate, Roosevelt and University District neighborhoods to existing routes including downtown Seattle and SeaTac airport.

Sound Transit dedicated more than a quarter of the project's estimated expense — \$440 million — to general contractor JCM Northlink LLC to handle the tunnel segment. JCM is a joint venture formed in 2013 between Jay Dee Contractors of Livonia, MI, Frank Coluccio Construction of Seattle, WA and Michels Corp. of Brownsville, WI. The contractors regularly collaborate on large-scale projects and brought experience working on a different section of the extension they completed in 2013.

JCM project leaders knew immediately that the schedule would be demanding. They had to work around the clock six days a week to meet deadlines. The extension runs through highly populated areas, meaning contractors had to follow strict city noise restrictions between 10 p.m. and 7 a.m. Plus, supervisors needed to manage the scheduling of nearly 250 employees to keep work running smoothly.

"We had eight different operations and four different subcontractors trying to work in one tunnel," said Chris Wood, JCM site project superintendent. "It's important that we keep work linear. That's the biggest challenge: keeping a path in and out so you can pour concrete, keep electricians and carpenters going, and accomplish everything else."

Project planners also realized they wouldn't be able to use the same equipment they had in the past for tunneling projects. The tunnels would run directly below

**To meet noise restrictions, JCM crews used Metalliance rubber-tired vehicles, like this one seen below, instead of a train to transport people, equipment and supplies in and out of the tunnels.**



the University of Washington, which has long-standing, ongoing sensitive science projects. The train and tracks JCM used for past projects to transport crews and supplies through tunnels are loud and produce significant vibrations, which would have disrupted the experiments. To lower noise levels throughout the tunnel and to avoid disturbing the university, project leaders incorporated new sound abatement methods. JCM brought in seven Metalliance rubber-tired vehicles that stretched 16-m (52-ft) long but were just 2-m (6-ft) wide and could handle 41 t (45 st). Crews could use them as an alternative to a locomotive-on-rail for transportation in and out of the tunnel. In addition, the vehicles work with a number of attachments, including high-car platforms and concrete distribution attachments, reducing the need for additional equipment.

Crews started the tunneling portion of the project by digging two large vertical shafts and a tunnel portal to initially be used as access points for tunnel boring machines (TBMs), service work, material removal and supplies. The shafts will be converted to light rail stations when the project is complete. JCM used a Kroll 15000 tower crane with 49,000 kg (108,000 lbs) of lifting capacity, the third largest capacity in North America, to lift stacks of tunnel liner segments, equipment and material in and out of the 31-m (100-ft) deep shafts.

Once shaft construction was well underway, JCM began digging the twin-bore tunnels from Northgate to the already-excavated University of Washington station and existing light rail track. Crews used Hitachi Zosen (Hitz) and Robbins TBMs to simultaneously dig two parallel 6.4-m (21-ft) diameter tunnels. The machines stretch about 122-m (400-ft) long and advanced an average of 9 to 15 m/day (30 to 50 ftd).

The tough soil did not make the job easy. The TBMs hit harder ground than anticipated, slowing down the machines as cutters and scrapers heads wore down or broke against cobbles and boulders.

As tunneling moved along, crews started digging 23 cross passages between the tunnels. The 5-m to 6-m (16- to 20-ft) long openings house electrical rooms and serve as safe havens and escape routes for train passengers in case of an emergency.

Cross passages are typically constructed using pneumatic tools and mini-excavators, but about five years ago, on another section of the light rail expansion, JCM began using a different approach: Brokk remote-controlled demolition machines. They made the switch to limit worker exposure to harsh tunnel environments and reduce the inevitable fatigue and potential injuries that come with using handheld tools all day. The remote-controlled technology also allows workers to operate the units from a safe distance, minimizing exposure to falling debris. JCM owned a Brokk 260 from an earlier project but with the increased demands and tight deadlines of the Northgate project, they decided to invest in two larger Brokk 400Ds and rented another in order to maximize productivity. The equipment's efficiency and precision sped up the excavation portion to less than three weeks, shaving off more than a week of work compared to handheld tools. In addition, the machines held up well in tough tunneling conditions.

"I tell everybody that anything that goes down into that tunnel will get broken. I can give these guys a glass of water and somehow they'll break the water," Wood said. "But the Brokk remote-controlled machines withstand the conditions. When we do have issues, Brokk field mechanics work with our mechanics to limit detrimental downtime by bringing in parts and fixing the unit right away."

JCM worked on multiple cross passages at a time. Crews typically started the passages by pairing the Brokk 400D with a TEI 350 rock drill attachment drilling 10-cm (4-in.) diameter holes for well points and 6-m (20-ft) steel

spiles. These were installed about every foot to create a canopy to secure the ground and protect workers from falling debris. Once the spile canopy was completed, JCM needed the maneuverability and compact size of the Brokk 260 paired with an Atlas Copco SB 302 hydraulic breaker to break through the tunnel wall. After getting through the concrete, JCM brought back the B400D to complete the passage, often alternating between an Atlas Copco SB 552 hammer to break through the ground and a Simex road header to mill the walls. Workers used mini excavators to remove material and load it into dump trucks, and crews coated the walls with shotcrete to keep them in place. Each passage took seven to nine weeks to complete, including waterproofing, installing rebar, pouring the invert and headwalls, and finalizing 90- to 110-yards of fiber-reinforced concrete.

Staying true to its "Rain City" nickname, Seattle gave JCM much more ground water than expected, causing complications. The TBMs had earth pressure balance systems that pushed water away, allowing technicians to do inspections and service cutterheads, but the cross passages were not as easy. The water volumes that needed to be pumped at some of the cross passages was far greater than what the municipal system could handle. Project leaders knew freezing the soil was a solution that would prevent structural issues and ensure safety during excavation. They originally planned to freeze five of the cross passages but expanded that to 10 after encountering the excess water. Crews again used the Brokk 400D, this time to drill holes for freeze pipe they installed within the haunches of the cross passages. They then pumped the pipes with a brine solution, chilling the soil to a frozen 12° C (10° F) and making it an easy target for a Brokk machine's hydraulic breaker.

"The freezing technique is invaluable to keeping work going quickly and safely," Wood said. "It is very effective. The frozen sand ends up being like concrete until it thaws. This makes it really easy to chip away at without worrying about stability issues."

After three years of tunneling with the TBMs, JCM completed the final breakthrough on Sept. 1, 2016. Once the cross-passages are completed, likely by March 2017, the crews will have removed about 555,000 m<sup>3</sup> (725,000 cu yd) of material — enough to fill about 242 Olympic-sized swimming pools. JCM will continue followup work until February 2018. The next contractors will continue work on the stations, rail and electrical components in preparation for project completion in 2021.

The transit plan approved by voters in 2013 also included an 13.6-km (8.5-mile), above-ground light rail extension from Northgate to Lynnwood. Project construction is expected to begin in 2018 with a goal of service starting in 2023. Another expansion including 100 km (62 miles) of new light rail and other transit additions appeared on the ballot in November 2016. The project is just one of a series of planned improvements, all part of an overall goal to relieve commuter headaches. ■

## FEATURE ARTICLE

# Doha tunnels its way to the top with 111 km in new metro tunnels

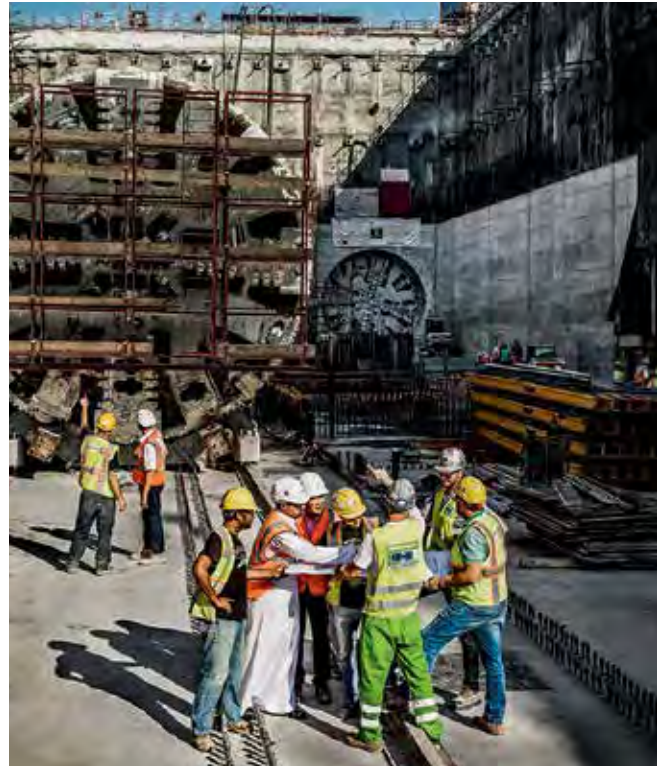
**I**t is Sept. 25, 2016, 10.44 am local time in Doha at Hamad International Airport when a 7-m (23-ft) tunnel boring machine (TBM) pierces the final target wall of the “Red Line South.” It is the last of 76 breakthroughs in the gigantic milestone project Doha Metro. The TBM breaking through marks the spectacular finale of one of the most ambitious tunnel structures in the world. Cleverly master-planned and highly professionally directed by client Qatar Rail, it took just 26 months to provide the capital of Qatar with three city-wide metro lines: 111 km (68 miles) of brand new, ultra-modern metro tunnel systems. Where before there was nothing, at peak times 2.5 km (2 miles) of tunnel per week were added underground and the result was more than just an entry in the Guinness Book of Records.

“The world has never seen such performance. What Qatar Rail and our contractors in Doha have accomplished in just 26 months of construction time with the highest standards of performance, safety and quality is an absolutely Olympic achievement in modern infrastructure development,” said Herrenknecht Chairman of the Board of Management Dr.-Ing. E.h. Martin Herrenknecht in summing up the mega tunneling project Doha Metro that was completed on Sept. 25, 2016 with the final breakthrough of one of the company’s earth pressure balance (EPB) shields. High-level political guests such as the Qatari Prime Minister and Minister of the Interior H.E. Sheikh Abdullah bin Nasser bin Khalifa al Thani, the Minister of Transport and Communication of Qatar H.E. Jassim Saif Ahmed al Sulaiti as well as the ambassadors of France, Korea and Japan in Qatar showed their admiration at an official completion ceremony. A total of around 200 guests, including the top management of Qatar Rail and leading representatives of the joint venture contractors, celebrated a unique technical construction and engineering achievement. About 111 km (68 miles) of newly bored and built tunnels under the capital of Qatar in just more than two years outshine everything previously achieved in urban metro tunneling worldwide.

### Tunneled into the Guinness Book of Records

From August 2014 to September 2016, on three main lines (Red Line, Green Line, Gold Line) four international joint ventures consistently pushed forward a total of 21 TBMs designed and equipped by Herrenknecht specifically for the project. A performance presentation of superlatives. 470,497 individual concrete segments (so-called lining segments) were mechanically assembled into 70,071 high quality tunnel rings. At peak times 20 TBMs tunneled their way forward simultaneously, 2.5

**After the arrival of the first machine in the capital of Qatar and the assembly on site, in August 2014 excavation of the new metro lines for Doha began. For the coordination of all work on the three lines optimally harmonized teamwork was essential.**



km (1.9 miles) per week of spotless metro tunnels grew under Doha. This Olympic-quality parallel performance has gained the project a place in the Guinness Book of Records. In addition to the geology consisting primarily of Simsima Limestone, the demands on each TBM were complex – just from the dense urban development alone. The routes of the individual metro lines run under highly populated areas, for example near the impressive beach promenade Corniche, under the high-rise neighborhoods of Doha City and the tourist centers with their attractive hotel facilities. Settlement-free tunneling was, therefore, one of the core requirements during construction.

### Ideally prepared for all eventualities

With innovative German tunneling technology the construction joint ventures completed a total of 76 breakthroughs; more than 40 times the machines were quickly pushed forward in intermediate shafts ready for the next section – and, once again, tuned for speed. Up

**Since Sept. 25, 2016 all tunnelling work on the three new metro lines has been complete. Further construction work at the individual stations and the finishing of the segmentally lined tunnels will continue until 2020.**



to 125 Herrenknecht service staff and specialists from 19 countries were at hand wherever contractors, machine technology and extraordinary events required them.

In order to keep to the ambitious masterplan and the tight schedules, man and machine were in operation on the huge construction site around the clock, seven days a week. In addition to excellent planning, expertise and high material and machine quality, for Markus Demmler, senior director of the Qatar Integrated Railway Project, one prerequisite was vital for the success of the project: “Managing 21 TBMs working smoothly beneath a metropolis like Doha is only possible with 100 percent commitment from all partners involved.”

All of the participating companies handled the gigantic project with pioneering boldness and the highest degree of team spirit and operational professionalism. The Herrenknecht full-service competence center set up near Doha specifically for the project provided additional support. Competent and proactive contacts were available here for all matters relating to tunneling technology, assembly and disassembly, provision of specialist personnel, tunneling support, spare and wear parts management as well as the maintenance and refurbishment of the used cutting tools.

## **The centerpiece of a grand vision**

The newly emerging metro system in Doha is only the beginning of the mobilization of public transport in Qatar. Whether in the urban centers or in the countryside – everywhere people will be able to travel by public transport. “Qatar’s vision is to connect every corner of the country by public transport,” explained Demmler. “The Doha Metro project represents the supporting backbone of an integrated public transport system,” said Qatar’s Minister of Transport Katar H.E. Jassim Saif Ahmed al Sulaiti in describing the substantial significance of the

metro network, the first three lines of which are scheduled to be opened by 2020. By 2026 an extensive expansion by 72 additional stations and another metro line is planned.

The station Msheireb in the center of the metropolis already forms the accumulation point of the whole system. All lines meet here, 12 breakthroughs ended at this mammoth station alone. Linked in all directions of the city, soon every metro journey will save valuable time and several kilograms of polluting greenhouse gases compared to a trip by car. Acceleration, mobility and environmental protection are the driving forces of the mega project. The development of the regional and national network will conveniently bring all residents of Qatar closer together.

In 26 months, four international construction joint ventures have built a 111-km (68-mile) metro tunnel system in Doha on three lines – a new benchmark worldwide. Cleverly master-planned and highly professionally directed by client Qatar Rail, a rapid pace was maintained at all times while ensuring the highest standards of safety, quality and health. Herrenknecht’s contractors are:

- Red Line North the ISG joint venture (Salini Impreglio S.p.A./ SK Engineering & Constructing Co Ltd/ Galfar Al Misnad Engineering & Constructing W.L.L
- Red Line South the Qatari Diar Vinci Construction JV (QDVS)/ GS Engineering & Construction Corp./ Al-Darwish Engineering W.L.L
- Green Line Contractor PORR Bau GmbH/ Saudi Binladin Group Company Ltd/ Hamad Bin Khalid Contracting Co. W.L.L.
- Gold Line the joint venture Aktor S.A./ Larsen & Toubro Limited/ Yapi Merkezi Insaat VE Sanayi Anonim Sirketi/ Sezai Turkes Feyzi Akkaya Marine Construction/ Al Jaber Engineering LLC). ■

## FEATURE ARTICLE

# TBM assembled on site to bore emergency water supply tunnel

After an onsite first time assembly (OFTA) lasting just 2.5 months, Atlanta, GA's newest tunnel boring machine (TBM), dubbed "Driller Mike," made its initial startup on Oct. 13, 2016 and ramped up to full production two weeks later. Atlanta's Mayor Kasim Reed and city officials gathered with local and national media to celebrate the occasion. The 3.8 m (12.5 ft) diameter Robbins main beam TBM is now boring the 8-km (5-mile) Bellwood Tunnel after being walked forward 30 m (100 ft) into a starter tunnel. The Bellwood Tunnel path will travel from an inactive quarry and run below a water treatment plant and reservoir before ending next to the Chattahoochee River.

The project was green-lighted by the City of Atlanta's Department of Watershed Management due to the city's current emergency water supply shortage. The PC/Russell joint venture (JV), the project's construction manager at risk, subcontracted with the Atkinson/Technique JV to operate the TBM and will oversee construction of various intake and pumping shafts as well as final lining operations. The project is of utmost importance for the city of Atlanta, explained Bob Huie, senior project manager for the PC/Russell JV. "Right now, the downtown area's emergency water supply is approximately three days. With the tunnel the supply will increase to between 30 and 90 days. To be a part of the city's emergency water supply solution is huge. This tunnel will protect the city for a very long time."

With the tunnel on the fast track, swift TBM assembly was key. The OFTA process involved coordination by multiple crews at the large quarry site. "The OFTA went very well. The overall assembly process was well organized and supervised by the Atkinson/Technique JV and Robbins. We had a good team of folks to put it all together," said Huie. He continued: "This is a unique job where there's a lot of people with a variety of backgrounds, but everyone came together to make the OFTA happen."

The Robbins TBM is now excavating in granite, with at least 300 m (1,000 ft) of zones in three separate areas that will require continuous probing. In a section directly below an existing reservoir, monitoring will be particularly crucial

**The Robbins Main Beam TBM, dubbed "Driller Mike," was launched on Atlanta, GA, USA's Bellwood Tunnel in October, 2016.**



to ensure no water inflows occur. The Robbins machine will also be required to negotiate several curves: "We have one curve in the first 300 m (1,000 ft) and the main 370 m (1,200 ft) radius curve is 1,800 m (6,000 ft) in. We plan to do short TBM strokes in this section — about 20 cm (8 in.) to 30 cm (1 ft) shorter than normal to get through the curves," said Larry Weslowski, tunneling superintendent for the PC/Russell JV.

Excavation is scheduled to be completed in the first quarter of 2018. After final lining, the tunnel will be filled with water and the quarry site will become Atlanta's largest reservoir and park, totaling hundreds of acres. While the park site is a bonus for residents, the water storage capacity it will provide is critical. Nearly 1.2 million customers, including 200,000 passengers who pass through the world's busiest airport every day, count on the water supply each time they turn on the tap. "If the city were to lose water supply for a day, the estimated economic impact would be at least US\$100-million per day. If you consider that this is a US\$300-million project, that seems a pretty good investment in comparison to what could happen," said Huie. ■

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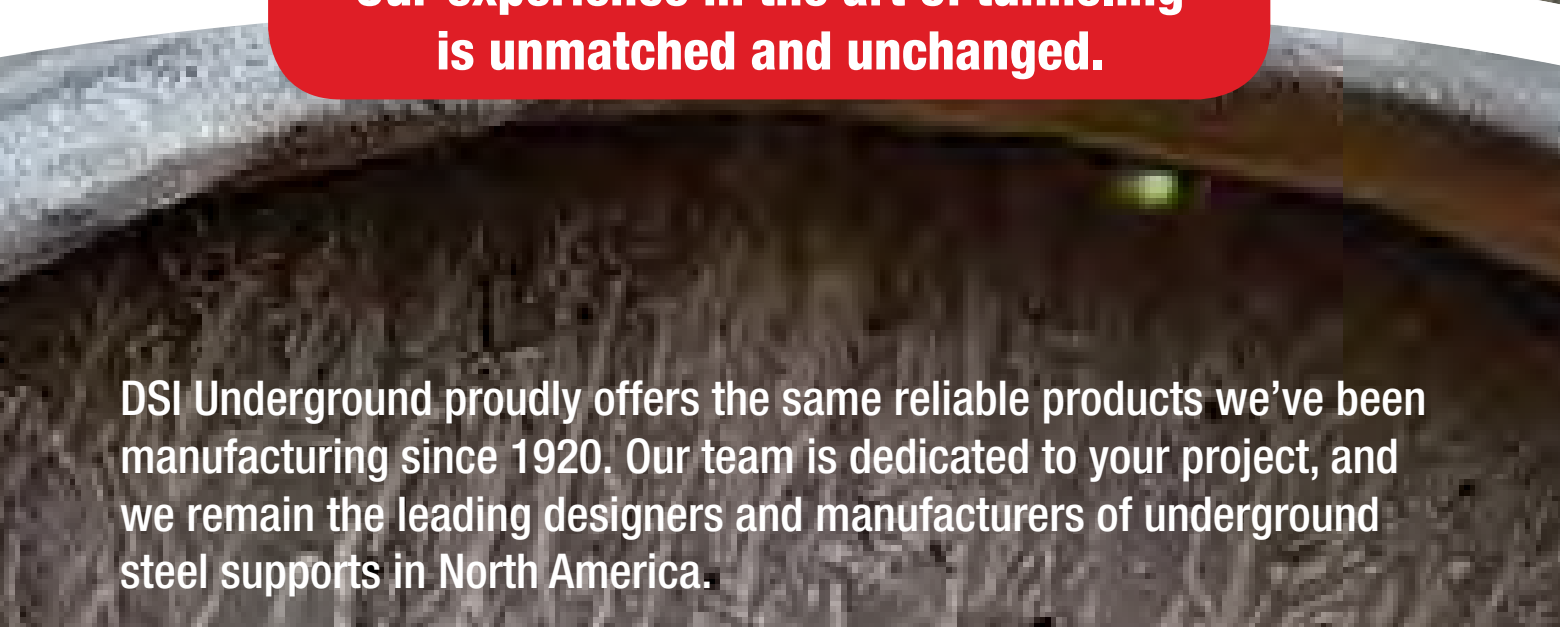
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## Setting the Tunneling Standard

With over 60 years of experience, The Robbins Company is the world's foremost developer and manufacturer of advanced underground construction machinery. Robbins TBMs made swift headway on many worldwide projects in 2016, and will continue this progress into 2017. Innovative concepts keep expanding the company's scope, from efficient TBM assembly methods to high-performance machine designs resulting in landmark performances in soft ground and hard rock.

## Robbins is Focused Forward

Every technological breakthrough Robbins has ever made has been an answer to a client's challenges. From minimizing downtime in mixed geology with Crossover TBMs to maximizing safety and performance with the latest ground investigation solutions, Robbins is committed to keeping even the toughest projects moving forward.



Throughout 2016, Robbins' Crossover Series of TBMs have proven themselves on difficult projects around the world. Crossover TBMs are field tested, rugged Dual Mode machines that feature aspects of two TBM types, and are ideal for mixed ground conditions that might otherwise require multiple tunneling machines. The first North American Crossover TBM, for the Túnel Emisor Poniente II (TEP II) Project in Mexico City, has proven itself in 2016 by achieving not one but two national records: a 702.2 m (2,304 ft) in one month, and 57 m (187 ft) in one day. The 8.7 m (28.8 ft) dual-mode type machine is an XRE TBM designed to "cross over" (X) between two modes, rock (R) and EPB (E). Designed with field-inspired features including a single-direction cutterhead, multi-speed gearboxes, and improved probe drilling capabilities, the machine has navigated abrasive volcanic rock and fault zones with great success. The success in Mexico is being followed up by the first Crossover TBM to be used in the United States.

Currently under assembly, the 9.3 m (30.5 ft) diameter XRE TBM for the Akron Ohio Canal Interceptor Tunnel (OCIT) will be launched in 2017.

In 2016, Robbins introduced its latest package of innovations to help contractors stay a stroke ahead of their TBM in challenging conditions. Difficult Ground Solutions (DGS) is a suite of options available for shielded hard rock and Crossover TBMs that can keep a machine moving in long tunnels, high cover, and tough geological features. From Continuous Advance Shield Design to Water Inrush Control, Robbins is making the impossible no longer impossible. These designs will be featured on a new 6.6 m (21.7 ft) diameter Single Shield TBM for New York City's Rondout West Branch Bypass Tunnel. The customized TBM will be capable of withstanding up to 30 bar water pressure and will utilize enhanced probe drilling and grouting technology able to be employed 60 to 100 m (200 to 330 ft) ahead of the TBM operation.

With major projects currently underway in North America and abroad, Robbins continues to lead the tunneling industry in innovation and partnership.

**For more information about Robbins and our past and present projects, visit [www.TheRobbinsCompany.com](http://www.TheRobbinsCompany.com) or call +1 (440) 248-3303.**





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## STAYING AHEAD OF YOUR NEXT CHALLENGE

Right now on Mexico City's TEP II project, a Robbins Crossover machine is excavating at record-breaking speed through varying geology. Since the beginning, we have been on a relentless pursuit to find innovative solutions to the tunneling challenges our partners face. We don't innovate for innovation's sake. We innovate to break records on your next project.



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- Field Services
- Wire Rope NDT



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CONTROLS



HEADFRAMES



HOISTS



SHEAVES



SKIPS



FIELD  
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BRAKEMAN  
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VERTICAL  
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## DESIGN. BUILD. INSTALL. SERVICE.

FKC-Lake Shore serves the underground heavy civil and mining industries throughout North and South America. We offer design-build-install services for innovative hoisting, elevator, and vertical conveyance systems used to transport personnel and material. Our Field Services Division provides routine maintenance, inspections, wire rope NDT, and **24/7 emergency repair** of electrical and mechanical systems.

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For more information, visit us at: [www.frontierkemper.com](http://www.frontierkemper.com)



# North America's Leader in Geotechnical Construction

Hayward Baker handles geotechnical challenges both large and small. Our extensive experience with the full range of ground modification techniques has been applied to hundreds of tunneling projects. Commonly applied tunneling services include earth retention, underpinning, waterproofing, soil improvement, and ground stabilization.

## Seattle, WA

### Brightwater Conveyance System

Construction of the Brightwater Conveyance System required surgical jet grouting to facilitate tunneling operations. Utilizing their proprietary jet grouting equipment, Hayward Baker created soilcrete blocks outside of four deep vertical shafts to assist with both TBM and hand-mined tunneling operations. The ground improvements allowed TBMs to be launched or received into and out of the shafts without the risk of water and ground run-in. Overlapping columns to depths of 94 feet compose the soilcrete blocks.



Brightwater Conveyance System

## Los Angeles, CA

### Lower North Outfall Sewer Rehabilitation Project

Rehabilitation of the 82-year-old Lower North Outfall Sewer included grouting around the outside of the tunnel to densify and strengthen the soil above the tunnel in order to protect the overlying structures from settlement. Hayward Baker performed permeation and fracture grouting through over 3,500 holes from within the tunnel, stabilizing the overlying structures. State-of-the-art survey technology and proprietary grouting instrumentation allowed Hayward Baker to first probe the soil to determine existing conditions, and then observe the soil response during grouting, while monitoring the ground surface in real time.



## Los Angeles, CA

### Metro Gold Line C800

Construction of twin subway tunnels for the LA Metro's Gold Line would cause ground loss, endangering overlying structures unless the soils surrounding the tunneling zone were treated prior to excavation. Using conventional horizontal drilling to install steel and PVC sleeve port grout pipes, Hayward Baker performed chemical grouting to stabilize soils, and fracture grouting to protect overlying structures. Heave and settlements were monitored by exterior remote robotic total stations and interior wireless tiltmeters.

## St. Louis, MO

### Baumgartner Tunnel Alignment

Water-bearing rock formations in the path of the Baumgartner Tunnel Alignment needed to be sealed. Unsafe levels of hydrogen sulfide forced the grouting to be performed from the surface in advance of the tunneling operation. Hayward Baker drilled and grouted the water-bearing rock formations along a 1,200-foot-long segment of the proposed 20,000-foot-long, 12-foot-diameter combined sewer tunnel. A total of 40,000 feet of grout holes was drilled to complete the project. Depths of the drill holes were approximately 170 feet from ground surface.

## Big Bend Tunnel Improvement

### Big Bend, WV

Big Bend rail tunnel, constructed in 1932, required extensive ground and wall improvements over a 1,200 foot stretch due to its age and frequent use. Hayward Baker stabilized the tunnel walls with cement-bentonite structural grout, several rows of rock bolts and dowels, and compaction grout underpinning. Epoxy and cement grouting were utilized to repair an existing fracture of the tunnel liner along the spring line. Hayward Baker also stabilized the invert with compaction grouting at approximately 4,000 locations.



Big Bend Tunnel Improvement

## Hayward Baker

### Geotechnical Construction

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Hanover, MD 21076 USA

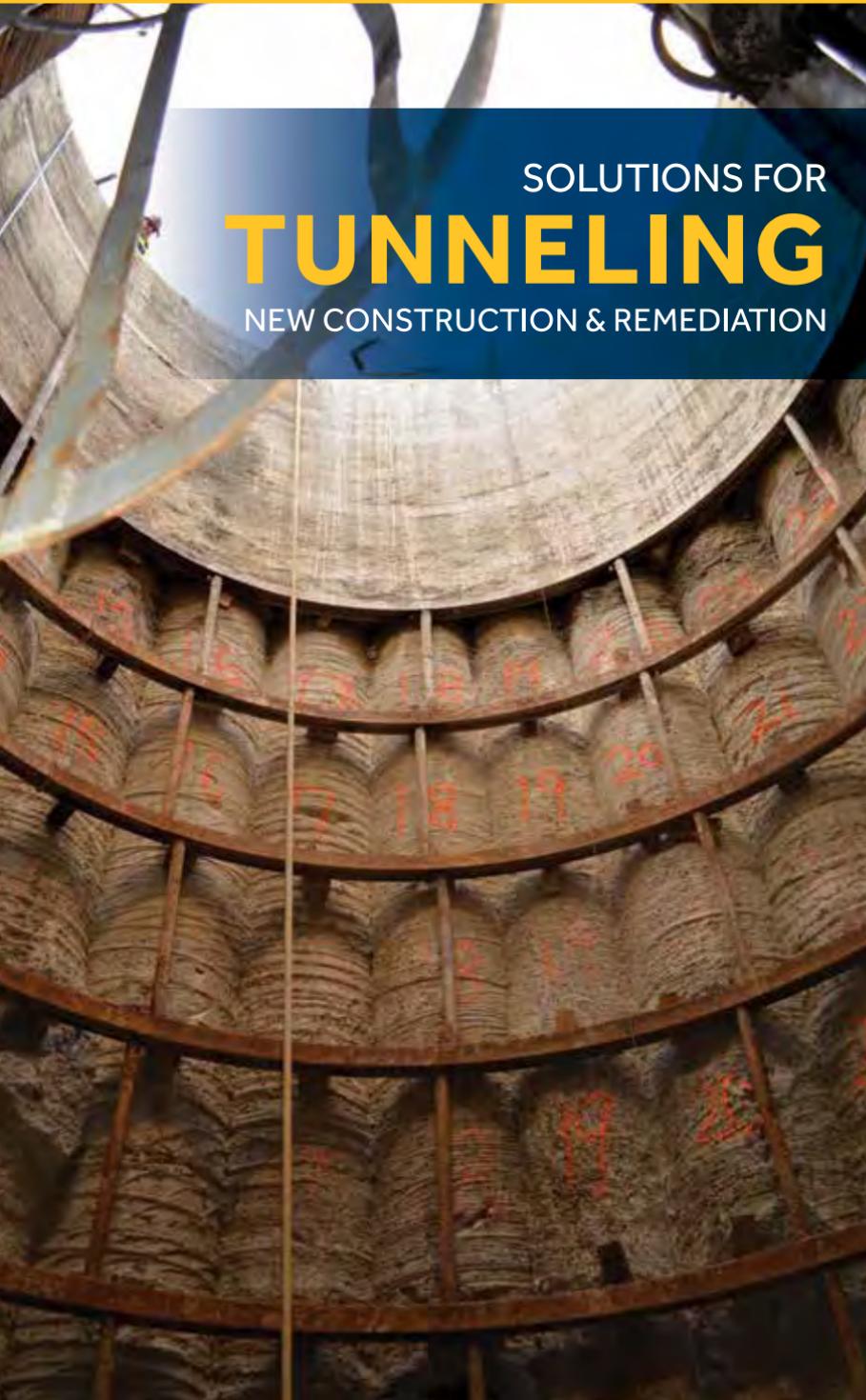
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Chemical grouting and jet grouting for excavation support in an urban subway tunnel.



Sheet piles for a cut and cover CSO tunnel.



Drilling and grouting for water control around a CSO tunnel.

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# New Expanding Polyurethane Injection Resins for Water Stopping and Leak Repair

Simpson Strong-Tie® has introduced RPSInject™, a premium line of injectable polyurethane resins used to stop the infiltration of water and mitigate the detrimental effects of that water on reinforced concrete structures. RPSInject polyurethane resin products are activated by water and use an MDI curing agent that's safe for contractors to use.

Patching over cracks is a temporary fix; water remains and can ultimately build hydrostatic pressure, causing structural damage and failure of the patch repair. On the other hand, excavation can be expensive and destructive and result in extended time out of service.

RPSInject™ is a single-component line of four versatile polyurethane injection resins formulated for water stopping and crack injection. RPSInject products are available in 5 US gallon (18.9 L) pails and 50 US gallon (189.3 L) drums.



- RPSInject™100, the lowest-viscosity hydrophobic version, is ideal for hairline cracks
- RPSInject™101 is a hydrophilic formula effective in constantly submerged applications
- RPSInject™102 is UL-certified under NSF/ANSI Standard 61 for potable water
- RPSInject™103 features the best of both hydrophilic and hydrophobic polyurethane in terms of flexibility and water stopping



#### Benefits:

- Both hydrophobic and hydrophilic formulations
- Easy-to-apply single component with adjustable cure times using RPSInject™110 accelerator
- High elongation properties provide excellent seal in

moving cracks

- Can be injected by manual pumps or high-pressure injection equipment
- Non-flammable and non-toxic
- 100% solids formulation
- Excellent chemical resistance
- Non-hazardous shipping

Simpson Strong-Tie® RPSInject™ expanding polyurethane injection resins are designed, tested and manufactured to offer high-performance solutions and lasting results.

A trusted manufacturer of the most comprehensive product lines for the infrastructure, commercial, industrial and residential construction markets, we continue to expand our offerings to provide innovative and practical solutions designed to your individual project specifications. Our team of 60 licensed professional engineers, 14 licensed field engineers and 41 technical representatives are a phone call away to provide local, onsite support for the entire duration of your repair project.

**For complete information including product data sheets, please visit [strongtie.com/RPSInject](http://strongtie.com/RPSInject) or call your local RPS Specialist at (800) 999-5099.**



# Stop water dead in its tracks.



## Introducing RPSInject™ from Simpson Strong-Tie.

Stop water leaks without costly excavations. RPSInject™ polyurethane injection resins give you a safe, versatile and easy-to-use solution for repairing cracks to prevent water infiltration. These non-toxic, non-flammable expanding resins are available in four formulations and adjustable cure times to help you solve your next concrete repair challenge.

With RPSInject resins, you can repair in place. Call us about your project at (800) 999-5099 or visit [strongtie.com/rpsinject](http://strongtie.com/rpsinject).



# HNTB: Innovative tunnel solutions

With growth in the urban core and increased demand for more efficient transportation, reliable power, water and wastewater conveyance, and communication systems, many cities are opting to add infrastructure underground. Modern technology makes that solution possible and preferable. Impressive, sophisticated underground structures can help solve current and future urban congestion and development challenges.

HNTB Corporation has more than 50 years of experience in the design, construction and restoration of tunnels and underground structures in various grounds in the highway, transit, rail, aviation and water resources markets. Our experts have the insight and knowledge to provide innovative solutions on a wide range of tunnels, including cut-and-cover, tunnel boring machine (TBM) tunnels, conventional

tunneling, NATM, immersed tube tunnels, shaft construction and micro-tunneling. Our long history in planning, program management, design, construction management and technical services for tunnel structures includes award-winning projects on some of the country's most complex tunneling projects.

HNTB provides full service in tunneling and underground engineering including:

- Program and construction management
- Design of soft ground tunnels, rock tunnels, caverns, shafts, New Austrian Tunneling Method, cut-and-cover structures, immersed tunnels, micro-tunneling and pipe jacking
- Condition survey and rehabilitation
- Geotechnical and engineering geology
- Excavation support, protection of existing facilities, and underpinning
- Settlement analysis and mitigation
- Seismic design and retrofit
- Geotechnical and structural instrumentation
- Ground improvements and groundwater control
- Tunnel ventilation and fire-life safety design
- Tunnel security and hardening

Among its recent notable projects are:

- Istanbul Strait Road Crossing in Turkey (2016 ENR Best Global Projects, Bridge/Tunnel)
- Midtown Tunnel in Norfolk, Virginia
- Amtrak's B&P Tunnel in Baltimore
- Crenshaw-LAX subway line in Los Angeles
- The Alaskan Way SR99 Tunnel in Seattle
- Tom Lantos Tunnels at Devil's Slide in California
- Structural assessment and rehabilitation of several subway tunnels and stations in New York in the aftermath of Super Storm Sandy

**HNTB**

[www.hntb.com](http://www.hntb.com)



# WORLD CLASS TUNNELING EXPERIENCE



**2016 ENR Global Best Project, Bridge/Tunnel**  
**2015 ITA Tunneling Awards, Major Project of the Year**



**2014 ASCE OPAL Award of Merit | 2013 UCA Project of the Year**  
**2012 ITA Tunneling Advisor/Program Manager of the Year Award**

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TOP: Istanbul Strait Road Tunnel Crossing *Istanbul, Turkey* | MIDDLE: Tom Lantos' Tunnels *California*

**Sanja Zlatanic**  
**SVP | Chair, HNTB National Tunnel Practice**  
**Chief Tunnel Engineer**  
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**HNTB**

The HNTB Companies  
Infrastructure Solutions

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# Putzmeister Shotcrete Technology, Your Worldwide Partner for Quality and Innovation

Putzmeister Shotcrete Technology provides you with one source for the world's most complete offering of solutions and equipment for sprayed concrete.

Since purchasing Allentown Equipment with its more than 100 years of shotcrete expertise, and combining it with Putzmeister's innovative concrete technologies and experience, Putzmeister Shotcrete Technology can provide world-class support for contractors' needs in the Refractory, Underground, Mortar and Civil industries.

In the early 1900s, Allentown's pioneering technology was first developed for taxidermy purposes when its originator Carl Akeley, a famous hunter and professor, devised a method for spraying plaster onto a wire frame. The outcome was a strong, thick plaster coating that didn't slump from the frame or set before being fully placed.

Forty years later, a new process was developed involving the use of pressure tanks to force stiff mortar through a hose. This new wet-process became known as shotcrete - and the rest is history.

"In this day and age, very few companies are able to succeed in business for over 100 years," says Patrick Bridger, president of Putzmeister Shotcrete Technology. "We are very proud of our longevity, and see it as a



Mixkret 4 - Low Profile Concrete Mixer

testament to our reputation for quality, and the value we have brought our customers for more than a century."

Since the 1950s, the Allentown name has been synonymous with the process of spraying mortar at high velocity onto surfaces in the refractory, underground, mortar and civil industries. The equipment line has expanded to include a wide range of Gunning Machines, Pre-dampeners, Dosing Pumps, Pumps, Combination Mixer-Pumps, Mixers, Chemical Additive Pumps, Nozzle Carriers, Mortar Machines, Concreting Machines and parts and accessories.

Throughout the years, numerous milestones have been achieved:

- 1900s - Carl Akeley develops method for spraying plaster onto wire frames.
- 1910 - First Cement Gun introduced at New York Concrete Show.
- 1911 - Patents and trademarks issued for the Cement Gun and its Guniting process.
- 1950s - Wet-process shotcrete application developed.



SPM 307 Nozzle Carrier

- 1960s - Dry-process rotary gun developed.
- 1970s - Swing-tube technology used on wet-process shotcrete equipment, making application and use more practical.
- 2007 - Company acquired by Putzmeister America, Inc., resulting in most comprehensive line of sprayed concrete equipment. Name changed from Allentown Equipment to Allentown Shotcrete Technology, Inc.
- 2008 - Allentown becomes exclusive United States distributor of the Sika/Aliva family of wet- and dry-process shotcrete equipment.
- 2009 - Putzmeister America's Special Application Business forms partnership between Allentown, Esser Pipe Technology and Maxon Industries, Inc., creating a comprehensive systems approach for tunnel and mining, dam and power generation, transportation, marine and off shore projects. MacLean Engineering, in partnership with Allentown, develops new self-contained shotcrete spraying machine.
- 2010 - Allentown Celebrates 100th Anniversary.
- 2012 - Allentown Shotcrete Technology, Inc. is re-branded Putzmeister Shotcrete Technology.

With Putzmeister's reputation for excellence and expertise built on our commitment to application-oriented engineering and customer service - put the strength of Putzmeister to work for you. Contact us at (800) 553-3414 or visit [PutzmeisterShotcrete.com](http://PutzmeisterShotcrete.com).



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PERFORM AT A HIGHER LEVEL

# TK 70

**Putzmeister**

## Trailer-Mounted Concrete/Shotcrete Pump

Built to tackle the toughest structural concrete jobs, the Putzmeister Thom-Katt® TK 70 Trailer-Mounted Concrete/Shotcrete Pump can pump a variety of materials – including the harshest mixes – up to 74 yd<sup>3</sup>/hr. Enhanced with premium technologies that improve strength, safety and operation, the TK 70 provides the long-term performance you demand.

At Putzmeister, exceeding your expectations isn't a goal – it's mandatory.



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# JENNMAR

JENNMAR is a global, family-owned company that is leading the way in ground control technology for the mining, tunneling and civil construction industries. Since 1972, its mission has been focused on developing and manufacturing quality ground control products. Today, JENNMAR makes a broad range of reliable products, from bolts and beams, to channels and trusses, to resin and rebar. We're proud to make products that make the industries we serve safer and more efficient. And with more than twenty manufacturing plants around the world and a network of affiliates, JENNMAR is uniquely positioned to react to ground control needs anywhere, anytime.

## A Single Source Provider

JENNMAR's network of affiliates includes engineering services, resin manufacturing, rolled-steel and drill-steel manufacturing, custom steel fabrication, chemical roof support and sealing products, and even includes staffing solutions and our own trucking company. This ability to provide a complete range of complementary products and services ensures quality, efficiency and availability resulting in reduced costs, reduced lead times and increased customer satisfaction.



## JENNMAR Affiliates

### JENNMAR Civil

JENNMAR Civil is dedicated to providing products and services to the Civil Construction and Tunneling industries. Products include various types of rock support bolts, anchoring systems and resins to support tunneling, geotechnical, foundation and earth retention projects.

### J-LOK

J-LOK manufactures state-of-the-art resin anchorage systems that are designed to complement JENNMAR products and provide an optimum bolt and resin system. J-LOK equipment is among the most technologically advanced in the resin industry.

### JENNCHEM

JENNCHEM designs and delivers chemical roof support, rock stabilization and ventilation sealing products to the mining and underground construction industries.

### KMS (Keystone Mining Services)

KMS (Keystone Mining Services) is JENNMAR's engineering affiliate that provides advanced engineering services such as structural analysis, numerical and 3-D modeling, as well as conducting research and development of new products.

## JENNMAR Specialty Products

### JENNMAR

Specialty Products is a full-scale steel fabricator specializing in roll-forming coil, sheet and structural

beams to provide quality arch and corrugated products. In conjunction with KMS, we can also custom design and fabricate products for a variety of applications.



### JM Steel

JM Steel's steel processing facility, located on Nucor Steel's industrial campus near Charleston, SC, has the processing capability and extensive inventory to provide a variety of flat rolled steel products including master coils, slit coils, blanks, beams, sheets, flat bars and panels.

### JENNMAR McSweeney

JENNMAR McSweeney is a leading manufacturer of forged drill steel products for the underground mining and civil construction industries, along with a complete line of bolt wrenches, socket accessories, chucks, augers, and other related products.

### CSA (Compliance Staffing Agency)

CSA is an energy industry staffing service that provides trained, experienced, drug-screened personnel and can supplement an existing workforce during peak work periods or act as a screening service for potential new hires.

### MARJENN Trucking

MARJENN Trucking provides trucking services throughout the eastern and mid-western U.S. to transport raw materials, supplies and finished products between JENNMAR plants, suppliers and customers.

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

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**Email: [info@jennmar.com](mailto:info@jennmar.com)**  
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## Demanding Conditions Demand JENNMAR.

We've been an innovative leader in ground control for the mining industry for more than forty years. Over the past decade, our growth has led us to make key acquisitions of resources to further enhance our deep commitment to serve the tunneling industry as well. Our rock bolts, anchoring systems, liner

plates and resins are backed by experienced engineers and technicians who are with you every step of the way, from initial consultation to qualified instruction and on-going technical support. *And, of course, our customer service is second-to-none. That's something we've always demanded of ourselves.*



# Moretrench

The challenges inherent in tunneling operations are well known. What is perhaps not so well known is that only one geotechnical contracting company has the in-house range of ground improvement tools to resolve even the most complex subsurface conditions. That company is Moretrench. Whether the issues are known in advance or occur unexpectedly, call Moretrench because when it comes to the complexities of underground construction, the key to success is choosing the right partner and choosing them early.



Delivering liquid nitrogen to the Port Mann off-shore working platform.

## Port Mann Water Main: Ground Freezing

Mining of the new, 3,280-ft long Port Mann Water Main was well underway deep below the Fraser River in Vancouver, British Columbia, when an unanticipated mechanical failure occurred in the cutter head, halting mining operations. When initial more conventional approaches to allow access for repair were ruled out, the tunneling contractor contacted Moretrench. Moretrench developed a liquid nitrogen ground freezing solution that would not only allow safe access for inspection and repair but could also be implemented quickly. The remote TBM location, 160 ft below river mud line and 650 feet from the exit shaft, meant that all equipment and materials, including liquid nitrogen storage tanks, had to be ferried to the pile-supported work platform. Pinpoint drilling for freeze pipe installation was critical to ensure freeze build up exactly as designed. After just 12 days of freezing, the freeze was sufficiently formed to allow safe entry into the cutter head for repairs to begin.



High mobility grouting of karstic rock enabled dry excavation of the OARS CSO shafts.

## OARS Relief Sewer Phase 2 Shafts: High Mobility Grouting

Drill and blast installation of three deep shafts through highly variable karstic conditions was the challenge facing the design and construction teams for Phase 2 of the CSO project in Columbus, OH. The shafts extended through shale underlain by three distinct strata of karstic limestone. With the water table 20 ft below the surface, and the high hydraulic conductivity of the rock evident from pumping tests, it was estimated that inflows of thousands of gallons per minute could be anticipated during shaft excavation under hydrostatic head of up to 150 ft. Pre-grouting was therefore required. A Moretrench-designed alternate to the original in-shaft staged grouting plan allowed all grouting to be accomplished around the shaft perimeter from the surface. A suite of four, balanced-stable grouts developed by Moretrench catered to the highly variable subsurface conditions. With grouting complete, excavation proceeded with only minimal shaft inflow.



Jet grout cut-off for installation of the Mulry Square vent plant.

## Mulry Square Vent Plant: Jet Grouting

The Mulry Square emergency vent plant is designed to serve a portion of both the 8th and 7th Avenue subway lines in Manhattan, New York. With offsite groundwater drawdown during construction prohibited, a perimeter cut-off was required. This was designed as secant pile walls, with jet grouting specified for closure where the vent plant penetrated the wall of the subway tunnel. Groundwater modeling by Moretrench demonstrated that the jet grouting would need to extend only to a minimum depth of 53 ft to achieve cut-off, rather than the 100 ft originally anticipated, reducing the quantity of secant piling and jet grouting required. Subsequent groundwater monitoring during excavation to full depth within the secant pile/jet grout cut-off structure confirmed the accuracy of the groundwater modelling and offsite drawdown did not exceed the specified limits.

For more on these and other tunneling projects, visit us at:  
**[www.moretrench.com](http://www.moretrench.com)**.

A large underground tunnel under construction. In the foreground, a worker in an orange safety vest and blue hard hat is working on a complex system of pipes and machinery. The tunnel walls are lined with concrete segments, and the floor is wet and reflective. In the background, the tunnel extends into the distance, illuminated by warm orange lights.

*When it comes to the complexities of underground construction,*

# No One Has Seen More Than Moretrench

**MORETRENCH**

No one has seen more.™

Groundwater Control

Earth Retention

Deep Foundations

Ground Freezing

Grouting

# Kiewit

As a construction, mining and engineering leader, Kiewit is a FORTUNE 500 company with 2015 revenues of \$9 billion. Kiewit, through its operating companies, brings a wealth of diverse resources and a track record for delivering the highest quality results — on budget and on schedule. Kiewit's size and experience provides the stability, predictability and know-how our clients and partners expect — and the flexibility and overall best value they deserve.



Kiewit has been constructing underground facilities for over 50 years, offering some of the most highly skilled and experienced teams in the industry. We have completed more than 100 underground related projects totaling more than \$1 billion. Our tunneling portfolio includes projects related to transportation, water / wastewater facilities, power, mining, and telecommunications. In addition, Kiewit has the resources to construct cut-off walls, structural slurry walls, drilled shafts and ground improvement. We perform these operations with our fleet of specialty equipment and the management resources of one of the top builders in North America. Through the use of cutting-edge technology, industry-leading safety performance and a wide range of capabilities, we offer our clients an innovative, one-stop shop for all their tunneling needs.

Our projects range from fast-track mining jobs to a \$1 billion undersea rail tunnel. No project is too large or small when it comes to meeting our clients' needs. Our clients in these markets have come to expect the industry's safest work environments, the highest-quality delivery and superior compliance with requirements of all types. Behind it all are the core values that have shaped how we manage our business — for our clients and other key constituents.



**Kiewit Infrastructure Co.**  
302 South 36th St., Suite 400  
Omaha, NE 68131  
402-346-8535





# Kiewit



## KIEWIT FOUNDATIONS GROUP

Keeping safety in the forefront, Kiewit Foundations Group performs complex geotechnical projects across North America. We deliver innovative and cost-effective solutions tailored to the specific needs of each project. Our range of services include:

- Diaphragm Walls
- Slurry Cutoff Walls
- Ground Improvements
- Drilled Shafts

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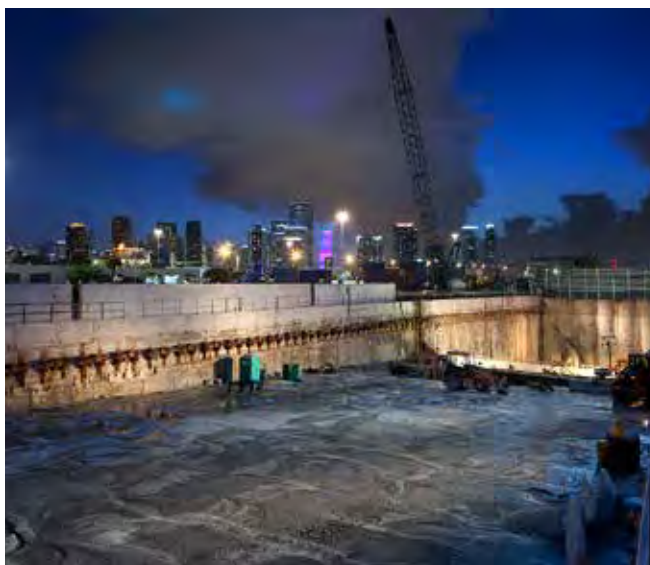
# Leading the Way

Every structure needs a strong foundation and John Malcolm established Malcolm Drilling Co. Inc. (Malcolm) on a strong foundation of hard work, dedication and an unwavering commitment to pursue new technologies. Over the course of 50 years the company has become one of the country's foremost practitioner and authorities in deep foundation, retention systems and ground improvement work, operating the largest fleet of drilling equipment in the country (valued at more than \$190 million). Malcolm is committed to reinvesting capital back into the company in the form of state of practice equipment and cutting-edge technology, which allows the company to serve client needs on a broad geographic basis.

Malcolm's list of core services as it relates to tunneling includes access shafts, excavation support systems, cutoff and secant pile walls, jet grouting, deep soil mixing, cutter soil mixing and dewatering. The company has augmented its construction and engineering expertise along with a strong safety record into an equally impressive resume that represents a significant number of high-profile, highly challenging tunneling projects throughout North America.



Malcolm crews recently completed work on the Alaskan Viaduct Replacement Project (SR 99), in Seattle where we installed the support of excavation (SOE) which incorporates large-diameter secant piles to construct the portal for Bertha, the world's largest tunnel boring machine (TBM). Various ground improvement techniques were used to construct several TBM Safe-Haven's in challenging glacial till with a myriad of undocumented obstructions. At the Port of Miami Tunnel Project in Florida, Malcolm installed the launch and retrieval pit for the TBM incorporating various Soil Cement Mixing techniques for the SOE as well as the break-in and break-out structures in highly permeable limestone. For the New Irvington Tunnel in California, we drilled very deep Secant Piles to construct the access shaft in rock with verticality requirements which until recently were unachievable.



Our large equipment fleet and highly skilled personnel affords Malcolm the unique ability to comply with the most rigorous schedule compression, while delivering a high quality product in the most difficult ground conditions. Our experience facilitates a Design/Build approach to projects and allows for timely collaboration with owners and contractors. We provide these services nationwide through our regional offices. We welcome the opportunity to work with you in developing the most efficient and cost effective solution to your next project.

Look to the Blue

**Malcolm Drilling**  
[www.malcolmdrilling.com](http://www.malcolmdrilling.com)





# MALCOLM

Look to the Blue

## ACCESS SHAFTS

Alaskan Way Viaduct Replacement  
Seattle, WA

Large Diameter Secant Piles for  
Bertha Rescue Shaft

Malcolm Drilling has been providing support for our clients for over 50 years. Our innovative technology and extensive equipment fleet uniquely positions Malcolm as a national leader in the deep foundation industry. Find out more about what we can do for you at [Malcolmdrilling.com](http://Malcolmdrilling.com).

## Gall Zeidler Consultants

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

The company specializes in mastering difficult ground conditions by using cutting-edge ground improvement methods such as dewatering, grouting, and ground freezing. GZ employs over 50 staff

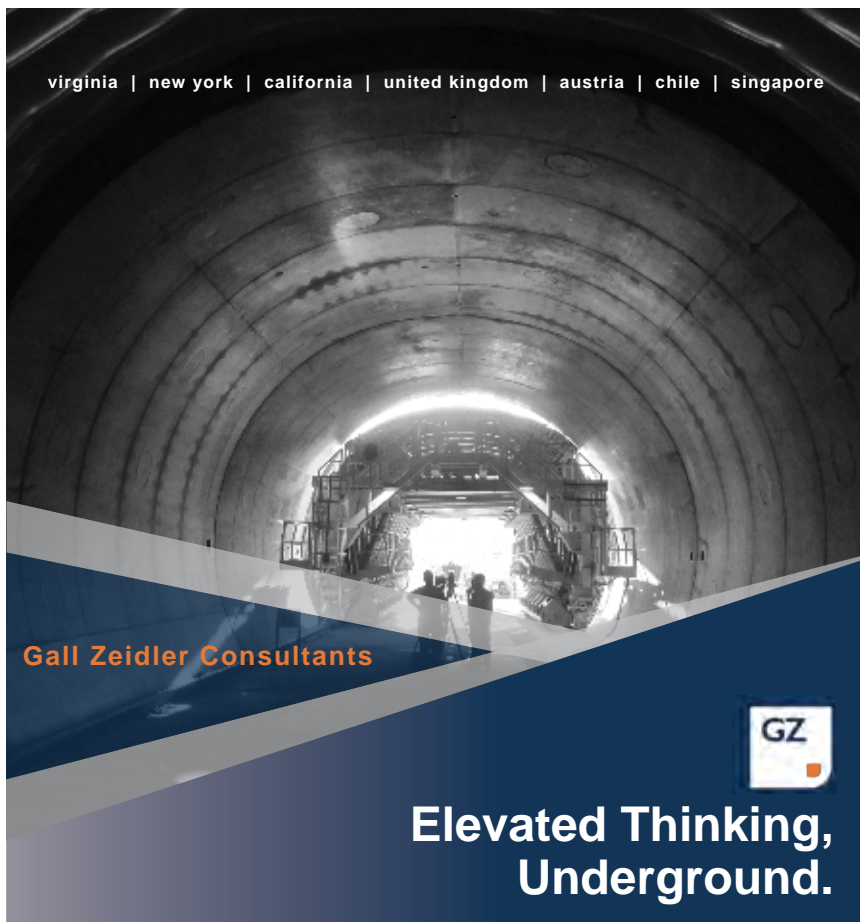
worldwide, and has a history of over 170 miles (275 kilometers) of successfully completed international tunneling projects. The company's expertise has consistently been sought after by major contractors and project owners in the industry developing tailored tunnel solutions and to assist with the mitigation of risks associated with tunneling.

GZ's ongoing projects include East Side Access, New York, Northgate Link Extension, Seattle, Crossrail, London and Riyadh Metro. GZ was involved in the recently completed Caldecott Tunnel Fourth Bore and Devil's Slide Tunnels in California, Dulles Metrorail Extension, Washington, D.C., Cable Tunnels in London and Singapore and multiple underground station upgrades in London.

## Schnabel Engineering

Schnabel Engineering, formerly Lachel & Associates, specializes in design and construction management services for tunneling and other heavy civil construction projects in the areas of transportation, water and wastewater infrastructure, and hydroelectric power. Our goal is to meet the needs of clients by providing fully integrated management and technical services that are objective, thorough, and effective.

We combine our expertise in the design and construction of underground structures with a keen understanding of nuances and interrelationship of geology, hydrogeology, and geotechnics on underground projects. From inception, through design, risk assessment, estimating, construction, and operations, we provide time-critical answers to difficult questions that help make certain the project comes in on time and within budget.



virginia | new york | california | united kingdom | austria | chile | singapore

**Gall Zeidler Consultants**

**GZ**

**Elevated Thinking,  
Underground.**



Founded in 1956, Schnabel has a long history of providing tunnel design services for constructors, owners, and other A/E firms for project across the United States. Some of our recent projects include:

- DC Water Clean Rivers Program, Washington, DC
- Loudon Water Raw Water Supply Tunnel, Leesburg, VA
- East End Crossing Tunnels, Louisville, KY
- Waller Creek Flood Tunnel, Austin, TX

#### TUNNEL DESIGN SERVICES

Some of our design services for tunnels and underground projects include:

- Feasibility Studies
- Alignment Optimization
- Assessment of Geotechnical Conditions
- Tunnel Initial and Final Support Design
- Numerical Methods for Design
- SEM / NATM
- Cavern Design
- Shaft Design
- Constructability Review and Cost Estimating
- Geotechnical Baseline Reports (GBRs)
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Alpine Equipment is the industry leader in hydraulic rock and concrete grinder attachments, roadheaders, shaft sinkers and soil remediation equipment, with over 40 years of expertise in North America. Our customers range from owner-operators to the largest tunneling firms. Alpine supplies attachments for construction, demolition, excavation, scaling, trenching, mining and tunneling. The rotary cutter heads come in range of sizes to fit on skid steer loaders, backhoes and excavators or any equipment with a hydraulic circuit. With a range of options and customizations, we can get you working more efficiently and with more precision than your current tools. Many of our customers are using the cutter head for concrete



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# Schauenburg

We are pleased to announce the formation of a cooperative Business Alliance between Schauenburg Flexadux Corp ([www.schauenburg.us](http://www.schauenburg.us)) and Protan AS ([www.protan.com](http://www.protan.com)) to better serve the Tunnelling and Mining across the United States.

This cooperative approach involves combining the strengths of Protan's years of manufacturing and supply of top quality Tunnel Ventilation PVC Ducting and Technical solutions to the global mining and tunnelling industries with Schauenburg Flexadux's 40 plus years of local US Manufacturing, Supply and customer service to these industries.

The major benefits of this Business Alliance is to combine the 60 plus years of Protan experience in designing and supplying lower friction Ventilation Technology with the dedicated local commitment of Schauenburg Flexadux to supply fast deliveries to meet our customers production requirements.

The major benefits to our valued end-user clients are:

1. Combination of Recognized World Class Ventilation Technology with dedicated local manufacturing, sales, service, and support.
2. Fast response time to design and manufacture of specialty products.
3. Elimination of supply logistics related to long delivery concerns, customs and other import administrative costs.
4. Addresses the fluctuating currency exchange rates.
5. Competitive pricing to address the realities of the US Market Demands.

We look forward to working jointly together with you to provide quality ventilation products and services to assist you to be a profitable leader in the United States mining and tunnelling business.

Please feel free to contact us at any time with any questions.

**John Kelleher, P.Eng.**  
President  
Schauenburg Flexadux Corp.

**Mark Andersen, P.Eng.**  
Director N. America  
Protan AS



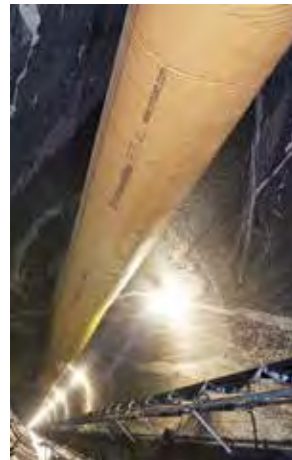
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## Brokk Inc.

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

Brokk recently introduced the new Brokk 280. The machine features increased demolition power over its predecessor, includes the all-new Brokk SmartPower™ electrical system, and incorporates additional hardened parts for extra durability in tough environments. The improvements increase the reliability and versatility for Brokk customers working on harsh jobsites in industries such as tunneling, mining, construction, metal processing and nuclear.

The Brokk 280 features a 20-foot (6.2-meter) reach and weighs 6,945 pounds (3,150 kilograms). By generating as much as 25 percent more breaking performance over the Brokk 260 it replaces, the Brokk 280 delivers a significant boost in productivity. Beyond packing a harder punch and knocking out more breaker blows per minute, the Brokk 280 features improved maneuvering capabilities with softer, smoother movements. It does this without sacrificing any of the compactness, precision and flexibility for which Brokk machines are known.

Brokk also introduces an all-new electrical system, Brokk SmartPower, on the Brokk 280. The intelligent system includes hardened components and fewer moving parts. The system optimizes machine performance based on a number of factors, including power supply quality and ambient temperature.

**For more information: Brokk Inc., 1144 Village Way, Monroe, WA 98272; 800-621-7856; [info@brokkinc.com](mailto:info@brokkinc.com); [www.brokk.com](http://www.brokk.com); Facebook and Twitter: @BrokkUSA; LinkedIn: Brokk Inc.; YouTube: BrokkIncUSA.**



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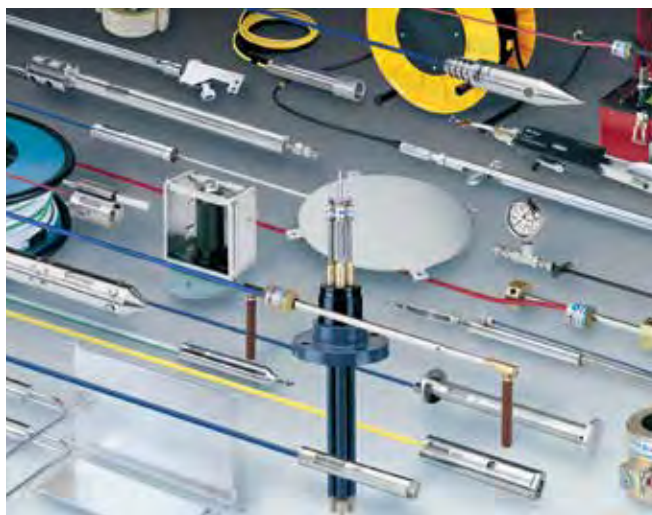
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# Geokon, Incorporated

Geokon, Incorporated, is a 35 year-old company based in Lebanon, New Hampshire, USA. It operates on a worldwide basis through a network of over 45 agencies for the manufacture and sale of geotechnical instruments. Founded in 1979, Geokon currently has over 100 experienced employees, many of whom have been with the company for over 25 years. Geokon, Inc. has emerged as The World Leader in Vibrating Wire Technology™ and one of the major global instrumentation companies due to our high-quality products, responsive customer service and industry-leading designs.

In addition to almost all major cities in the USA, our instruments have been used in tunnels and subway systems around the world, including those found in Seoul, Taipei, Guangzhou, Istanbul, Hong Kong, Singapore, London and the Channel Tunnel.

Tunnel-specific instruments include NATM-style concrete pressure cells for monitoring stresses in shotcrete linings; convergence meters and tape extensometers to measure tunnel closures; multiple-point borehole extensometers and instrumented rockbolts to monitor the stability of the surrounding ground; piezometers to monitor ground water pressures and displacement gages to measure movements across cracks and joints. Dataloggers are used to take readings at programmed intervals and transmit real-time data (and any triggered alarm signals) to local stations or to remote readout locations using web-based



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Geokon's experienced staff is at your disposal to assist in instrument design, selection and installation. For more information please visit [www.geokon.com](http://www.geokon.com), e-mail us at [info@geokon.com](mailto:info@geokon.com) or call 1-603-448-1562 and speak to a sales representative.

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Recently Mining Equipment has supplied a string of rolling stock including 5th wheel dump muck cars to Stillwater Mining in Montana. The cars will be used to haul muck out of a new TBM mined tunnel.

Another recent project for Mining Equipment was the New Irvington Tunnel in northern California. 12-Ton explosion proof diesel locomotives were supplied as well as a large spread of 5th wheel dump muck cars, flat cars and personnel cars.

Mining Equipment is based in Durango, Colorado. Their primary shop is in Farmington, New Mexico. They also have a fabrication facility near Shanghai, China and an office in North Bay, Ontario.



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## Brookville

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

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

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

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



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A Brookville locomotive is shown at a construction site. A worker in a blue shirt and hard hat is standing near the locomotive. The locomotive has "BROOKVILLE" written on its side.

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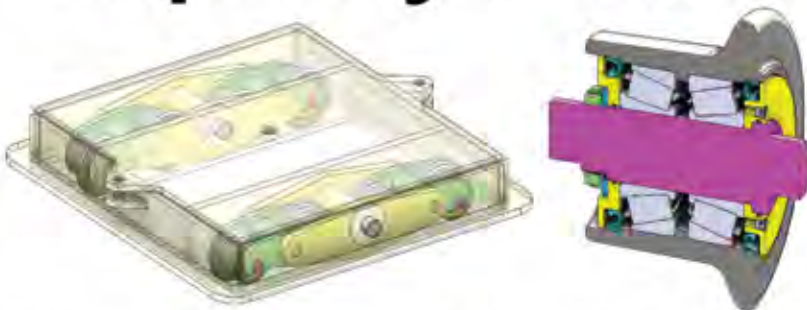


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Kelley Engineered Equipment, LLC was founded in 2007 by Brian and Cindy Kelley. The company has a growing staff of mechanical engineers, control system technicians, designers and drafters with extensive equipment design experience. Brian has nearly 30 years of tunneling equipment design experience at Robbins, Kiewit and Kelley Engineered Equipment. Jesse Schneider has been added to the engineering team. Jesse has 10 years of experience in tunneling and tunneling equipment design at Frontier Kemper. Recently, Jay White has joined us as shop operations manager, and Travis Schroeder as control systems technician. Mechanical PE licenses are held in 8 states. The company specializes in custom equipment design, including lifting systems, mucking systems, gantries, pipe carriers, trailing gear, custom attachments, conveyors, lift cars, equipment modifications, ventilation systems, heavy load handling systems, custom cranes, personnel access systems and more. **See [www.KEELLC.com](http://www.KEELLC.com).**



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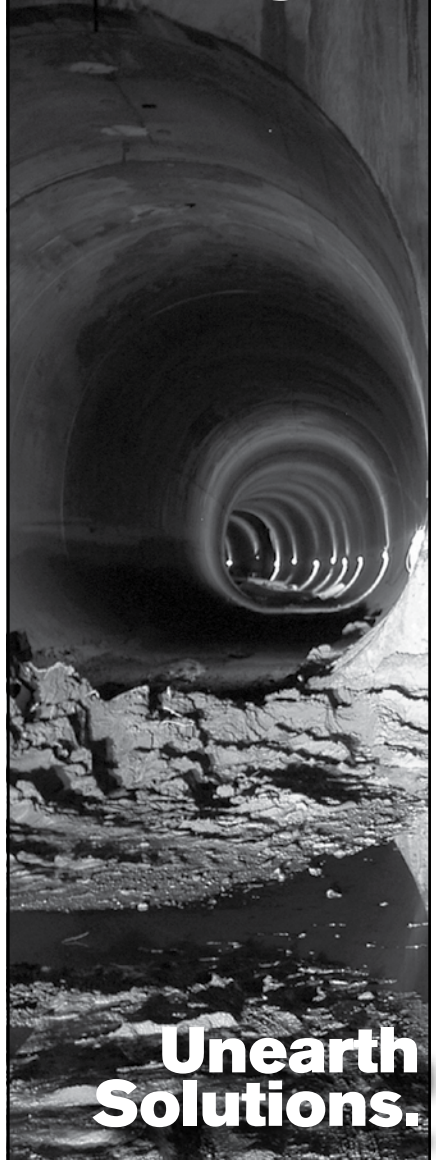


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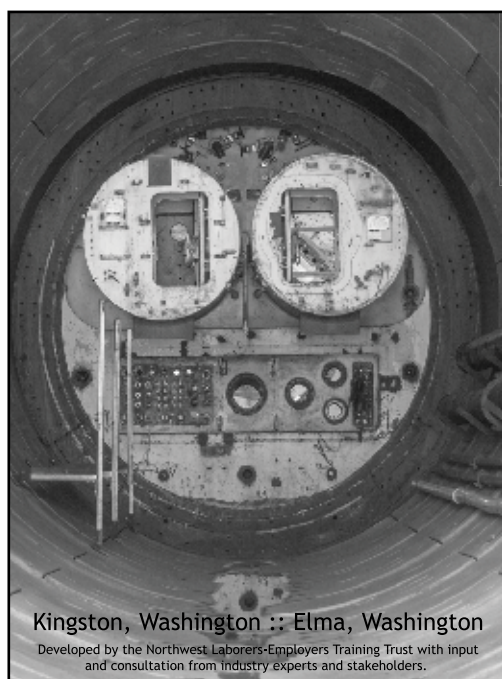
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Developed by the Northwest Laborers-Employers Training Trust with input and consultation from industry experts and stakeholders.



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Dr. Gary S. Brierley started operating as an independent consultant under the corporate name of Doctor Mole Incorporated (DMI) on January 1, 2013. Doctor Mole Incorporated is a one-stop-shopping-center for the design of all types of underground openings in all types of ground conditions. DMI can help clients meet their underground design and construction needs. No job is too small and it is our intention to help owners, designers, contractors, geotechnical engineers, and developers create successful underground projects from start to finish. Based in Denver, Colorado, DMI is strategically located and available to help with projects across the United States. Give us a call at 303.797.1728 or visit us on the web at [www.drmoileinc.com](http://www.drmoileinc.com).

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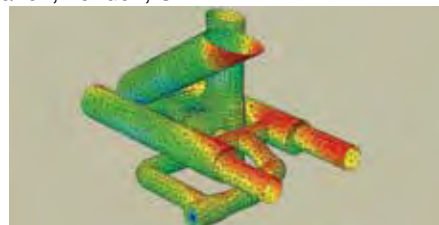
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Dr. Sauer & Partners is an independent consultancy specialised in providing the full range of design and construction management services for SEM tunnels, shafts and caverns. The firm delivers innovative, cost-effective and environmentally-aware design solutions and has over 30 years of experience providing design and construction for more than one hundred of the world's most complex tunnelling projects (Metro, Highway, Water, Rail and Mining). Dr. Sauer & Partners designs tunnels in urban and rural locations and in any type of geology. Current and recent projects include: Chinatown Station (San Francisco, USA), Ottawa Light Rail (CAN), Bank

Station Capacity Upgrade Project (London, UK), Crossrail (London, UK), Red Line (Tel Aviv, Israel), Eglinton Crosstown LRT (CAN)

The image shows: 3D FE Model of Step Free Access at Green Park Station, London, UK



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We contribute to projects at the planning, design and construction phases. Clients benefit because we understand project drivers at all stages and can provide cost-effective alternatives. We are small enough to remain focused on service and quality rather than profit centers and internal bureaucracy and large enough to offer expanded services and a deep bench of technical expertise.



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Mueser Rutledge Consulting Engineers (MRCE), founded in 1910, is a leading engineering firm focused on the below-ground disciplines of geotechnical engineering and structural foundation design for all structures.

Providing design solutions for tunnels and shafts is an MRCE specialty and involves the firm in a wide array of tunnel projects in both soft ground and rock for railroads, highways, subways, pedestrians, utilidors, CSOs, interceptors, as well as water and wastewater treatment.

MRCE's recent tunneling projects include LIRR East Side Access, NYCT 2nd Avenue Subway, CSX Virginia Avenue Tunnel, VDOT Midtown Tunnel, DC Water's Blue Plains and First Street Tunnels, Toronto Subway Yonge-Eglinton Station, and NYCDEP's Catskills and Delaware Aqueduct Rondout-West Branch Tunnel and Brooklyn to Staten Island Harbor Siphon Tunnel.

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TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Gateway Tunnel	Amtrak	Newark	NJ	Subway	14,600	24.5	2018	Under study
2nd Ave. Phase 2-4	NYC-MTA	New York	NY	Subway	105,600	20	2017-22	Under study
Water Tunnel #3 bypass tunnel	NYC-DEP	New York	NY	Water	20,000	22	2015	Kiewit - Shea JV awarded
Water Tunnel #3 Stage 3 Kensico	NYC-DEP	New York	NY	Water	84,000	20	2020	Under design
Bergen Point Wastewater Outfall	Suffolk Co., DPW	Babalon	NY	Sewer	14,200	12	2017	Under design
Cross Harbor Freight Tunnel	NYC Reg. Develop. Authority	New York	NY	Highway	25,000	30	2022	Under study
Amtrak B&P Tunnel	Amtrak	Baltimore	MD	Rail	10,000	30	2018	Under design
Thimble Shoal Parallel Tunnel	Chesapeake Bay Bridge & Tunnel Dist.	Chesapeake	VA	Highway	5,700	45	2016	Dragados/Schiavone awarded
Northeast Boundary Tunnel	DC Water and Sewer Authority	Washington	DC	CSO	17,500	23	2017	Proposals due 02/2017
Potomac River CSO Tunnel	DC Water and Sewer Authority	Washington	DC	CSO	4,500	33	2022	Under design
Olentangy Relief Sewer Tunnel	City of Columbus	Columbus	OH	Sewer	58,000	14	2017	Under design
Alum Creek Relief Tunnel Phase 1	City of Columbus	Columbus	OH	Sewer	30,000	18	2018	Under design
Phase 2					21,000	14	2019	Under design
Doan Valley Storage Tunnel	NEORS	Cleveland	OH	CSO	9,700	17	2017	Under design
Westerly Main Storage Tunnel	NEORS	Cleveland	OH	CSO	12,300	24	2020	Under design
Shoreline Storage Tunnel	NEORS	Cleveland	OH	CSO	16,100	21	2021	Under design
Southerly Storage Tunnel	NEORS	Cleveland	OH	CSO	17,600	23	2024	Under design
Ohio Canal Interceptor Tunnel	City of Akron	Akron	OH	CSO	6,170	27	2015	Bid date 4th Q 2015
Continental Rail Gateway	CRG Consortium	Detroit	MI	Rail	10,000	28	2015	Under design
ALCOSAN CSO Ohio River Allegheny River Monongahela River	Allegheny Co. Sanitary Authority	Pittsburgh	PA	CSO	10,000 41,700 53,900	30 30 30	2019 2020 2021	Under design Under design Under design
Three Rivers Protection/Overflow	City of Fort Wayne	Fort Wayne	IN	CSO	26,400	12	2016	Bid date 1/19/2017
Louisville MSD Tunnel	Lousville MSD	Lousville	KY	CSO	13,200	22	2018	Under design
Deer Creek Sanitary Tunnel	St. Louis MSD	St. Louis	MO	CSO	21,000	19	2016	JayDee/Frontier Kemper low bid
Lower & Middle River Des Peres Storage Tunnel	St. Louis MSD	St. Louis	MO	CSO	47,500	30	2020	Under design

# FORECAST T&UC

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Lower Meramec Tunnel	St. Louis MSD	St. Louis	MO	CSO	35,900	8	2020	Under design
KCMO Overflow Control program	City of Kansas City, MO	Kansas City	MO	CSO	62,200	14	2018	Under design
Minne Lusa Tunnel	Omaha Public Works	Omaha	NE	CSO	28,500	17	2017	Under design
Mill Creek Peaks Branch Tunnel	City of Dallas	Dallas	TX	CSO	5,500	26	2014	To be rebid
Ballard to Wallingford Tunnel	Seattle Public Utilities	Seattle	WA	CSO	14,250	14	2018	Under design
L.A. Metro Westside Phase 2 Phase 3	Los Angeles MTA	Los Angeles	CA	Subway	26,500 26,500	20 20	2016 2017	No award to date Under design
Speulvada Pass Corridor	Los Angeles MTA	Los Angeles	CA	High/Trans.	55,500	60	2018	Under study
Northeast Interceptor Sewer 2A	LA Dept. of Water and Power	Los Angeles	CA	Sewer	18,500	18	2014	Delayed indefinitely
River Supply Conduit - Unit 7	LA Dept. of Water and Power	Los Angeles	CA	Water	13,500	12	2015	Advertize 03/2017
JWPCP Effluent Outfall Tunnel project	Sanitation Districts of LA	Los Angeles	CA	Sewer	37,000	18	2015	Advertize 02/2017
Two Mile Bar Tunnel	Oakdale Irrigation	Oakdale	CA	Water	5,950	11.5x13	2017	Advertize 12/2016
Freeway 710 Tunnel	CALTRANS	Long Beach	CA	Highway	26,400	38	2016	Under design
BDCP Tunnel #1 BDCP Tunnel # 2	Bay Delta Conservation Plan	Sacramento	CA	Water	26,000 369,600	29 35	2018 2019	Under design Under design
SVRT BART	Santa Clara Valley Trans Authority	San Jose	CA	Subway	22,700	20	2016	Redesign activated
Silicon Valley Clean Water Tunnel	Silicon Valley Clean Water	Silicon Valley	CA	CSO	17,500	13	2017	Under design
Coxwell Bypass Tunnel program	City of Toronto	Toronto	ON	CSO	35,000	12	2015	Advertize 3Q 2017
Keswick Effluent Outfall	City of Toronto	Toronto	ON	CSO	11,600	23	2018	Under design
Yonge St. Extension	Toronto Transit Commission	Toronto	ON	Subway	15,000	18	2016	Under study
Taylor Massey Tunnel	City of Toronto	Toronto	ON	CSO	20,000	18	2018	Under design
Inner Harbour West	City of Toronto	Toronto	ON	CSO	18,400	19	2021	Under design
Scarborough Rapid Transit Extension	Toronto Transit Commission	Toronto	ON	Subway	25,000	18	2017	Under design/ delayed
REM Transit Tunnel	City of Montreal	Montreal	QC	Subway	27,000	22	2017	Prequals underway
Newfoundland-Labrador Fixed Link	Gov. of Newfoundland/Lab	Newfoundland	NL	Transit	56,000	40	2020	Under study
Green Line LRT	City of Calgary	Calgary	AB	Traansit	26,250	20	2018	Under design
Second Narrows Tunnel	City of Vancouver	Vancouver	BC	CSO	3,600	14	2013	Under design
Annacis Island Outfall	City of Vancouver	Vancouver	BC	Water	8,000	10	2017	Under design
Burnaby Mountain	Kinder Morgan	Vancouver	BC	Oil	8,000	12	2017	Under design
UBC Line project	Trans Link	Vancouver	BC	Subway	12,000	18	2015	Under design
Northern Gateway Houlst Tunnel	Enbridge Northern	Kitimat	BC	Oil	23,000	20	2014	Under design

## AWARDS

## McMillen Jacobs wins engineering award

**M**cMillen Jacobs Associates has played a crucial role in the DC Water Blue Plains Tunnel project, which was recently awarded the *Engineering News Record* 2016 Project of the Year Award in the water/environment category in the mid-Atlantic region. The award

was presented Nov. 1 in Baltimore, MD. The award recognized project challenges, safety programs, innovation, contributions to the industry, and the function and aesthetic quality of the design.

The Blue Plains Tunnel is the first tunnel delivered under DC

Water's Long Term Control Plan and was procured under the design-build delivery method. Excavation proceeded through soft ground using "Lady Bird," an earth pressure balance machine. Tunneling began in April 2013 and concluded in July 2015. ■

## PERSONAL NEWS

**CHRIS S. RHOADES** has joined Gomez International as Director of Sales and Business Development. Most recently, he was director of sales for Brookville Equipment Corp. He will be working remotely from Pennsylvania. With the assistance of **TOM CRNJAC**, he will be responsible for coordinating the sales efforts at Go-



RHOADES

mez International.

Specialty geotechnical contractor Moretrench has hired **JONATHAN BENNETT, P.E.**, as business development manager for its mid-Atlantic and Midwest regions. Bennett has 25 years of experience with deep foundations, earth retention and other geotechnical construction spe-



BENNETT

cialties, as well as extensive business development experience.

**PETER TURTON, P.E.**, will join Arcadis as vice president and project director. He will be responsible for managing the construction of the firm's future multi-billion-dollar rail transit projects. Turton brings more than 40 years of professional experience to Arcadis and is among an elite handful of world-renowned rail construction management experts. Arcadis is a global design and consultancy firm for natural and built assets. ■

## NEW PRODUCTS

## Tytro shotcrete system from GCP applied technologies

**G**CP Applied Technologies Inc. has introduced the Tytro Shotcrete System, a complete state-of-the-art admixture solution for underground construction. The Tytro system includes a nanotechnology-based rheology control agent formulated to improve the pumpability and sprayability of the shotcrete mix. It also offers patented, macro-synthetic fibers used as a replacement for steel fibers and wire mesh and a number of other newly developed admixtures that enhance the productivity of the spraying operation and material performance.

Advantages provided by the system compared to conventional mixes include: up to 10 percent lower installed cost achieved through mix

optimization, waste minimization and shorter cycle times; rebound rates reduced down to 5-8 percent; faster re-entry times due to more rapid early-age strength development at equal accelerator dosage rate; superior

bond-to-rock and adhesion between layers, providing greater thickness in one pass and a more robust and dosage efficient system. ■

<https://gcpat.com/construction/en-us/shotcrete-technology>



Tytro system in action.

## NEW PRODUCTS

## Tsurumi pumps provide critical support for D.C. Clean Rivers Project

Many Tsurumi pumps contributed to The D.C. Clean Rivers Project in Washington, D.C., a massive infrastructure project that will capture the combined sewer overflows (CSOs) wreaking havoc on the region's waterways. The project involves the construction of four tunnels that will divert the CSOs for wastewater treatment before they reach the capital city's rivers.

The first phase of the ambitious program was the Blue Plains Tunnel Project. A massive excavation was needed to construct the 7,193-m (23,600-ft) tunnel that measures 7 m (23 ft) in diameter and runs more than 30.5 m (100 ft) below the surface. The completed tunnel extends from the Blue Plains Wastewater Treatment Plant past Joint Base Anacostia-Bolling to a main pumping station on the north bank of the Anacostia River, just south of Nationals Park. Nine types of Tsurumi pumps removed water and moisture from the tunnel as crews constructed the piping system that now diverts the harmful CSOs.

J&K Equipment, based in Glenelg, MD, was the pump distributor responsible for supplying dewatering pumps and overseeing operations during the tunnel's excavation. The process of removing excess moisture

from a shaft as it is excavated is a rigorous job that required nonstop pump usage. The Tsurumi LH311W, a three-phase, portable, submersible dewatering pump, moved nearly 757 L/min (200 gpm) at the required 49 m (160 ft) of head with an 11 kW (15 hp) motor. In addition to the LH311W, J&K used Tsurumi pumps that ranged from the 22 kW (30 hp) LH422 three-phase dewatering pump to the 0.5 kW (2/3 hp) LSR2.4S-61 residue pumps.

As the Lady Bird tunnel boring machine made its way along the tunnel's path, Tsurumi pumps removed groundwater from the shaft. Concrete slurry was poured behind concrete support segments to construct the 7-m (23-ft) wide pipe through which CSOs would eventually travel. It's here that the ruggedness and durability of Tsurumi pumps enabled the project to stay on schedule. While it's never the intention, concrete slurry also gets removed through the pumps.



Traylor-Skanska-Jay Dee was the joint venture contracting team in charge of operating the Lady Bird tunnel boring machine in the construction of the Blue Plains Tunnel.

This typically results in the pump being scrapped fairly quickly, but four sets of impellers were worn out on one of the LH311Ws before having to replace the internal seal. The impellers in the Tsurumi pumps are made using high-chrome cast iron.

The narrow dimensions of the excavation tunnel also presented a challenge on the job site, but the compact nature of the LH311W submersible dewatering pump helped J&K overcome the tight quarters. The Blue Plains Tunnel Project finished construction in July of 2015. ■

[www.tsurumipump.com](http://www.tsurumipump.com)

## Agru America expands East and West Coast facilities

Agru America's geosynthetic products have been meeting or exceeding regulatory requirements for more than 20 years, which has made the company a leading manufacturer of flat die extrusion geomembranes, geonets, geocomposites and geotextiles. Recently, Agru has extended its manufacturing capabilities with additional production lines at the company's Georgetown, SC and Fernley, NV facilities to better

serve the U.S. East and West Coasts.

The company also supplies geosynthetic clay liners, vertical barrier systems and large diameter piping systems for the U.S. and international civil/environmental markets. Agru America's products include Agru Smooth Liner/MicroSpike (structured textured products), Super Gripnet and Drain Liner in LLDPE and HDPE. In addition, Agru's product line includes the ClosureTurf system,

an innovative and economical final cover system designed in partnership with Watershed Geosynthetics for impoundment and landfill applications.

Agru America is part of Alois Gruber GmbH with production facilities in Austria, the United States, Germany, China and India, and distribution in more than 80 countries worldwide. ■

[www.agruamerica.com](http://www.agruamerica.com)

## The ITA announces tunneling award winners

**T**he International Tunnelling Association (ITA) has presented the Young Tunneller of the Year Award, the Lifetime Achievement Award and awards to eight outstanding projects. After a detailed examination process, 30 finalists were given the chance to present their projects to tunneling-industry attendees at the ITA meeting in Singapore Nov. 10-11, 2016.

### **Major project of 2016 (exceeding \$535 million) — New Guanqiao Tunnel on the Qinghai Tibet Railway**

The New Guanqiao Tunnel is a key project of the second line of the Xining-Golmud section of the Qinghai-Tibet Railway. The tunnel is a two-set, single-track tunnel and operates with a freight and passenger electrified railway. The construction stage began on Nov. 6, 2007 and the tunnel was opened up for operation on Dec. 28, 2014.

### **Tunneling project of the year (\$53.5 to \$535 million) — Fort Canning Station and Tunnels, Singapore**

As Singapore's underground space becomes more congested, the construction of new underground metro lines has become more challenging and complex. This tunneling project encountered challenges such as cutterhead interventions to remove foundations of buildings, close proximity to national monuments and in-service metro lines.

### **Outstanding Tunneling Project of the Year (up to \$53.5 million) — Chongqing Hongqihou Metro Station**

Chongqing Hongqihou metro station is located in a busy area of Chongqing and is under the main road to airport. The whole tunnel section is divided into four drifts. Two are on the top and another two in the bottom to be excavated. In this way, four drifts can be driven simultaneously. By using the inherent bearing capacity of "inner rocks supporting,"

the horizontal and vertical temporary support of the tunnel is saved.

### **Renovation/Upgrade Project of the Year — Vauxhall Station upgrade**

London underground's Vauxhall station upgrade will provide step-free access for users. Bechtel Ltd. is the main contractor with Gall Zeidler Consultants the designer in a design-build contract. Tunneling work will be done by Joseph Gallagher Ltd. The project team changed the reference design to a complete sprayed-concrete-lined (SCL) design to provide a more efficient construction program and reduce ground movements. The SCL approach resulted in nearly \$12.8 million in total cost savings.

### **Technical Innovation of the Year — Large diameter shield tunneling in pure sands with hybrid EPB shield technology**

The shield-driven tunnel of metro line 4 in Rio de Janeiro, Brazil is approximately 5.2 km (3.2 miles) long. The excavation was done using a hybrid earth-pressure-balance (EPB) shield with an excavation diameter of 11.51 m (37.8 ft) and passed through complex geology that included a long stretch of pure sand bounded by two stretches of hard, highly abrasive rock. Considerable reduction in materials and energy consumption was achieved with hybrid EPB technology.

### **Environmental Initiative of the Year — the Emscher Project**

The Emschergerossenschaft in Essen, Germany is one of the largest environmental projects in the world — the restructuring of an entire river system. This system has been used as an open wastewater transport system for more than 100 years. After 2020, the Emscher River will be transporting clean water again. To reach this target, it will be necessary to build a large 51-km (31.7-miles) long underground sewer from Dortmund to Dinslaken through a densely popu-

lated area of cities and suburbs.

### **Safety Initiative of the Year — ABSIS (Activity-based Safety Improvement System)**

ABSIS allows workers to view video footage of themselves on the job. Bypassing any language barrier, they are then able to see their own safety lapses, as well as good practices they can adopt.

### **Innovative Use of Underground Space — Jurong rock caverns**

The first commercial underground rock caverns facility for storage of liquid hydrocarbons in Southeast Asia, the Jurong Rock Caverns (JRC) will store liquid hydrocarbons such as crude oil and condensate. By using subterranean storage, the JRC ensures the security of the product and will save approximately 60 ha (148.3 acres) of land for other uses.

### **Young Tunneler of the Year — Derek Eng**

Derek Eng studied civil engineering and currently works as an assistant manager in the tunnel department for MMC Gamuda KVMRT (T) Sdn Bhd., a Malaysian-based company and the main contractor for mass rapid transit projects. In addition to his tunneling activities, he has focused his efforts on helping young people choose engineering as a career.

### **Lifetime Achievement — Martin Herrenknecht**

Martin Herrenknecht received the Lifetime Achievement Award for his remarkable contributions to tunneling. He received a doctorate from the Konstanz University of Applied Sciences in 1964, then founded his own company in 1975, which specialized in tunnel boring machines. In 2010, Herrenknecht AG was recognized for drilling the largest tunnel in the world. He also took part in the Eurasia Tunnel Project, which received the ITA Major Project of the Year Award in 2015. ■

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