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TUNNELING & UNDERGROUND CONSTRUCTION

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TBM at Stillwater Mine

Conveyor challenges in tunneling

Special Editorial Section from the publisher of *Mining Engineering*

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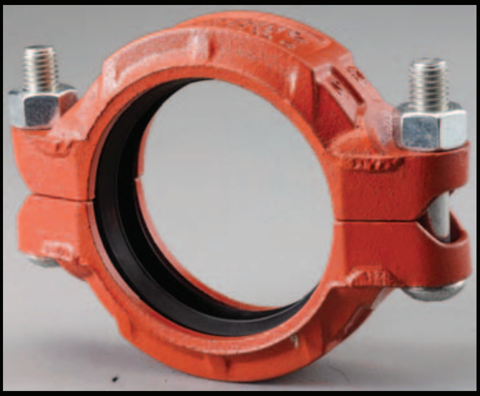

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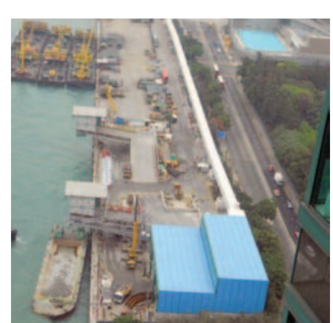

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CHAIRMAN'S COLUMN

Change is all around our industry and we should enjoy the ride

I would like to share some thoughts on the status of underground construction and tunneling in the United States based on some remarks I made while attending the Tunnelling Association of Canada in October.

Overall, I think the tunneling market is strong in the United States, especially compared with many other markets in this tough economy in recent years. You might say it is exciting and challenging at the same time.

One challenge I see is that we donot have a very good common data source that tracks our industry. But I think I can say our market outlook is strong for the years to come. Let me share some specifics that we do know. This is not scientific data. Rather, it is data gathered from many sources and is accurate information to the best of my knowledge.

For work to be potentially bid during the next 12 years, we are tracking just over $67 billion of tunnel work (160 projects), and $40 billion of that is to occur in the next five years. For these projects, our information suggests the following contract size breakdown: 10 percent less than $20 million, 15 percent between $20 and 50 million and 75 percent of the projects will be greater than $50 million. I think we are seeing a trend to larger projects and more mega jobs, which can be challenging for smaller companies.

The strongest market continues to be sewer and solid waste. Of those 160 jobs, 50 percent, or $14 billion, is in the sewer market. I think this has a lot to do with our mandated CSO programs. More than 700 cities in the United States have CSO problems and many implement tunneling into their solutions.

Currently, significant tunnel jobs are under way and will be for many years in Cleveland, OH, Indianapolis, IN and Washington, D.C., for example. Future programs requiring tunnels in various stages of planning and design are in Akron and Cincinnati, OH, Pittsburgh, PA and St. Louis and Kansas City, MO, to name a few.

Other markets that are showing improved strength are transportation and water. Transportation makes up 20 percent of the 160 projects and approximately $30 billion, almost one-half. While this sounds good on the surface, these seem to be the jobs with the greatest funding challenges.

Another point to consider is the type of tunneling. Of the 160 jobs referenced above, 50 jobs, or 30 percent, are hard rock tunneling boring machines (TBM); 50 jobs, or 30 percent, are pressured face TBM (slurry or EPB) and 30 jobs, or 18 percent, are drill-and-blast or sequential. I believe we are seeing an increased trend of pressurized face TBM work. As technology continues to improve, we are able to build tunnels in locations and ground types not previously considered for tunneling.

Another observation concerns procurement and contract type. The predominate procurement method still seems to be design-bid-build — about 70 percent of our market that I am referencing. Interestingly, about 20 jobs we know of will be design-build. This is an increasing trend and I think we will see more.

A significant change that seems to be gaining traction in our future is the design-build-finance, or P3 procurement. This is not entirely new to the industry, as other countries have been using it. However,

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Jeffrey Petersen,
UCA of SME Chairman

Work on $3.5 billion tunnel through the Andes could begin as early as 2013

Construction on 205-km- (127-mile-) long railway with a 52-km- (32-mile-) long tunnel through the Andes Mountains that will connect Chile and Argentina could begin as early as next year, according to a report by *The Associated Press*.

The proposed $3.5 billion private railway, known as the Aconcagua Bi-Oceanic Corridor, would link train and trucking hubs on both sides of the mountain range. Construction would take 10 years, but once completed, it could save millions of dollars and carve days off shipping times.

As it stands, the only major Andean pass in the southern half of the continent is snowed in each winter, stranding hundreds of cargo trucks in temperatures that can fall to minus -25° C (-13 ° F). And Pacific ports remain inaccessible to the Atlantic nation of Brazil, whose trans-Amazonian highway becomes a boggy mess even before reaching the mountains.

"There is a gigantic network of infrastructure on both sides of the mountain range with a bottleneck we must free up," said engineer Nicolas Posse, who is directing the project for Corporacion America.

The Argentine company leads a consortium that proposed the project. Both governments have committed to it as a matter of "national interest," creating a bi-national commission that is inviting bids. Initial feasibility studies have already been submitted.

Currently, much of the processed soy oils, wine and meat Argentina sends to China, as well as Asian electronics destined for Brazil, must first sail around the tip of South America, adding nearly 3,000 nautical miles and another week to the trip. Shipping by rail between Atlantic and Pacific ports would unite the most productive regions of Chile and its South American neighbors, making trade more competitive for all involved.

The Andean consortium also includes Japan's Mitsubishi Corp., Chile's Empresas Navieras SA, Contreras Hermanos SA of Argentina and Italy's Geodata SpA, which helped design other proposed tunnels linking Turin, Italy, and Lyon, France, as well as Europe and Africa through the Straits of Gibraltar.

All those efforts had government funding. The Andean project is unique in that it will be paid for privately by the consortium and through usage fees. The binational commission will provide loan guarantees, but put up no taxpayer money.

The initial phase would open a single tunnel and cost $3.5 billion with a capacity of 21.7 M/t (24 million st) of cargo a year. Depending on demand, the capacity could grow to 70 Mt (77 million st) and the total price tag to $5.9 billion by adding a second tunnel and additional rail lines on either side. As many as four mechanical excavators will be used to carve through the mountains. ■

UCA's *Handbook for Underground Construction and Tunneling* in the works

The Underground Construction Association (UCA) of SME has embarked on an endeavor with the goal to publish a book titled *Handbook for Underground Construction and Tunneling*. The UCA has asked UCA members Ray Henn and Dave Klug to lead the effort. Henn and Klug have put together a draft Table of Contents, and contacted other UCA members who have expressed an interest in serving as lead chapter authors. There are currently 47 chapters, with most chapters already having lead authors, but not all. If a chapter shows no current lead author listed next to the chapter title in the Table of Contents and you would be interested in filling this role, please contact Henn or Klug. Also we strongly encourage others to volunteer as chapter contributors. These interested individuals should contact the lead chapter authors directly. The current schedule has the completed book being turned in to SME for printing in the fall of 2014. The draft Table of Contents is on page 8 of this issue. If you have any questions please feel free to contact:

Ray Henn: email rhenn@brierleyassociates.com, phone 303-534-5789 ext. 3212.

Dave Klug: email DKlug@DRKlug.com, phone: 724-942-4670

It is believed by the UCA Executive Committee, as well as the SME's Board of Directors, that this type of book is much needed by the underground construction industry and, with the help of UCA members and others in the industry, we can make it happen. Updates on the progress of the book will follow in future issues of *T&UC Magazine*.

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Chairman's Column:

(Continued from page 2)

it has not played a significant role in the United States until recently.

At least four of the jobs that have I referenced are planned to have some sort of financing involved. This is a significant change that can impact many of us in different ways. For example, P3 jobs are expensive jobs to pursue. This can be difficult for many companies (engineer or contractor) to handle the up-front cost of procurement. In addition, it positions us in roles we are not accustomed to — engineers, finance teams and contractors all working together to provide a final product to a client, sometimes with long-term maintenance included. It also puts a new twist on subcontractors and suppliers, as they often price the work after a team has won the job, not before the bid. There is no doubt that these types of changes will have a significant impact on our industry in the near future, as clients explore new ways to finance projects.

One final market observation is one that I am sure those long-time industry professionals are familiar with. I think we are seeing a significant shift of work from the Northeast to the West Coast. Granted, there are significant tunnel programs and projects on both coasts and in the middle of the country. However, with many of the New York City jobs nearing completion, we are seeing a significant upturn in tunneling work in California — both in transit and water programs. It will be interesting to see how the industry engages in these new programs (the Bay Delta Conservation Plan — about $6 billion in tunneling in California), and if there really is a shift to the West for volume of work, or if it is just a "perception" when truly there is high demand across the nation and, quite frankly, into Canada.

So the market is not perfect for anyone involved. However, from the sampling of information that I presented here, I believe the tunneling market is strong in the U.S. and should continue to be so in the coming years, but not without its changing dynamics and challenges.

With that, here are a few challenges I see that will keep the industry from being successful if it does not deal with them appropriately. Of course, there are many challenges and elements to success (or failure) in our business; I want to address four of them specifically.

Safety: I know it is improving, but too many people are hurt in our industry and that is unacceptable. There is no good data source, so I do not have any specifics. I am not just talking about contractors. Everyone involved has a duty to do better — owners, clients, engineers, suppliers, and especially contractors.

Most people talk about safety first, but when it really comes down to it, they do not practice what they preach. Risks are ignored and shortcuts are taken, usually to "save"

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time or maybe even money. Oftentimes, people do not even notice they are taking shortcuts because we become complacent. That is until it is too late.

The worst thing for me to hear is when people say, "It is dangerous work; people are going to get hurt." I disagree. We have many tools and processes available to eliminate the danger. No one has to get hurt. I don't think there is an injury, accident or near-hit, that once a proper investigation has been completed, would not flush out a shortcut that was taken or a process was not followed, or the engineering was not complete.

Safe work is successful work. If we improve safety, we will improve our industry. It is obvious to me that this is the right thing to do. If you don't see it that way, then think about the cost. Bad safety performance has a significant negative impact on our industry. It keeps good people away, and they do not want to work where there is a perception of frequent injury — both in salary and craft levels. And we need more people. Bad safety slows down production, increases project costs and our insurance costs are higher. By improving safety, we will be improving our industry.

I hope the industry will someday find a way to share better statistics and, more importantly, share lessons learned so we can all gain from each other's experience in safety.

World Tunneling published an article by Peter Tarkoy on minimizing accidents in tunneling. It is a great "case study" format of lessons learned. I think every publication should start off with an article on safety. It does not have to be long and it could be a great way to send and reinforce the message of Safety First. Please take action today to think about what you can do to improve safety. We all have a duty to keep our friends, family, coworkers and ourselves from getting hurt.

People: The second challenge facing the tunneling industry is people. To take on all the work that we know about, we need more people. This includes engineers, management, craft and of all types of skills. We have a shortage now along with an aging workforce. This is only going to get worse. It takes many years to become skilled in this business. It is important that we start training more people now. I don't think there is a simple answer to solve this, but here are some ideas: We need to start at the schools — high schools, universities and trade schools.

We need to develop interest early — the Moles and Beavers do a high school career day in tunneling. I believe we need more of these types of programs.

The Colorado School of Mines is developing an undergraduate tunneling program.

We need more engineering programs for electrical and hydraulic engineers for the TBM's, drills and roadheaders. Our equipment is very complicated and is becoming more so.

Not everyone went or wants to go to college. We need more crane operators and skilled operators interested in our business.

The jobs my company is affiliated with tell a story about the lack of skilled, experienced people and the impact it has on our work. If we want to grow the capacity of our industry, to successfully take on more tunneling and underground construction, we must develop better engineering and technical training programs, and spur interest in this fun, challenging and rewarding industry sooner in the development of our future talent.

Technology: I believe the adoption of technology has had mixed success in our industry — some accept it, some resist it. Some elements are changing fast, and others are the same as they have always been. I think that is OK. I suppose the best solution is the right balance. I am excited to see where changing and improving technology will take us in the near future. Recent years have produced technological advances in many aspects of our work, such as safer operations, more productive equipment, larger TBM's, better ground conditioning, and high performance concrete and shotcrete. This is true in all aspects of our business.

So what does the future hold? I am sure there are many people that can answer this better than I can. What I do know, though, is that technology will continue to have a positive impact on the industry. I'm excited to see where underground and tunnel construction will go with improved technology, whether developed specifically by us or for us, or possibly things copied from other industries in a creative application to benefit us. I look forward to safer work environments and more production from our equipment and underground construction in places we do not normally go now. Ultimately, the better the product, the more cost effective it will be for our clients.

Funding: There is a large demand for new infrastructure in the United States. We also have a huge demand for repair and maintenance of aging infrastructure. All of this work shares limited resources, be it public or private funding. In addition, there are the varying impacts of local and global economic issues, not to mention the variables to be introduced following the presidential election a few weeks ago. I certainly cannot predict how it will work out. I do think we will see new, creative solutions to funding challenges, which will have a significant impact in the standard design-bid-build procurement process. But change is good. I believe that it is up to us to be engaged so we make change positive for the future.

I know there are many challenges and issues that have an impact on our industry, but those are four relative to our current conditions: safety, people demand, technology improvement and funding challenges.

I hope you join my optimism that we have a strong market ripe for opportunity. I look forward to the exciting changes ahead that take our industry to new levels and new environments. Working together, it will be successful. ■

Jollyville Transmission line uses three TBMs

Deep below Austin, TX, the sprawling Jollyville transmission main is set to increase capacity of the city's main drinking water reservoir. The 10.5-km- (6.5-mile-) waterway is being constructed using three tunnel boring machines (TBM), including two Robbins machines, up to 107 m (350 ft) below the city. The Southland/Mole JV is building the 2.1-m (84-in.) finished diameter pipeline below residential areas and the protected Balcones Canyonlands Preserve.

Three TBMs will excavate the pipeline, with one contractor-owned machine having completed its 1.4 km (0.9 mile) section in mid-2012. Robbins supplied an additional 3.25 m (10.7 ft) main beam TBM, and refurbished a 3-m (9.8-ft) double shield TBM in its Solon, OH manufacturing facility. Both machines were launched in August 2012 from deep shaft sites.

Conditions along the way are expected to consist of uniform limestone and dolomite rock. Although karst features are present throughout the formation, the depth of the tunnel should circumvent these features. Other obstacles are associated with the protected wildlife area — endangered cave-dwelling invertebrates including six species of arachnids and insects are present in and around the karsts. Because of this, no probe grouting can be performed due to the risk of seepage into the water features.

Within a week of its launch in late August 2012, the main beam machine had advanced about 90 m (300 ft). The fast advance is a result of extensive planning, as logistics are often a limiting factor at small tunnel diameters.

In the main beam tunnel, Southland has planned for two California switches and one shaft switch. An oversized vent duct and additional fans will help aerate the tunnel.

Once complete in 2013, the pipeline will transfer up to 190 million L (50 million gal) of treated water per day from Lake Travis. The tunnel, for the Austin Water Utility, will connect up with the new Water Treatment Plant 4 currently under construction — part of a larger scheme to provide increased water capacity for a projected 60 percent increase in population over the next two decades. ■

Aker Wirth delivers first TBM for Koralm Tunnel

Austria's Koralm Tunnel will be a high-speed train route between Graz and Klagenfurt that will be as much as 1,250 m (4,100 ft) below the Koralpe Mountains when it is completed.

In August, the first of two Aker Wirth tunnel boring machines (TBM) for the project was delivered. The two telescopic shield machines each have a diameter of 9.93 m (32.5 ft). The machines will be in operation from the end of 2012 at the main construction lot, KAT 2. This section, approximately 18 km (11 miles) in length, represents the heart of the 32.5-km- (20-mile-) long Koralm tunnel.

Access to the underground construction work areas is a particular challenge of this complex project. The only possibility is a 60-m- (197-ft-) deep shaft, through which the main components of the machine will be transported and subsequently assembled. "With this project, we can draw on more than 40 years of experience in hard-rock tunnelling," said Hans Greve, vice president Mining & Construction at Aker Wirth. "With our experienced employees and our customer's skilled personnel, we are confident that we will successfully meet the challenges regarding underground assembly."

Both telescopic shield machines are equipped with hard-rock cutting rings manufactured by Aker Wirth. The combination of these cutting tools with Aker Wirth's cutter head design ensures an optimal balance between durability and drilling performance.

"With the factory approval for the first TBM, we have reached a significant milestone for our KAT 2 (Koralm tunnel construction lot 2) tunnel construction project," said Robert Goliasch, machine engineer at ARGE Koralm tunnel KAT 2. "Together with our skilled personnel, we were able to be present during the assembly at the factory, to contribute to the installation and, consequently, get to know the new tunnel boring machine. As a result, we hope to gain time for the underground installation and for a speedy commissioning. The first performance tests have done justice to Aker Wirth's reputation as a manufacturer of high-quality tunnel boring machines for hard rock."

Koralm line project

With the Koralm line, the ÖBB (Austrian railway system) is constructing a new high-speed train route between Graz and Klagenfurt. This will reduce travel durations in the future by more than a half. This 130-km- (81-miles-) long key link is part of the Baltic-Adriatic Axis from Eastern Europe to northern Italy via Austria. With two parallel single-track tunnel tubes and a length of more than 30 km (18.6 miles), the Koralm Tunnel is the core of this railway line and will be one of the longest traffic tunnels in the world. ■

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T&UC BUSINESS PROFILES

A special advertiser sponsored advertorial section

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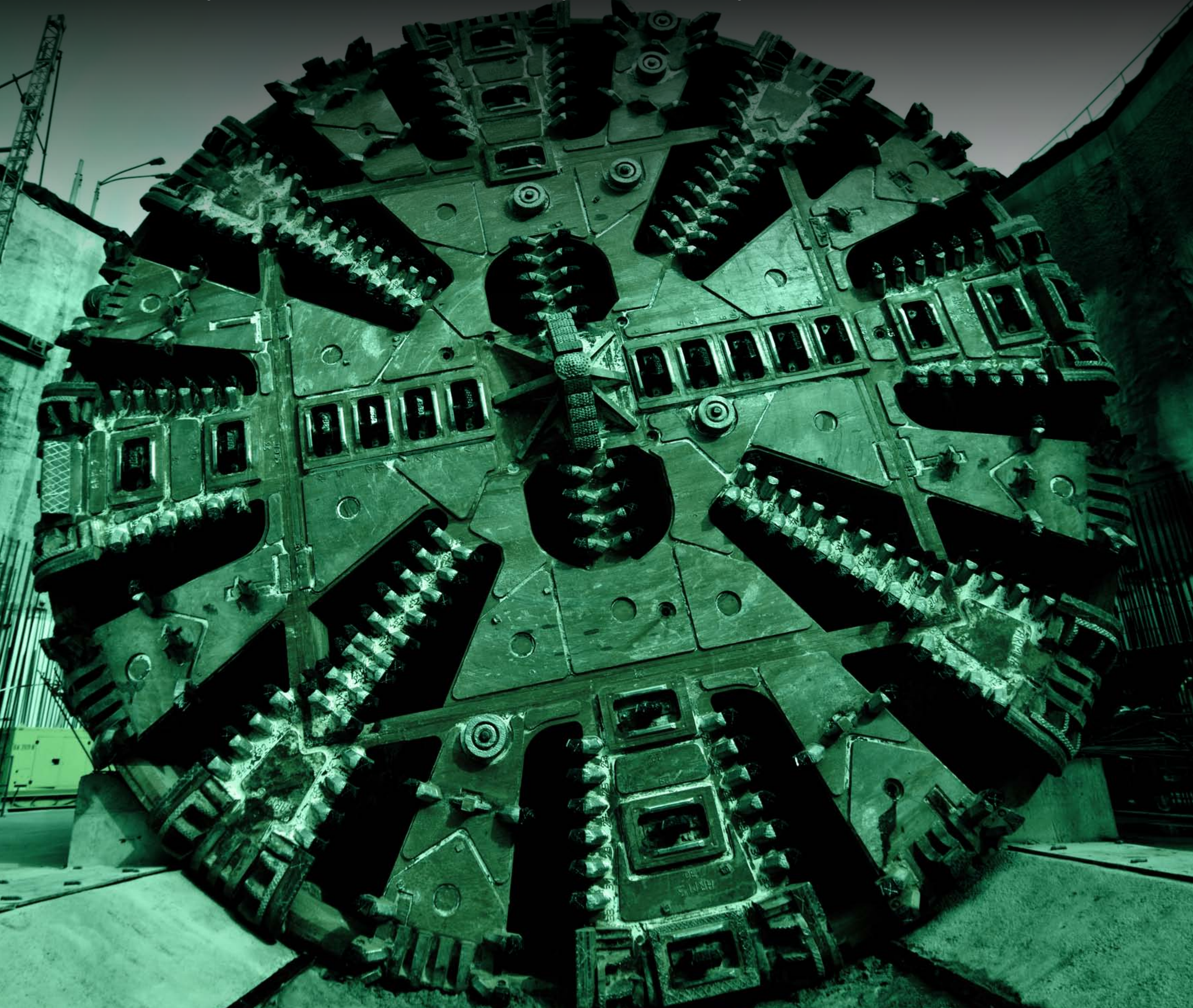
SME and T&UC acknowledge these companies that demonstrate a continued focus on providing the world with the best in underground technology, products and services.



Makers of Underground History

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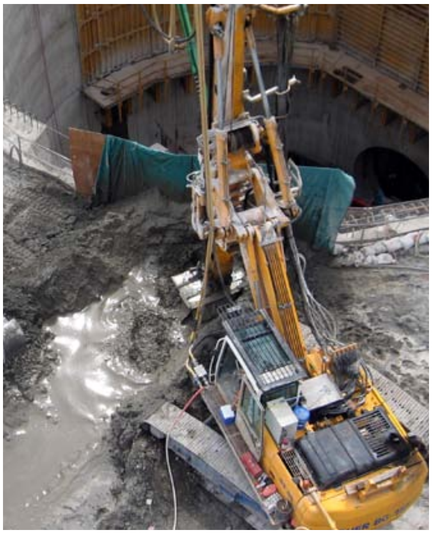
Hayward Baker handles geotechnical challenges both large and small. Our extensive experience with the full range of ground modification techniques has been applied to hundreds of tunneling projects. Commonly applied tunneling services include earth retention, underpinning, waterproofing, soil improvement,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


Lower North Outfall Sewer

River Supply Conduit Unit 4
Los Angeles, CA

Ground subsidence above a 108-inch-diameter tunnel for a water supply line required compaction grouting (low-mobility) to densify disturbed soil and control settlement. Hayward Baker drilled over 180 grout holes between 10 and 23 ft deep, and pumped over 350 cy of low-mobility grout over a 600-ft length of the tunnel. All work was completed safely even though a portion was within a major city intersection.


River Supply Conduit Unit 4

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-ft long segment of the proposed 20,000-ft long, 12-ft diameter combined sewer tunnel. A total of 40,000 ft of grout holes was drilled to complete the project. Depths of the grout holes were approximately 170 ft from ground surface.

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Messinger Bearings is one of an elite few companies in the world capable of producing large, custom-designed bearings in limited quantities for tunnel boring machines (TBMs). In its new business model, Messinger is addressing the challenge from most end users today about how to get new or repaired bearings of this size delivered in a reasonable timeframe.

TBM Bearing Customers Have an Option

Based in Philadelphia, Messinger Bearings was established in 1912 as a designer and manufacturer of large, heavy duty rolling element bearings. Today, Messinger Bearings focuses on providing large diameter custom bearings for unique applications, including those found in much of the TBM equipment. Messinger can manufacture new bearings to 25 ft in diameter, as well as repair them. In fact, Messinger is one of the few bearing manufacturers in the United States capable of turning bearings of this size. Messinger's manufacturing facility has been expanded to include a new state-of-the-art CNC vertical boring mill along with new induction heat treat capabilities.

New or Rebuild? Your Choice

Deliveries for 3-row TBM main bearings have been a recurring challenge for TBM customers. Given the increased focus in recent years for renewable energy, this will likely get worse. Messinger chooses not to participate in the wind energy business because it does not enable the company to support its current customers and its core business, that is, large heavy-duty custom bearings for specialty applications in limited quantities. Aside from new bearings, many of Messinger's customers ask us to repair their existing bearings.

For example, a TBM project was recently under way and the spare bearing was found to have a broken outer race. In addition to manufacturing a new outer race, Messinger was able to repair the entire bearing in more than enough time to have it on site when needed. Considerable savings were realized, not only with the repair itself but also by limiting downtime.

TBM Bearings and More, Planning for the Future

Messinger has expanded its capacity to manufacture and repair bearings up to 25-ft OD for TBM and other custom applications. Aside from equipment capacity, additional personnel for engineering, design and manufacturing have been and continue to be added to the team. In addition to the large 3-row and other style of cylindrical roller bearings, Messinger is also now well positioned to repair large bore tapered roller bearings.

Messinger Bearings
A Kingsbury Brand
Telephone: +1-215-739-6880
www.messingerbearings.com


CAP.
100
YEARS OF
DOING IT
BIG.

J.H. Fletcher & Co. – Technology at Work Worldwide

Since 1937, J. H. Fletcher & Co. has affirmed its position as the premier engineering and design firm that creates mobile equipment solutions for underground mines. When rail was recognized as too cumbersome, Fletcher applied rubber-tire technology to underground supply and haulage vehicles. When quicker timbering methods were needed, Fletcher introduced tire-mounted timbering machines. When new methods of roof control were being explored, Fletcher built the first practical roof control drill.

Today, Fletcher remote-controlled and operator-up roof bolters secure overhead rock using advanced computer technology that senses geologic conditions for optimum drilling and roof mapping – without the operator leaving the compartment. Fletcher single- and dual-boom drill jumbos cover headings up to 60' wide by 35' high, using high-performance hammers with unsurpassed efficiency, and new Graphic Operator Angle Display technology for greater accuracy. Fletcher scaling vehicles, built from the ground up for the rigors of underground work, remove hazardous materials from heights up to 50'. Fletcher powder loaders allow charging crews to work in lower-than-ever DPM and noise levels. And powerful Fletcher diesel tractors ply in and out of the mines hauling supplies quickly and efficiently.

Features like ergonomically-designed, pressurized operator compartments and demand-based engine speed improve efficiency and operator comfort. Today's Fletcher customers have more options than ever for integrating their overall equipment strategies across machines.

Listen. Think. Create.

Fletcher engineers spend more time in the field, listening to customers telling what they like – and don't like – about mobile equipment. How can operations be made more efficient? How can operators be kept safer, or more comfortable? Some of our best ideas begin when a customer asks, "Why can't..?" This eagerness to solve customer problems sets Fletcher apart.

Research & Development looks into major ideas that require new designs or application of new technologies. Perhaps a company with more than 70 years in the business has resolved that issue before. In that case, Engineering may be able to apply earlier solutions to modern machines. Either way, Fletcher hires and keeps some of the best electrical, mechanical and hydraulic engineering minds in the business – the same people who will work on your equipment.

Fletcher's unique manufacturing process allows each machine to be assembled by a single team of technicians, following the process from start to finish. It's their handiwork, and every team takes pride in the equipment it ships.

Managing Risk

Every equipment manufacturer and mine should do all it can to optimize the safety and comfort of its workers. No one takes safety more seriously than J. H. Fletcher & Co. Our full-time, fully-staffed Risk Management Department focuses on equipment safety and product liability issues. They support every customer with operator training and re-training programs, audio-visual operating programs, newsletters and safety bulletins, manuals, warning tags -- whatever it takes to help our customers operate profitably, efficiently and with greatest worker safety.

J.H. Fletcher & Co.
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Ramp Up Your Construction Operation

Roof Bolter

Drill Jumbos -
single and dual-boom models.

Roof Bolters -
operating in heights from 40' to 40".

Beam Setters -
transport, place and hold heavy beam assemblies during installation.

All are powerfully built to withstand years in punishing underground applications.

Beam Setter

Drill Jumbo

Time and money spent on constructing slopes and tunnels is serious business, demanding efficiency for that competitive edge. Call on Fletcher's expertise for your construction needs. Engineered for productivity with a focus on safety to meet your most severe requirements.

Email Ben Hardman at bhardman@jhfletcher.com or call 304.525.7811 for product details and information.

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DRILL JUMBOS • ROOF BOLTERS • BEAM SETTERS

H+E Logistics USA Inc.

Quality from one source.

New tunnel constructions require tunnel conveyor belts and conveyor systems. Providers that stay on the international market are those that remain competitive through continuous process optimisation. H+E does this; we have been able to position ourselves successfully as a highly specialised provider.

To give room to sustainability and corporate growth, we have expanded in 2010 with the opening of a further site: the H+E production facility in Aschersleben. Equipped with state of the art machinery, this production site is optimally geared towards the individual requirements of our clients.

The H+E site in Aschersleben, Germany is also a training centre which enables us to provide young people with individual opportunities for professional development within this highly interesting sector.

It is important to us that every employee – whether in development, production or projects around the world – upholds our philosophy: Innovation, reliability and competitiveness form the basis for the trust that our clients place in us

In tunnelling, even the best machines will not get far without a well functioning back-up system.

H+E conveyor belt systems guarantee that excavated material is removed quickly and smoothly. They are seamlessly linked to mechanical tunnelling systems as well as to conventional drill and blast application. They represent a clean logistics solution that does away with the need for truck or rail transport, so there are no exhaust fumes and therefore no need for ventilation systems. Instead, they require minimum staffing and pose a minimum danger of accidents. What is more, our conveyor systems are not one-way streets but also function as efficient supply routes.

Non-stop service. From initial planning to final operation.

H+E conveyor belt systems are high-tech systems which put huge and divergent forces on the right track with great precision. Making sure that nothing goes wrong requires expertise, years of experience and a good instinct. At H+E these qualities come together to produce ready to use conveyor systems with the highest degree of reliability.

The streamlined company. We transport all types of materials.

H+E Logistik offers tunnel conveyor systems for all companies which have a lot to move.

We plan, produce, supply and install ready to use systems, from a few meters to thirty kilometers in length. And if that's not long enough, we can easily provide even longer systems. We set up the systems and ensure they operate reliably. Our technology and expertise have proved their worth in many international projects.

Hurdles are no headache for us.

Our flexible conveying systems always offer smooth logistics solutions at construction sites and other locations. For us, difficult situations are not a problem, but a challenge.

Herrenknecht AG holds a majority share in H+E Logistik.

So our customers can rely on the security of an international leader in mechanical tunnelling – with over 3000 employees worldwide, more than 30 years of experience and hundreds of successfully completed projects around the world.

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JENNMAR

We're JENNMAR, a global, family-owned company that is leading the way in ground control technology for the mining, tunneling and civil construction industries.

JENNMAR was born in 1965 and by 1972 our mission had become focused on developing and manufacturing quality ground control products. Today we make 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 mining, tunneling and civil construction safer and more efficient. And with manufacturing plants and distribution networks around the world, we are uniquely positioned to react to ground control needs anywhere, anytime.

Worldwide

We now operate eleven manufacturing plants throughout the United States. Of these eleven facilities, ten are related to manufacturing ground control products, and the eleventh is a steel service center that supplies a steady flow of flat steel products. Globally, we operate eight manufacturing facilities, with two located in Australia and the others in China, Chile, Canada, Poland and the Czech Republic. J-LOK, our resin manufacturing affiliate, has two domestic manufacturing locations with another one in Australia.

A Single Source Provider

Our network of affiliates includes engineering services, resin and rolled steel manufacturing, custom steel fabrication, chemical roof support and sealing products, and even includes 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!

Our Affiliates

J-LOK Resins (www.j-lok.com) - 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 (www.jennchem.com) - JENNCHEM designs and delivers chemical roof support, rock stabilization and ventilation sealing products to the mining and underground construction industries. JENNCHEM's lab and test facility conducts meticulous and ongoing testing to ensure reliability and consistency of all products.

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

JENNMAR Specialty Products (www.jm-specialty.com) - JENNMAR Specialty Products provides custom steel fabrication services. Products include Square Sets, Impact Resistant Arch Sets, Bent Arch Sets and Long Radius Arch Sets.

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

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www.jennmar.com

Geokon, Incorporated

Geokon, Incorporated, is a 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. The company was founded in 1979 and 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 software.

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

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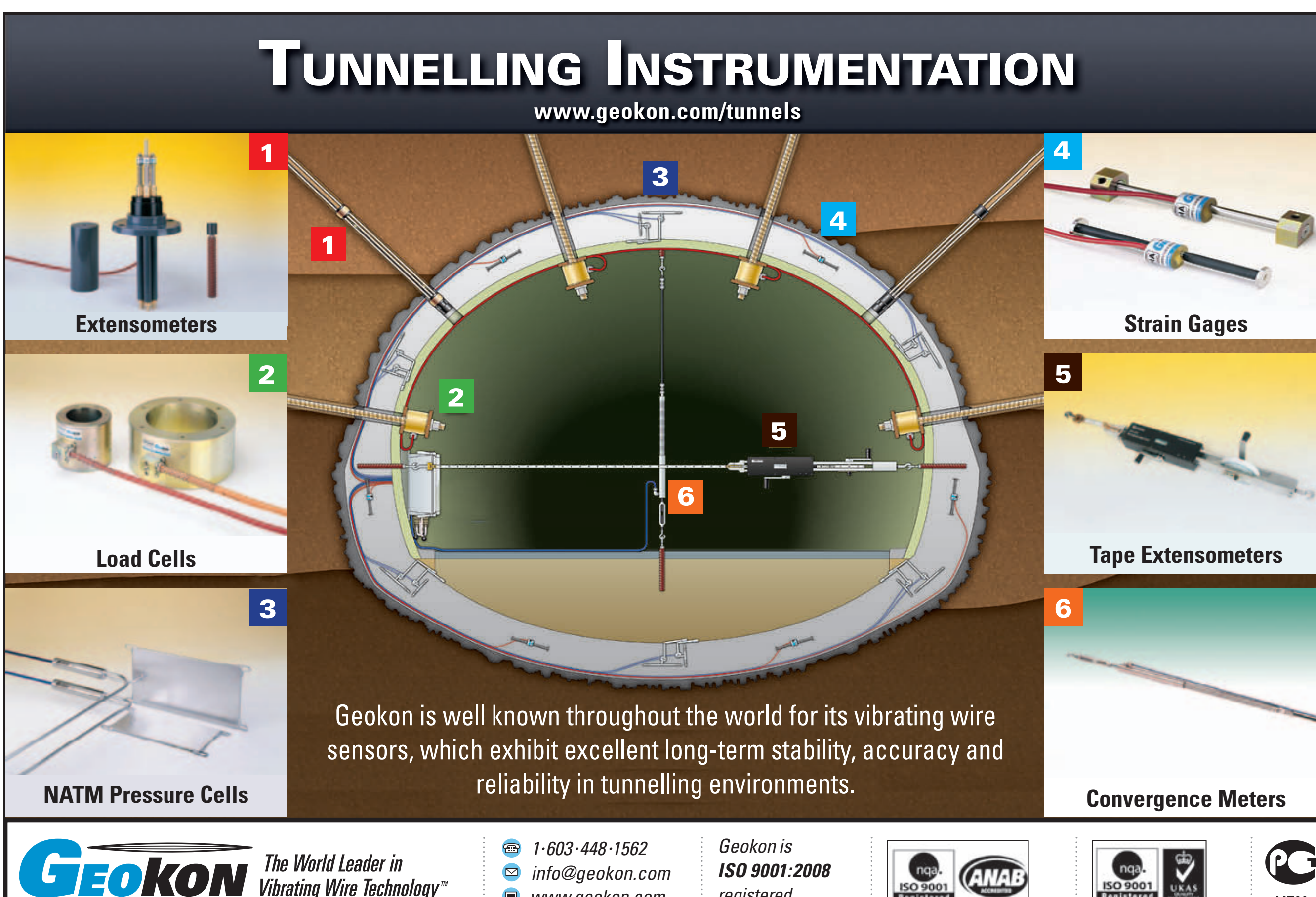


Connecting infrastructure across the globe

Founded in 1944, Parsons, an engineering, construction, technical, and management services firm that is 100% owned by the Employee Stock Ownership Trust, conquers the toughest logistical challenges and delivers design/design-build, program/construction management, and other professional services packaged in innovative alternative delivery methods to federal, regional, and local government agencies, as well as to private industrial customers worldwide. Parsons is a leader in many diversified markets with a focus on transportation, environmental/infrastructure, and defense/security. The firm employs more than 11,500 professionals around the world who are prepared to meet every technical and management challenge, no matter when or where, and to persevere until the job is done.

Parsons has been combining strong forward thinking with cutting-edge technology to improve the way people connect with the world since the firm's inception, striking a balance between big ideas and the technical ability to bring them to life. Thanks to Parsons' global network of resources, it has the power to combine state-of-the-art technology with unparalleled quality and control, all supported by an unwavering commitment to safety on all projects, under any conditions. Throughout its history, Parsons has provided transportation services on projects of all sizes and complexities. From the world's largest airports to iconic bridges and the most widely recognized tunnels, the firm has the scope, resources, people, and experience to deliver world-class performance on schedule and within budget.

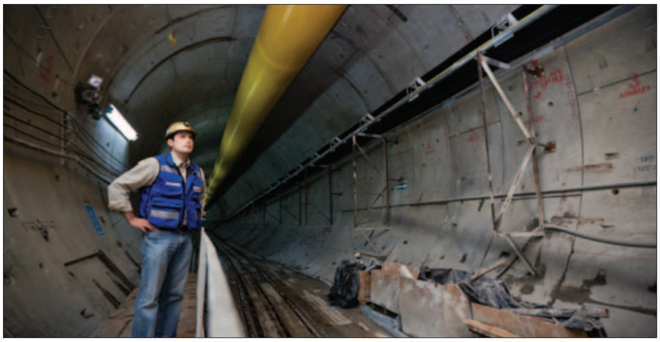
Parsons is the premier source for end-to-end design-build transportation engineering capabilities, including expert multidisciplinary planning, all phases of construction and implementation, and maintenance and improvements. Its Tunnel Division has contributed to 250 international tunnel projects, including the Caldecott Tunnel improvement project, which involves the construction of a fourth bore through the Berkeley Hills, near Oakland, California, and the Washington, D.C., Metro twin-tunnel program, cited by the American Underground Association as one of the most significant tunneling projects in the last 10 years.

Serving the underground engineering and program management needs of a diverse customer base, Parsons lends its expertise to projects such as underground utilities, water storage and transportation tunnels, and underground buildings. The firm has provided advisory services, performed subway construction, and delivered major highway tunnel projects, including the New York Gowanus Expressway and the English Channel Tunnel. Parsons offers a host of innovative tunneling techniques, like the New Austrian Tunneling Method, top-down tunneling, advanced hard-rock and soft-ground tunnel-boring machine technology, single-pass tunnel construction, and advanced tunnel waterproofing systems, to minimize the risks associated with underground structures. Throughout the firm's history, Parsons has worked to provide safer, better, more sustainable ways to travel the world — one project at a time. Learn more at www.parsons.com

Parsons
www.parsons.com

The New Standard for Tunneling

With 60 years of experience, The Robbins Company is the world's foremost developer and manufacturer of advanced, underground construction machinery. Throughout 2012, Robbins TBMs made swift headway on a variety of projects worldwide. Innovative concepts continue to expand the company's scope, from efficient TBM assembly methods to high-performance machine designs resulting in landmark performances through both soft ground and hard rock.



Total Supply Company

Robbins is a total supply company, offering everything from cutters and stacker conveyors to knowledgeable field personnel and technical support. Robbins' time-saving Onsite First Time Assembly (OFTA) method was first used at Canada's Niagara Tunnel Project in 2006 and continues to be successfully carried out on multiple projects and with all types of TBMs. The method results in significant time savings and cost reductions for the contractor, all by initially assembling the TBM at the jobsite rather than in a manufacturing facility. The method has been used most recently for the Kargi Hydroelectric Project, where a 10.0 m (32.8 ft) Double Shield TBM is excavating an 11.6 km (7.2 mi) headrace tunnel through fractured ground in Corum Province, Turkey.

Robbins' field service personnel bring years of engineering experience to each project. In the first quarter of 2013, personnel will help guide the transport of large TBM components through San Francisco, California's narrow and steep city streets. The team will then oversee the onsite assembly of two 6.3 m (20.7 ft) diameter Robbins EPBs in dense urban surroundings for the city's Central Subway project.

Continued Success in Hard Rock and Soft Ground

Robbins EPBs continue to achieve remarkable advance rates in soft ground, taking the industry standard from 400 m (1,312 ft) to 700 m (2,297 ft) a month. In 2012, Mexico's largest EPB, the 10.2 m (33 ft) Robbins giant boring Mexico City's new Metro Line 12 achieved advance rates up to 133 m (443 ft) per week, making its final breakthrough in early February. Also in Mexico City, three 8.93 m (29.3 ft) Robbins EPB machines are boring the Emisor Oriente wastewater line, with the first machine breaking through a critical portion of the line in Autumn 2012.

In Austin, Texas, USA, a 3.25 m (10.7 ft) Robbins TBM is flying through limestone rock at average rates of 55 m (180 ft) per day, with several days over 60 m (200 ft). The Main Beam machine and a refurbished 3.0 m (9.8 ft) Double Shield TBM are successfully boring the Jollyville Transmission Main, a new water tunnel, with minimal impact below the Balcones Canyonlands wildlife refuge.

Robbins innovations will continue to advance into 2013, with major hard rock and mixed ground projects gearing up across the U.S.—from mine access tunneling in Montana to a deep rock sewer bore in Indianapolis, Indiana. For further information on tunneling projects and groundbreaking R&D, visit www.TheRobbinsCompany.com or call +1 (440) 248-3303.

The Robbins Company
Telephone: +1-440-248-3303
www.TheRobbinsCompany.com

Tensar International Corporation

Tensar International Corporation (Tensar) offers a number of solutions to support the unique requirements of mining and tunneling construction. Tensar® Mining Systems include a family of polymeric grid products.

Made from high-strength, corrosion-resistant polymers, these geosynthetic reinforcement products are lightweight and easy to handle; this allows for safe, quick and easy installation, resulting in significantly fewer back, hand and facial injuries. Compared with metal reinforcement products, Tensar mining products can reduce installation and material handling time up to 75%.

Our Mining Systems offer cost-effective solutions for a wide range of underground mine and tunnel applications, including:

- Rib Control (Tensar® TriAx® and BX Mining Grid)
- Roof Control (Tensar® TriAx® and Tensar® UX3340 Roof Mats)
- Longwall Screens (Minex™ Rock Mesh)
- Highwall Screens (Tensar® TriAx® Mining Grid)
- Road Reinforcement (Spectra® Roadway Improvement System)

Tensar International Corporation
Telephone: +1-888-826-0715
www.tensarcorp.com

Rapid Set® Cement Products for Tunneling and Mining

CTS Cement Manufacturing Corporation is the largest manufacturer of Rapid Set® fast-setting hydraulic cement, well known for its versatility and high performance. Rapid Set® products are used for underground roadway repair, shotcrete, grout, cribbing for long- wall mining- mostly coal mining, and the precast concrete tunnel segment industry. Rapid Set® cement is not only a more durable alternative to portland cement on many projects, but its rapid-setting properties also make it an ideal solution for today's schedule- and budget-driven projects.

Rapid Set® cement offers reduced shrinkage and superior resistance to chemical attack. It achieves strength much faster and many installations can be put into service in as little time as one hour. Rapid Set® cement reaches typical compressive strengths in a few hours that an equivalent portland cement mix would require one month to achieve. In fact, Rapid Set® cement is a high performance binder that outperforms portland cement-based products consistently. Durability, versatility, speed and ease-of-use along with cost benefits are just some of the many benefits Rapid Set® cement offers.

Headquartered in Cypress, California, CTS manufactures Rapid Set® in the United States. Rapid Set® is distributed through a network of distributors and dealers throughout the United States and Canada. To learn more about Rapid Set® cement, visit www.ctscement.com or call 800-929-3030.

CTS Cement Manufacturing Corp.
Telephone: +1-800-929-3030
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Rapid Set®
Construction Cement Products

Envirosystems, LLC

ENVIROSYSTEMS has been designing and manufacturing industrial dust collection systems since 1988 for use in all types of manufacturing processes resulting in airborne contamination.

The current line of AirWall dust collection products have evolved into a very robust product design. Envirosystem's main product line is the many standard and custom versions of that initial AirWall dust collection unit, ranging from 1,200 CFM to over a million CFM. Adaptable to most variations of underground equipment the AirWall will provide underground dust capture at the source.

The high reliability and extremely low energy consumption per CFM of the AirWall units have lead to a high customer satisfaction, with a high percentage of sales attributed to repeat orders from existing customers.

Envirosystems, LLC
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www.envirosystemsllc.com

Mining Equipment Ltd.

12-ton explosion proof diesel locomotive pulling 8 cubic meter side-dump muck cars out of the tunnel.

Mining Equipment has been supplying the mining and tunneling industries with top quality rolling stock for more than 30 years. They supply diesel and battery locomotives up to 35 tons. As well as a complete line of non-propelled rolling stock including muck cars, flat cars, personnel cars, segment car and concrete agitator cars.

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. There primary shop is in Farmington, New Mexico. They also have a fabrication facility near Shanghai, China and an office in North Bay, Ontario.

25-ton diesel locomotive pulling a string of 15 cubic meter capacity roll-over muck cars through a dump at their mine in Papua New Guinea.

Mining Equipment Ltd.
Telephone: +1-970-259-0412
Fax: +1-970-259-5149
www.miningequipmentltd.com

Underground Intelligence with Brierley Associates

Brierley Associates partners with clients and peers to produce underground facilities that are cost effective and timely, and employ the best that tunneling technology has to offer. A vibrant and growing national firm with 60 employees in nine states and counting; Brierley Associates offers a full range of underground design, geotechnical, and construction consulting and management services. With extensive experience in design and design-build, the team has experience on hundreds of major projects in all types of ground conditions throughout the United States. We strive to create a working environment that is conducive to cooperation, motivation, innovation, and accomplishment.

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BRIERLEY ASSOCIATES

Creating Space Underground

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40 Years of High-Performance Waterproofing Solutions

Established in 1970, Stirling Lloyd leads the world in the provision of high performance waterproofing systems for tunnels and bridges. Utilizing our advanced MMA technology, over 75 million square feet of Integritank and Eliminator sprayed membranes have been applied and are protecting many of the world's key infrastructure crossings from premature degradation.

Innovative solutions are available for the external waterproofing of cut and cover and immersed tube tunnels as well as for the waterproofing of suspended decks in all tunnel types. The latest addition to the Company's range is the Integritank HF sprayed waterproofing membrane, which enables owners, designers and contractors to effectively waterproof the internal linings of SCL/NATM tunnels, and can be non-destructively tested to confirm 100% integrity.

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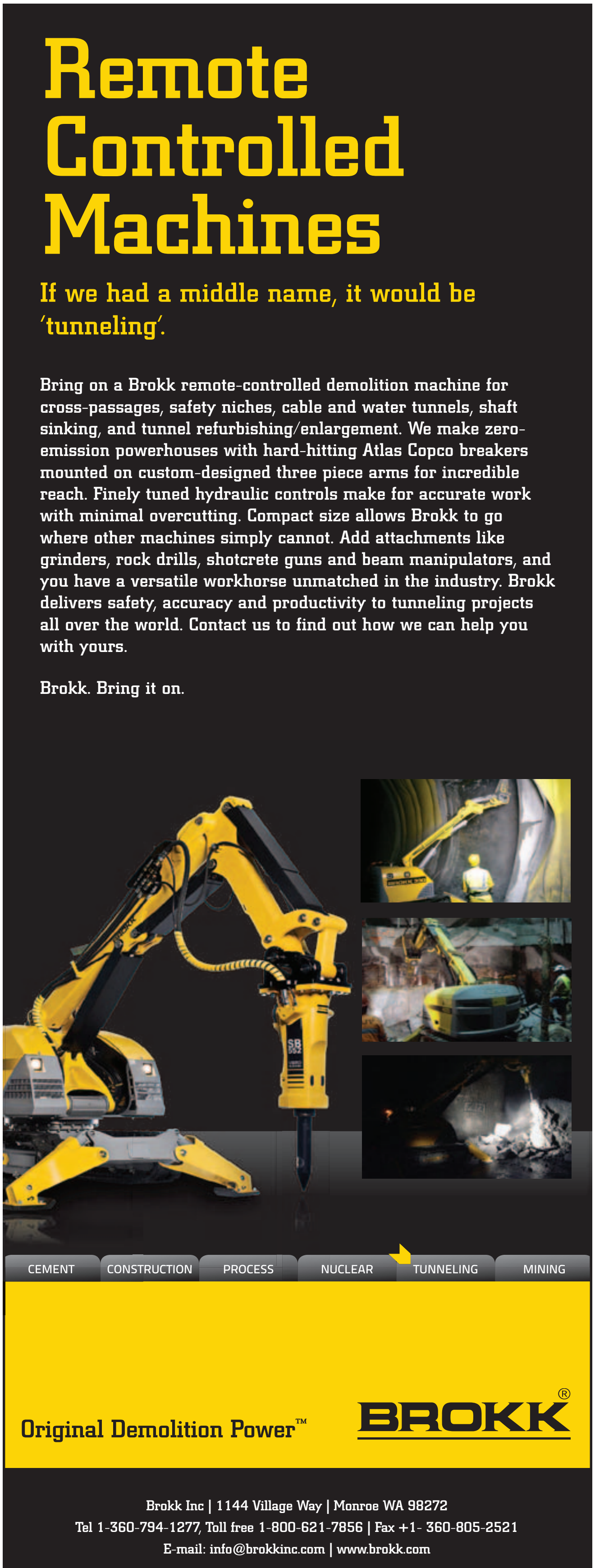

Brokk AB –
If We Had A Middle Name, It Would Be Tunneling

Whether cross-passages or safety niches, shaft sinking or tunnel refurbishment, there's nothing a Brokk can't handle. Brokk's zero-emissions, compact powerhouses go anywhere and stand up to the most demanding environments. Add in attachments like grinders, rock drills, shotcrete guns and beam manipulators, and you have the perfect combination to take on any application.

Your toughest tunneling challenge? Bring It. Brokk has the machine to tackle it.

Brokk 100

Featuring a more compact design, yet 35-percent greater breaking power, the all-new Brokk 100 is the ideal replacement to the popular Brokk 90 model.

Brokk 160

The Brokk 160 combines powerful performance and a lightweight design to offer the capabilities and flexibility for challenging applications.

Brokk 260

Our most popular model, equipped with a hydraulic rock drilling attachment, is perfect for drilling spiles, anchors or blast holes.

Brokk 400

The Brokk 400 is the second-largest machine in the Brokk range and features unsurpassed capacity.

Brokk 800S

The 12-ton Brokk 800S is breaking way for a whole new field of application when it comes to tunneling projects.

For more than 30 years, Brokk has been focused on developing remote controlled machines for use in the underground and tunneling industries. Today there are more than 5,000 Brokk machines in use all over the world. From safety and productivity, to power and profitability, Brokk machines provide cost-effective, efficient solutions.

For more information, contact Brokk's North American headquarters at 800-621-7856, email info@brokkinc.com, or visit the website at www.brokk.com.

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Email: info@brokkinc.com
www.brokk.com

BROKK®

Antraquip Corporation

Antraquip Corp. has established itself as a leading designer, manufacturer and supplier of roadheaders, hydraulic rock grinders (roadheader attachments), shaft sinkers, specialty tracked machines with a variety of boom options, and tunnel support systems. The newest addition to the Antraquip product line are diamond tipped rock saw attachments for excavators designed to cut hard rock and reinforced concrete for specialty applications. Antraquip machines, built to the highest technical standards, are being used all over the world in a variety of civil engineering and mining projects.

Antraquip offers not only standard roadheaders in the 12 to 75 ton weight classes but is proud to offer project oriented engineering solutions. Some of the recent projects have included AQM roadheaders equipped with customized drilling attachments and fully automated remote control operation. Antraquip also provides various tunnel support products including lattice girders, steel sets, and arch canopy systems which they have supplied to some of the highest profile projects in North America in recent years.

In addition to offering project consultations, innovative rock cutting solutions and tunnel support systems, Antraquip recognizes the importance of after sales service. Their commitment to offering the best service and technical support is carried out by highly proficient and experienced service technicians and reinforced with the largest roadheader parts inventory in North America. Innovation, reliablility and experience offered by Antraquip, continues to make them your reliable partner for any tunnel or mining project.

Antraquip Corporation
Telephone: +1-301-665-1165
Email: info@antraquip.net
www.antraquip.net

There's More to Moretrench

Moretrench, headquartered in Rockaway, New Jersey, is a full-service geotechnical contractor specializing in design/build and turnkey solutions for challenging construction requirements and subsurface conditions.

The company's wide range of services includes construction dewatering and groundwater control; ground/water treatment; ground freezing; grouting systems; cut-off and containment systems; earth retention and excavation support systems; underpinning and foundation support; deep foundations; landfill gas and leachate systems; and specialized civil and mechanical construction.

These services are available nationwide through full service offices in New Jersey, New York, Florida, Massachusetts, Pennsylvania, Delaware and Washington D.C. Moretrench is a USGBC member which oversees the LEED program.

Moretrench
Telephone: +1-800-394-MORE
www.moretrench.com

CDM Smith

CDM Smith provides lasting and integrated solutions in water, environment, transportation, energy and facilities to public and private clients worldwide. As a full-service consulting, engineering, construction and operations firm, we deliver exceptional client service, quality results and enduring value across the entire project life-cycle.

CDM Smith's underground construction staff includes geotechnical, structural, and civil engineers and geologists located worldwide. Our staff has extensive experience in providing the full range of tunnel and geotechnical related services. Our tunnel related work includes planning, feasibility and design, including both 2D and 3D FEM analyses. We offer construction services including construction and program management, inspection and geotechnical instrumentation monitoring and interpretation for soft ground and rock tunnels. Design and construction includes all types of ground modifications including ground freezing, grouting, and dewatering.

Our field equipment includes geotechnical instrumentation and construction data acquisition equipment. Our field personnel are NICET, OSHA and NRC certified. CDM Smith's tunnel services include:

- Shaft Design: Ground Freezing, Slurry Wall and Secant Pile Wall
- Conventional Soft Ground and Rock Tunnel Design, Microtunneling, Pipe Jacking and Directional Drilling
- Evaluation and Rehabilitation of Existing Tunnels
- Ground Investigation, Testing and Evaluations
- Groundwater Control System Design

CDM Smith
www.cdmsmith.com

CDM Smith
cdmsmith.com

Paul C. Rizzo Associates Inc.

Paul C. Rizzo Associates, Inc. (RIZZO) provides world-class technical expertise and innovative solutions for tunneling projects. Working in the water resources, mining, transportation, and nuclear markets, we encounter traditional and ground breaking projects around the world. The breadth of our services allows us to add value to a project at any stage: from conception to completion.

RIZZO's in-house services include design for tunnels and shafts; geotechnical engineering; seismic engineering; hydraulic engineering; construction management; environmental engineering; and developing tunnel rehabilitation programs.

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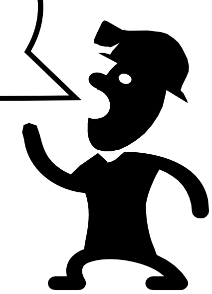

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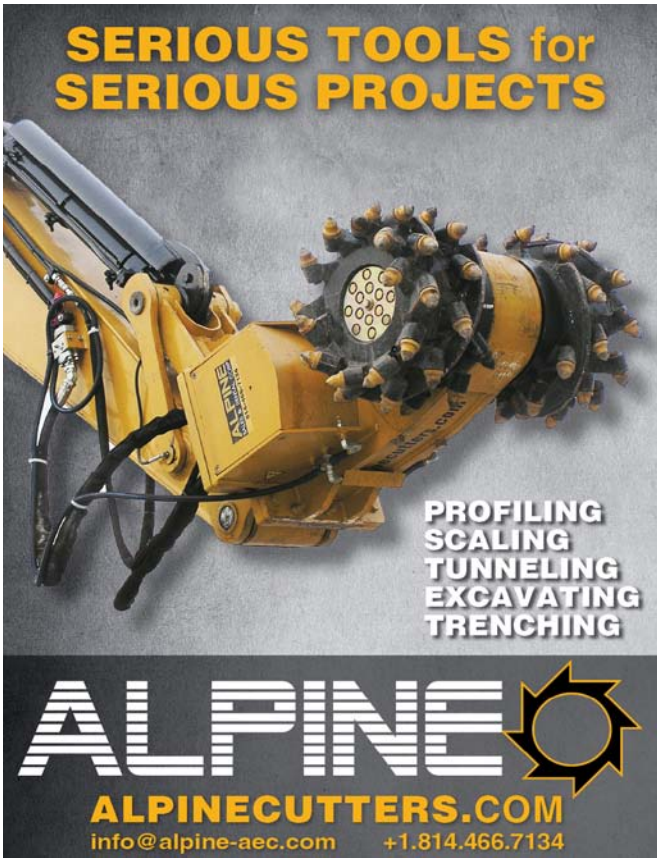

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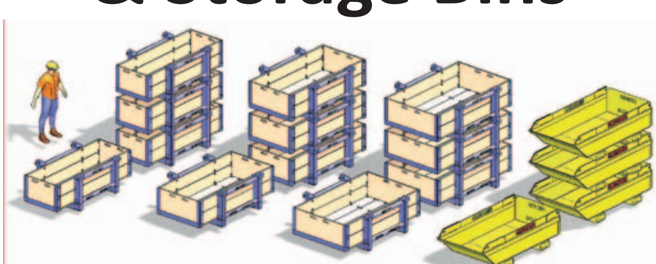

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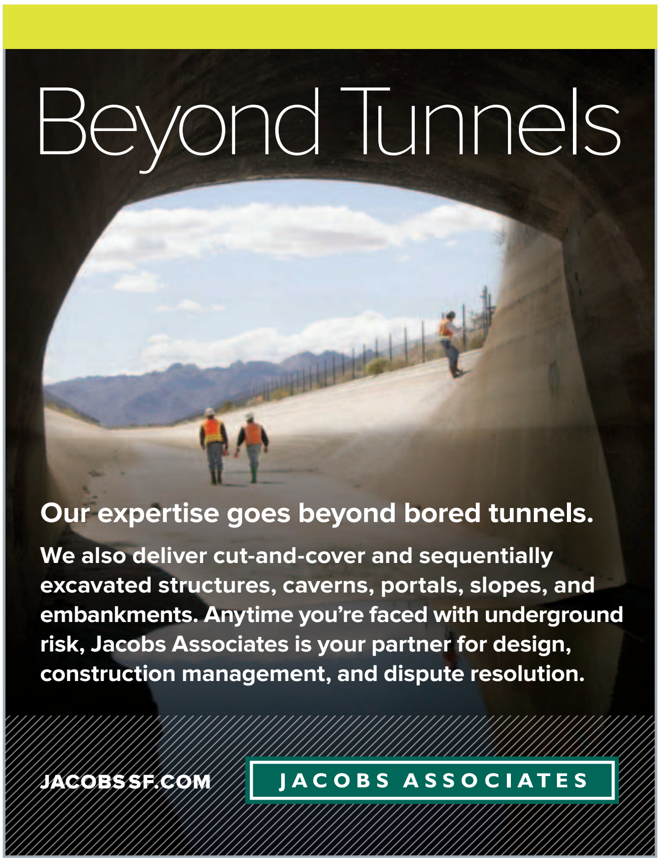
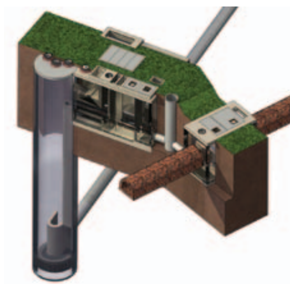


Clean Rivers Construction Underway in DC



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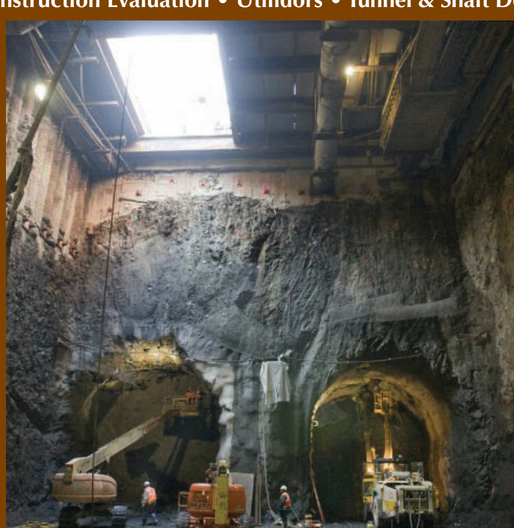

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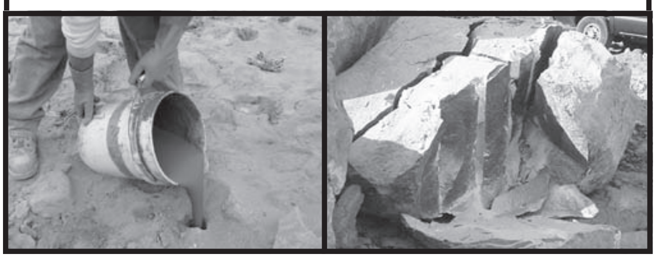

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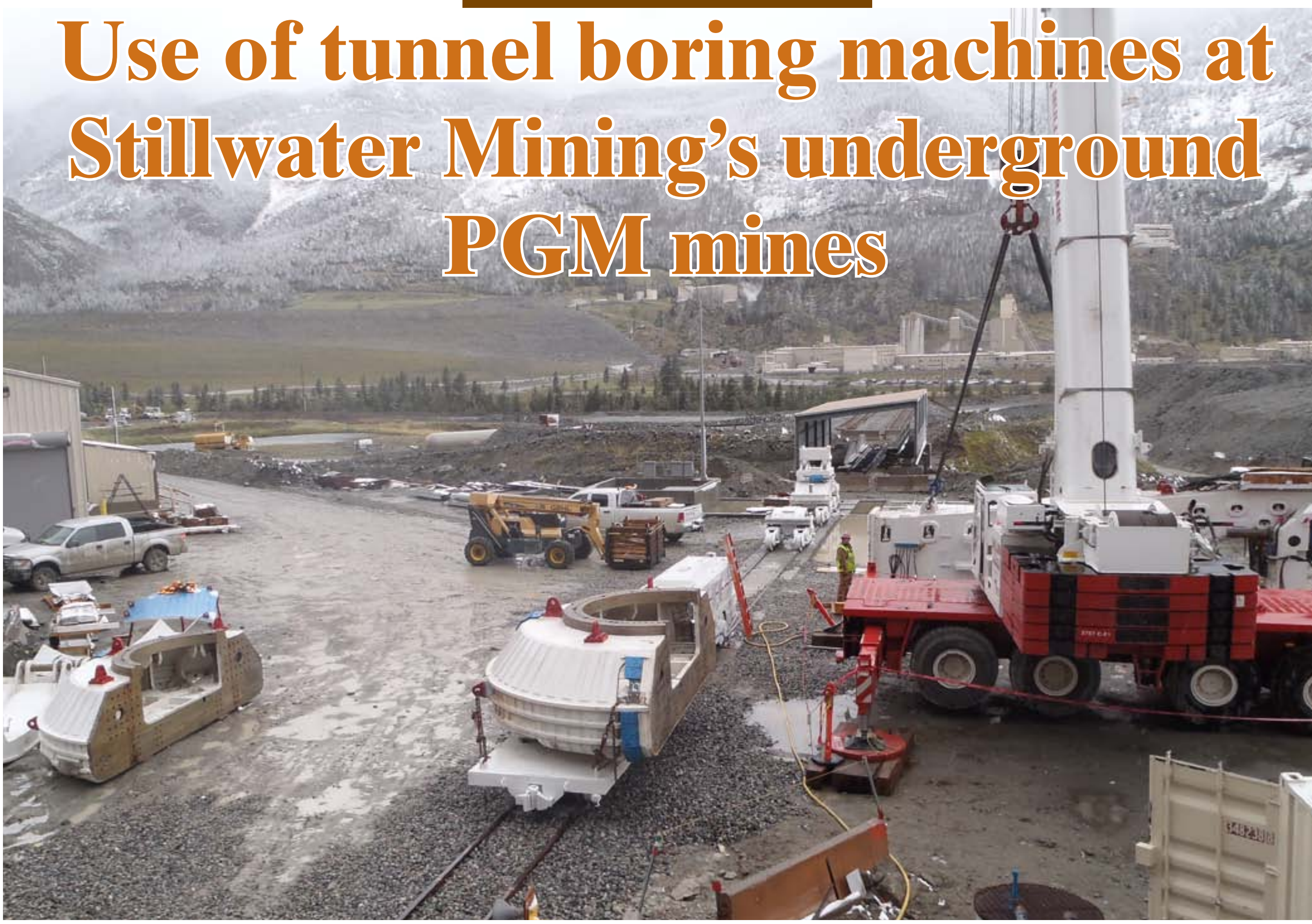
FEATURE ARTICLE

Use of tunnel boring machines at Stillwater Mining's underground PGM mines



A Main Beam cutterhead before it is pushed underground into the TBM chamber at the Stillwater Mine.

Tyler Luxner, Justus Deen and Mike Koski

Tyler Luxner, member SME, is project manager, Stillwater Mining Co., Nye, MT and **Justus Deen** and **Mike Koski** are technical services manager and chief geologist, Stillwater Mining Co., Nye, MT, email tluxner@stillwatermining.com.

Stillwater Mining Co. (SMC) is the largest primary producer of platinum and palladium in North America. SMC operates two underground mines in south central Montana, along the 45-km (28-mile) platinum/palladium J-M Reef in the Stillwater Complex. The Stillwater Mine exploits 9.6 km (6 miles) of deposit strike length and East Boulder Mine exploits 4 km (2.5 miles) of deposit length. The two mines are 20.4 km (12.7 miles) apart with SMC controlling a considerable length along the entire J-M Reef trace. Production at the Stillwater Mine began in 1986 and in 1988 the first tunnel boring machine (TBM) was commissioned, becoming an integral part of mine development at SMC.

TBMs have been used for developing production footwall laterals (FWL) to access new mining blocks at the Stillwater Mine, as well as boring twin crosscut access tunnels at the East Boulder. Two TBM development expansion projects are currently in progress: the Graham Creek project at the East Boulder Mine, which will extend footwall lateral development 2,591 m (8,500 ft) to the west, and the Blitz project, where a TBM will be commissioned to extend east out of the Stillwater Mine to 3,658 m (12,000 ft) beyond the current production mining front. General strike and dip of the Reef is west to east and to the north, respectively.

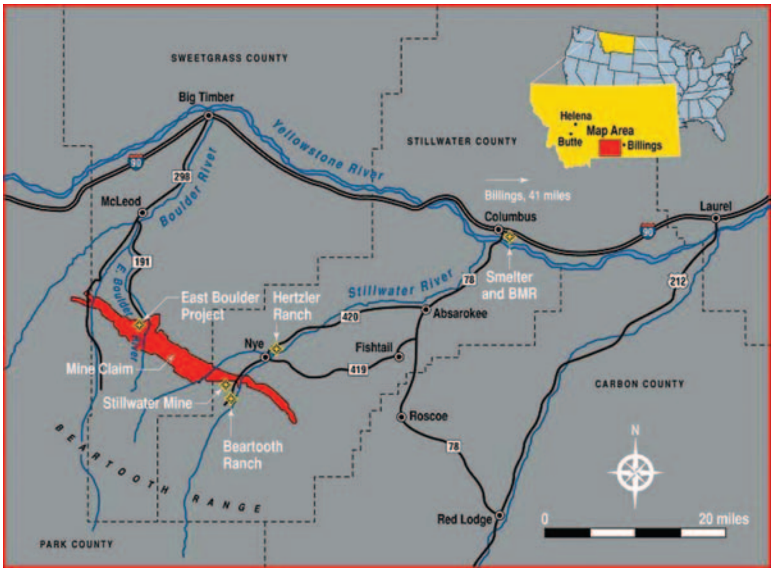
Geology

The Stillwater Complex is a 2.7-billion-year-old layered mafic/ultramafic intrusive. This igneous complex intruded 9.6 to 14.5 km (6 to 9 miles) below the surface (Labotka, 1985), cooling slowly to produce a very pronounced sub-horizontal layering. Later erosion and uplift during the Laramide Beartooth mountain building thrust the edge of the complex up to the surface, rotating the complex to a steeply dipping orientation. Several thrust faults, back thrusts and crosscutting transverse faults affect both the orientation of the layering and the ground conditions (Page, 1977).

Associated with one of the ultramafic layers is

FIG. 1

Location of SMC's Montana operations.



the J-M Reef, a thin platinum group metal (PGM) rich zone. This zone contains 0.5 to 1 percent copper nickel sulfide-chalcopyrite, pentlandite and pyrrhotite. The PGMs occur as embayments of tiny grains of platinum minerals, predominately as platinum/palladium/nickel sulfide (braggite, cooperite, vysotskite), moncheite and Pt-Fe alloy, as well as palladium contained in the solid solution replacement in the pentlandite (Todd et al., 1982).The J-M Reef pinches and swells and is typically very thin, averaging 1.2-m- (4-ft-) wide. Metals within the J-M Reef are primarily palladium and platinum at a 3.6:1 ratio, with recoverable byproducts of rhodium, copper, nickel, gold and silver.

Areas within the Stillwater Complex, including the Blitz project, can be structurally complex due to a number of large offsetting transverse fault structures. Some of the faulting have offsets of up to 152 m (500 ft) and can cause adverse ground conditions as well as create fracture systems that hold water. The layers in the immediate footwall of the J-M Reef are also typically weak due to the amount of mafic minerals and alteration.

General mine layout

The Stillwater and East Boulder mines are narrow vein mining operations on the J-M Reef, using cut-and-fill and sublevel mining methods. Accesses to the Reef are provided from FWLs, 3.3-m- (11-ft-) wide by 3.6-m- (12-ft-) high development drifts in the footwall parallel to the ore zone that are typically 39.6 m (130 ft) away from the reef. The FWLs are spaced every 91 m (300 ft) vertically with horizontal spacing dependent on the dip of the reef, which is approximately 50° at the East Boulder, 40° at the west end of the Stillwater and 60° to steeply overturned at the central and east areas of the Stillwater Mine.

The FWL drifts serve as the primary access, ventilation and haulage corridors for the mining stopes and are connected to each other by a network of ramps, ventilation raises and material raises. Development of new mining areas is performed by driving FWLs east and west along the reef and by establishing new levels above or below current levels. Diamond drilling is performed upon advance of FWLs to delineate the resource and determine new stoping areas.

Stillwater Mine

The Stillwater Mine is located on the intersection of the J-M Reef and the Stillwater River Valley in the Absaroka-Beartooth mountain range. The mine surface facilities and head frame sit on the valley floor at an elevation of 1,524 m (5,000 ft). Mining levels are based from mean sea levels; mine easting is referenced from the single production shaft on the west side of the Stillwater Valley.

Production mining at the Stillwater Mine started in 1986 at 446 t/d (500 stpd) beginning with the 5150 West FWL and initial development for the 5300 Westand the 5000 West FWLs. Production soon increased, and new levels at 5500 West, 6500 West, and 5000 East were planned (SMC, 1989). At this time, all levels were driven conventionally. However, to help facilitate increased production levels, the mechanical boring option for new FWL development was evaluated and approved in 1987. The TBM was purchased and crewed by SMC and allowed for developing a new heading without a conventional development crew. Rationale for use of a TBM at the Stillwater mine included:

- Advance rate: The generally straight west-to-east strike, limited offsets and planned development lengths greater than 1,219 m (4,000 ft) allowed for increased productivity and high advance rates from TBMs.
- Cost: Capital for a TBM was approximately 1.5 times a conventional mining fleet but had 33 percent of the operating costs, comparatively.
- Ground support: The elimination of blasting and the circular tunnel profile yielded higher integrity and reduced ground support requirements.
- Ventilation: The airflow resistance is reduced with the smooth wall, adding airflow to main intake levels (Tilley, 1987).

SMC reviewed multiple used TBMs available and purchased a Jarkva MK 15-28 3.96-m- (13-ft-) diameter main beam machine. Table 2 has the TBM specifications. Of special note with this machine:

Cutouts/demobilization. Cutouts were mined in the TBM drift by backing the machine out from the face and drilling the initial round by jacklegs. After blasting, the TBM would advance and remove the rock generated by mining into it.

A key feature of the Jarkva unit was the relative ease with which it could be removed between levels. After a drive was completed, the trailing decks would be pulled out, the main beam disconnected from the head and pulled out on rail, and the head disassembled and removed. Six to seven loads would then be transported between levels, the main beam being transported on a lowboy trailer by a Caterpillar D8 dozer. For the 5000 East, 5900 West and 5700 West FWL TBM drives, the machine was assembled on the surface. At the 5500 West, level the machine was brought 760 m (2,500 ft) in from the portal along rails and assembled underground.

Nye Jarkva TBM drives. Table 1 lists the TBM drives of the Jarkva machine. The first drive, the 5000 East FWL, was a major mine expansion, as it provided access to the new east side area of the mine. After 427 m (1,400 ft) of advance, the TBM intersected the Reef. It pulled off and continued, hitting major structures such as mafic dikes for an additional 549 m (1,800 ft) of advance. The complex structures of the east side and bands of weak mafic rocks were discovered with this drift. After 975 m (3,200 ft) of total advance, the machine was pulled out due to low advance rates and new planned drives for the unit.

The next TBM drive was the 5900 West FWL; this 3.2-km (2-mile) drive to the west was performed to access an area of mineralization now known as the Upper West. The TBM bored directly from the portal. However, the TBM had to pull out, and a chamber was excavated conventionally with steel sets due to the soft regolith rock that squeezed around the machine. Once the chamber was excavated, the TBM was moved back in and continued boring. The TBM still experienced soft ground, causing it to sink 7.6 m (25 ft) advancing until it found solid ground. Along this drive, a 121-m (400-ft) left lateral transverse fault was encountered; associated gouge and secondary slips created ground issues and slowed advance, but the machine made it through and finished the drive.

The TBM then moved to the 5700 West FWL, where it advanced until it reached the end of the Near West ore

FIG. 2

Map of FWL development at the Stillwater Mine circa 2011, TBM drives highlighted.

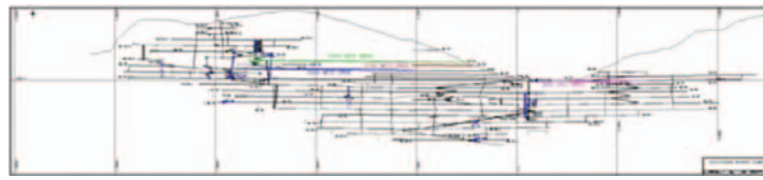


FIG. 3

Cross section of the Blitz project looking north.

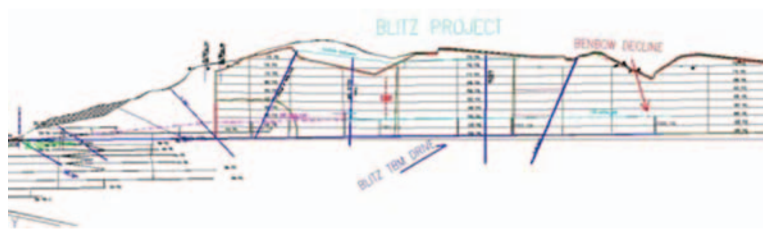


TABLE 1

List of TBM drives at SMC operations. *Indicates planned or in progress as of October 2011.

Mine	Machine	Drive	Date		Meters
			Start	Finish	
Stillwater	Jarvka	5000 East FWL	March 1988	July 1988	975 (3,200)
Stillwater	Jarvka	5900 West FWL	May 1989	August 1990	3,389 (11,120)
Stillwater	Jarvka	5700 West FWL	October 1990	January 1991	1,405 (4,601)
Stillwater	Jarvka	5500 West FWL	February 1991	June 1991	2,286 (7,500)
East Boulder	CTS	Access #1	July 1998	July 2000	5,630 (19,347)
East Boulder	Robbins	Access #2	March 1999	September 2000	5,630 (18,145)
East Boulder	Robbins	West FWL	September 2000	September 2008	2,197 (7,220)
East Boulder	Robbins	Graham Creek	January 2011*		2,591 (8,500)*
Stillwater	Robbins	Blitz 5000 East	May 2012*	6,858	6,858 (22,500) *
Total	**31,133**				**31,133 (102,142)**

TABLE 2

Specifications of TBM's used at SMC, circa 2011. * Indicates planned/in progress.

Site	Stillwater	East Boulder	East Boulder	Stillwater
Machine	Jarkva	CTS	Robbins	Robbins
Initial condition	Rebuilt	New	Rebuilt	Rebuilt
Starting year	1988	1998	1999	2012*
Finished year	1991	2000	2014*	2016*
Total drive, m (ft)	8,056 (26,430)	5,639 (18,500)	8,230 (27,000)*	6,858 (22,500)*
Typical ground strength-UCS, MPa (psi)	138 (20,000)	55 –131 (8,000–19,000)	55 – 131 (8,000 – 19,000)	83 – 110 (12,000 – 16,000)
Head diameter, m (ft)	3.96 (13)	4.57 (15)	4.62 (15.17)	5.5 (18)
Number of single, double cutters	31, 0	26, 3	25, 4	25, 4
Size of cutters - single and double, mm (in)	406 (16), 0	432 (17), 406 (16)	432 (17), 432 (17)	483 (19), 432 (17)
Individual cutter load, kN (lbs)	244 (54,839)	267 (60,000)	222 (50,000)	311 (70,000)
Propel thrust, kN (lbs)	7,562 (1,700,000)	8,541 (1,920,000)	8,541 (1,924,000)	10,898 (2,450,000)
Thrust cylinder stroke, m (in.)	1.52 (60)	1.22 (48)	1.55 (61)	1.83 (72)
Head power, kW (hp)	7 x 122 (150)	4 x 335 (450)	4 x 315 (422)	6 x 330 (440)–VFD
Head, RPM	8.5	3.6-11.6	4-12	7.2-10
Torque, Nm (ft-lb)	455,736 (617,896)	601,133 (815,000)	534,733 (725,000)	1,430,871 (1,940,000)
Gripper ground pressure, MPa (psi)	3.4 (500)	3.4 (500)	4.1 (600)	4.1 (600)
Length of complete machine, m (ft)	43 (141)	137 (450)	131 (431)	137 (450)
Estimated machine weight (tons)	158 (177)	246 (275)	214 (240)	321 (360)
Input/main drive/ hydraulic voltage, V	13,200/480/480	13,800/480/480	13,800/480-600/480	13,200/690/480
Number of trailing decks	3	16	11	11
Car loading method	Hagglunds 115C cars	train on trailing deck with passing switch	train on trailing deck	train on trailing deck
Conveyor size, m (in.)	.61 (24)	.91 (36)	.91 (36)	.91 (36)
Ground support drill	Jackleg drills	2 Boart HD 150 drills	2 Boart HD 150 drills	2 1238R Atlas Copco drills
Ventilation size, m (in.)	.91 (36)	1.37 (54)	1.37 (54)	1.52 (60)
Source: BHP Copper Inc., CTS, Robbins, 2011; Tilley, 1987.				

zone. At the time, it was not desired to drive the level an additional 2,134 m (7,000 ft) to access the Upper West. The final Jarvka TBM drive was the 5500 West FWL, which was driven as a second access to the Upper West mining area.

With the completion of the 5500W FWL the TBM was shut down with the planned accesses to the Upper West area complete. The TBM was ideal for Upper West development due to the starting location for levels near the surface in the valley, the overall competent ground in this area and the long drives with ventilation restraints to reach the target locations. Long-term development at the Stillwater Mine now focused on the Reef from beneath the valley floor at levels below 1,524 m (5,000 ft) elevation. This activity had more vertical development with declines, shorter drives and was economically better suited for conventional mining.

East Boulder Mine

The East Boulder Mine provided western access to the J-M Reef, from Sweet Grass County, MT, and was the second fully permitted access to the J-M Reef. In 1996, SMC began work on the initial exploration phase of the East Boulder project, including site preparation and procurement of a TBM. The project consisted of developing surface facilities near the East Boulder River, 20.4 km (12.7 miles) west of the Stillwater Mine; twin tunnels driven south — intercepting the J-M Reef from the hanging wall — would provide access for Reef development. Independent contractors would be engaged to work with SMC to drive the tunnels (Alexander, 1999).

These twin access, 4.6-m- (15-ft-) diameter tunnels, named Tunnel #1 and Tunnel #2, were driven at an azimuth of 208° with a plus 0.5 percent vertical grade, approximately 5,568 m (18,328 ft), to reach the J-M Reef.

The tunnel geology consisted of approximately 1,006 m (3,300 ft) of sedimentary rocks, 2,530 m (8,300 ft) of gabbro, 430 m (1,400 ft) of norite, 1,140 m (3,750 ft) of anorthosite, 335 m (1,100 ft) of olivine gabbro and 210 m (700 ft) of troctolite. Overburden at the portal sites consisted of talus at the surface that varied in thickness from 18 to 37 m (60 to 120 ft) (Alexander, 1999).

Tunnel #1: CTS tunnel boring machine

Construction and Tunneling Services (CTS) designed and built a custom TBM for SMC. This TBM was used for the initial East Boulder project access. Construction of the TBM began in 1996 and completed in June 1998. The machine was delivered to the project site in July, reassembled and field-tested. Table 2 lists the specifications of the machine of note with the CTS TBM:

Ground support systems. Two Boart HD150 drills were supplied with the TBM. These machines drilled a hole to accept 1.5-m (5-ft) rock bolts. The drills were mounted on a rotating, sliding arm that comes off the front of the gripper shoes. Drilling was done under the slotted tail shield, just behind the main drive motors. When grouting was required in front of the TBM, the Boart HD150 drills were removed from the roof drill mounts and mounted in the grout drilling position. Two mounts on the top portion of the bridge allowed the drills to probe ahead of the machine. In this mode, the drills used 1.2 m (4 ft) sections of drill steel for extension drilling. The HD150 drills were provided with hydraulic clamps to aid in adding drill steel (Alexander, 1999).

Tight radius turning. The TBM was configured for a 61-m (200-ft) horizontal turn and a 305-m (1,000-ft) vertical turn. The ability to maneuver the machine through such a turn was a function of internal clearances and the ability of the front shielding to adjust to a nonconforming profile. Horizontal clearances exist that allow the conveyor and bridge to side shift in the turn. The propel cylinder ball sockets were provided with sufficient angular rotation ability. The front shield accommodated the turn because it was not a fixed diameter shield. The bottom of the front shield rode on wear plates that allow clearance between the skin and the bore and let the machine turn. The top shield was a three-piece construction that can pivot and slide in relation to the cutterhead drive. Thus, it continued to support the ground and stabilize the cutterhead while it maintained alignment to the tunnel (Alexander, 1999).

Backup system. The backup system consisted of 16 rolling decks, two ramped decks and one set of sliding rail points. The backup system was designed for rail haulage of the excavated muck. The backup conveyor ran from the front of Deck 1 and discharged at Deck 6. A section of the backup had a double track layout to allow an empty muck train to be brought in while loading another muck train. The rest of the backup provided room for the TBM power units, electrical supply and other auxiliary functions.

Deck 1 – Operator's control station; workbench; TBM/backup conveyor transfer point.
Deck 2 – Hydraulic power unit.
Deck 3 – Lubrication power unit.
Decks 4/5 – Electrical transformers; motor control cabinets.
Deck 6 – Lunchroom; car mover.
Deck 7 – Ventilation electrical cabinets; rail switch; backup conveyor discharge.
Deck 8 – Ventilation fans and scrubber; rail switch.
Deck 9 – Car mover, auxiliary fans.
Deck 10-15 – Passing track for muck train; rail switch.
Deck 16 – Rail switch; incoming power cable tray.
Forward Ramp – Incoming power cable tray.
Aft Ramp – Ventilation cassette lifter (Alexander, 1999).

Advance for the CTS machine averaged 8.5 m/d (28

FIG. 4

The 5000E TBM chamber with cutterhead, grippers, vertical front support, side supports and roof shield before the main beam was brought in.

ftpd) over the course of the project tunneling operation. Once the TBM intercepted the J-M Reef, it continued to advance south to develop a sand plant and reservoir. It was later decommissioned and components of it still reside in the East Boulder Mine.

Tunnel #2: Robbins TBM

The original project plan called for the CTS machine to bore one access tunnel and have a raisebore driven to the surface for the exhaust. As the project proceeded, it was determined to bring production forward. The most critical element in the acceleration of the project schedule was the early establishment of a second means of egress and having a second tunnel for exhaust. Accordingly, a second TBM, a used Robbins main beam machine, was purchased from Magma Copper. An independent contractor refurbished this machine in Billings, MT. Machine specifications are in Table 2, of note with this Robbins TBM are:

Cutterhead. The cutterhead was mounted to the main bearing assembly, which accepted both radial and thrust loading. The cutterhead assembly was the mounting structure for the 33 removable cutter rings used on this machine. Four cutter assemblies located at the center of the cutterhead were twin-disc type, and were mounted on a quad pedestal. The remaining 25 single-disc cutter assemblies were mounted in individual housings. The cutterhead was a two-piece construction (Alexander, 1999).

Ground support systems. Two Boart HD150 hydraulic rock drills were mounted on each side of the main beam of the machine. These machines drilled a hole to accept a 1.5-m (5-ft) rock bolt. The drills were mounted on a rotating, sliding arm located in front of the gripper carriage. Rock bolt drilling can be in progress as the machine was boring forward (Alexander, 1999).

Electrical system. High-quality, industrial-grade electrical components and cabling were provided. Heavy duty dust and water-tight control cabinets and underground duty, open drip proof transformers were supplied. All necessary monitoring devices, circuit protection and failsafe interlocks were provided. Control functions utilized an Allen Bradley SLC500 PLC system (Alexander, 1999).

Control station. The primary controls and indicators available to the operator for selecting and monitoring machine hydraulic and electrical functions were located on an operator's console assembly located inside the operator's cab. The operator's cab was located on Deck 1. The operator's console assembly was divided into several sections. These included hydraulic indicators, electrical indicators, electrical controls, hydraulic controls, TV system controls and water spray controls (Alexander, 1999).

The Robbins machine averaged 9.75 m/d (32 ftpd) over the course of the project. The TBM was turned west after it intercepted the Reef and drove limited FWL for several years. In 2010, SMC announced the Graham Creek project, where the Robbins TBM will drive 2,600 m (8,500 ft) west of current East Boulder mining activities for additional reef development.

Blitz project

In 2010, the Stillwater Mine was producing more than 4.4 kt/d (5,000 stpd). A shaft sunk in 1994 and an extensive ramping system allowed development of the Off Shaft area down to the 2000 level. Development in the Upper West had reached the 7500 level and more than 6,096 m (20,000 ft) west. Development on the east side had progressed up to the 5400 level and 3,658 m (12,000 ft) east. In December of 2010, SMC announced plans to develop the Blitz project, extending two levels east to new mining areas, out to 7,620 m (25,000 ft) east (SMC, 2010).

The Blitz development plan involves three accesses: The Benbow decline, a new portal near Dean, MT, the

5600 East level and the 5000 East TBM tunnel. The Benbow crosscut declines in from the north and will be driven 1,829 m (6,000 ft) to the Reef at 6,858 m (22,500 ft) east. This decline comes in at the 1,707 m (5,600 ft) elevation, intercepts the Reef toward the eastern end of the project, and will provide main ventilation for production. The 5600E level is a conventional drive from the Stillwater Mine out to 6,858 m (22,500 ft) east.

The final access is a 6,858 m (22,500 ft) TBM drive from the Stillwater Mine on the 5000 East level. This access will serve as the main ventilation intake and the haulage level for all of the rock generated by development and production in the Blitz area. The 5000 East being a long ventilation access, highlighted the opportunities of driving the new level with a TBM. Specifically, ventilation studies indicated that a 5.48-m- (18-ft-) diameter excavation is the most efficient drift size for the ventilation, haulage and utility piping requirements. Using a TBM also allows:

- Faster development: A fully staffed, 24-hour-seven day/week TBM drive would complete the excavation in 2.5 years at a 7.6-m/d (25-ftpd) overall advance rate.
- Different skill set required: Staffing the 5000 East development with experienced conventional miners presents challenges and risks. Completion with a TBM will allow mining without removing skilled miners from existing operations.
- Rail haulage: The new 5000 East level will utilize 63.5 cm (36 in.) gage rail to handle the Blitz rock generated, as it is a proven method at SMC. A TBM will allow for permanent rail to be installed in advance, allowing for the new level to be immediately used for haulage once the TBM is complete.
- Ground support: Given the complex structure of the J-M Reef east of the Stillwater Valley, the circular shape of the excavation and elimination of blast-induced damage will increase ground integrity.

After reviewing available TBMs on the market, SMC selected a used Robbins main beam machine in May of 2011 for use on the new 5000 East FWL development. Table 2 has the machine specifications. Of particular note with the Stillwater Mine Robbins TBM:

Machine assembly. Assembly of the Blitz machine will be in a newly excavated TBM chamber just off of the original TBM chamber in the 5000E FWL; the entrance of the new TBM chamber is located 61 m (200 ft) in from the 5000 East portal. Compared to the 4.6-m- (15-ft-) by 4.6-m- (15-ft-) by 46-m- (150-ft-) long chamber for the original Nye TBM, the new TBM chamber is 91 m (300 ft) long and will be 6.1 m (20 ft) wide by 7.6 m (25 ft) high at its largest opening.

TABLE 3

Location and length of Blitz 5000 East diamond drilling program. + Indicates intercept location above tunnel horizontall. All footages approximate.

Drill	Hole name	Footage, m (ft)
1	Straight ahead	183 (600)
2	Perpendicular reef touch	183 (600)
2	45 ° reef touch	183 (600)
3	+ 45 m (150 ft) perpendicular reef touch	183 (600)
3	+ 91 m (300 ft) perpendicular reef touch	183 (600)
3	Perpendicular South structure	183 (600)
Total	**6 holes**	**(1,097) 3,600**

After completion of the TBM chamber in May 2012, the cutterhead was moved to the face in two sections, the weights of the sections being 35.7 t (40 st) and 26.8 t (30 st) for the lower and upper sections, respectively. The cutterhead sections were brought in on a rail car and lifted to the face using four 22-t (25-st) capacity air hoists. After the cutterhead was secured at the chamber face, the vertical front support, side supports, roof shield and grippers were placed in the chamber. Concurrently, the cutterhead support, main beam and gripper carriage were assembled outside and brought into the chamber on rail dollies as one unit. The bridge and the trailing decks were brought in and, once machine power was established, the components brought into the chamber before the main beam was attached. A short start is utilized, as the machine will bore 61 m (200 ft) with only seven trailing decks and a reduced two car train loaded by a temporary conveyor off of the last trailing deck. After this point, the remaining four cars can be installed and a full 10-car train utilized. In Q3 of 2012 the Blitz TBM began operation.

Blitz TBM drive geology. The new 5000E will be driven 122 to 183 m (400 to 600 ft) in the footwall, south of the J-M Reef in competent norite rock. This norite zone is 305 m (1,000 ft) thick and lies between the softer Melano gabbro units in the immediate footwall of the reef and the softer Ultramafic series rocks to the south. Both these softer units would be poor ground for TBM advance due to the parallel structure associated with the more mafic layers and as ultramafic rocks are known for movement along altered slip surfaces causing intense squeezing.

The major geologic structures that are anticipated in the new 5000E drive are at least three right lateral offsetting transverse faults, which may offset the reef south: the Big Seven, the Benbow and A-26. Each fault will have a layer — 0.9 to 15.2 m (3 ft to 50 ft) plus — of weak fault clay gouge, possible water courses and a zone of influence of up to 61 m (200 ft) on each side of the fault with weaker rock (Lipin et al., 1985). Numerous minor offsetting faults and dike perpendicular to the structure are also expected.

The offsetting faults will contain the most difficult ground for the TBM and are part of the reason for the large distance of the TBM from the Reef. The distance from the Reef should provide for ample turning radius in relation to reef offsets.

Diamond drilling. A significant feature of the Blitz TBM is the diamond drilling to be performed from the machine. Standard practice at SMC is that any FWL development includes diamond drill probe drilling from the face after 152 m (500 ft) of advance. The core holes target the planned course of the drift and confirm location of the J-M Reef. This pattern is to search for potential structural offsets, probe for water, get Reef information and gather geotechnical information to determine ground conditions ahead of a FWL. The information gathered from these probe holes is used to adjust the planned FWL development, keeping the drift the desired distance from the Reef and eliminating costly interruptions due to unexpected offsets or weak ground on advance.

The new 5000 East TBM will follow the standard SMC practice of diamond drilling every 152 m (500 ft) of FWL advance. Not probing could result in difficulties as encountered with the original 5000 East TBM when it intersected the Reef and hit an unexpected dike. Diamond drilling provides two important functions to the new 5000E TBM development. First, determining the location of the Reef, the south ultramafic zone and upcoming offsets on advance will allow the TBM to stay in the target norite zone. Second, the Reef intercepts off the TBM will be critical to developing the Blitz area as it will provide resource definition information for future development. This information from the 5000 East level will be used to position the conventional drive on the 5600 level.

Three Sandvik DE 130 diamond drills to complete BQ size core will be used on the TBM. Drill 1 will be mounted on the main beam above the gripper shoes 15 m (50 ft) behind the cutterhead. Its position will be fixed to drill directly ahead and above the cutterhead. Drills 2 and 3 will be mounted on flat cars and moved to the first and eighth trailing deck, respectively. The first drill will remain on the TBM during boring with the second and third being brought on during diamond drilling cycles.

Table 3 lists the approximate drilling to be performed every 152 m (500 ft) of TBM advance from 3,658 m (12,000 ft) east to completion. TBM advance from 1,829 m (6,000 ft) east to 3,658 m (12,000 ft) east will have a reduced drilling profile of 366 m (1,200 ft) per every 152 m (500 ft) of advance as Reef location is already known from existing mining. In all, more than 36,940 m (121,200 ft) of probe drilling is planned to be performed off of the TBM during its 6,858 m (22,500 ft) of boring. This amount of drilling is unique considering normal TBM drives, but is a cost that SMC considers essential to the successful and economic boring of the new 5000 East TBM drive and the development of the Blitz project.

Ground support. 1.5-m (5-ft) split sets and 2.4-m (8-ft) rebar bolts within 120° of the vertical will be installed by two Atlas Copco 1238 units mounted on slides off of the main beam. The drills will drill through finger steel behind the rear of the roof shield. All of the other bolts will be installed by jacklegs off of the structure and the "pit" area. Where steel sets are required, a ring steel erector at the rear of roof support section will install W6x15# steel sets on 1.82 m (6 ft) spacing. The McNalley support system will also be available as a ground support option in addition to steel sets and shotcrete.

Ground water. A multitude of meteoric water pockets have been encountered on the Stillwater Complex. These are usually found with fault structures. To minimize ground water influx, probe holes with steel casing at the collars and Halliburton style valves are used in the event diamond drill probe holes hit water. The valves are used to bleed off water or allow grouting of the hole. The Blitz TBM will have a ring style probe drill that is capable of drilling 22.8 m (75 ft) ahead of the TBM and is able to fully encapsulate the perimeter of the excavation with grout.

Rail. The Stillwater Mine operates conventional rail haulage system at two production levels, and it will increase to three levels once the 5000 East TBM drive is complete. Rail is completed with 41-kg (90-lb). RA on wood ties and compacted, engineered ballast; it is the preferred standard design. To accommodate this design during Blitz tunnel construction, two cycles of rail installation will be completed. First, rail will be installed from the TBM rail pit during the boring cycle using beveled wood ties that place the top of rail at 35.5 cm (14 in.) above the invert. During the diamond drill probe cycles, the TBM will be idled, allowing for installation of permanent rail by raising the existing rail and installing rail ballast, increasing the final rail grade to 61 cm (24 in.) above the invert.

Summary

The new 5000 East TBM FWL is a critical component of the Blitz expansion project. It will allow for an efficient and economic rail haulage level to be built, while providing critical Reef information to the project. The fast advance rates and minimal ground disturbance of the TBM has proven essential to the development plans at SMC's underground mines. Given the use history of TBM development at SMC and the present planned effort for the Blitz project, the TBM method is likely to remain a viable option for development of the J-M Reef well into the future. (References available from the authors.) ■

Making headway: All-tool carriers and attachments are making an impact on advanced tunneling

A view from inside the University Link Tunnel. This project will connect downtown Seattle, Capitol Hill and the University District with a high-speed light rail line.

Whether drilling through tough clay or breaking rock, or facing the most severe conditions including mixed face ground, perched water and running and flowing sands, working underground certainly comes with no shortage of challenges.

In an environment where the unknown is faced on a daily basis, tunneling contractors must be able to rely on their equipment to get the job done properly. Not only that, their equipment must comply with two of the highest priorities: safety and efficiency.

In addition to being the number one concern, a proven safety record provides additional benefits to a company. A safe work environment serves as a key component to company growth, including the ability to remain competitive in bidding and maintaining higher-level, more challenging projects. However, safety is easier to talk about than to implement, especially considering ever-present factors like emissions, the risk of falling debris and heavy machinery in motion.

But safety is just one of the many concerns tunneling professionals face on a daily basis. Projects also have tight budgets and schedules, making efficiency imperative. Traditional methods like drilling and blasting, and equipment, including hand-held drills, excavators, tunnel boring machines (TBM) and roadheaders, offer proven performance on a variety of tunneling tasks. But contractors now have more options – and options better suited, not just for construction, but for repair as well, thanks to advanced technology.

Roadheaders of the future?

Remote controlled all-tool carriers are primary example of equipment innovation at work. These machines have emerged as a practical, efficient and safe solution to several tunneling challenges.

First, and perhaps most importantly, are the safety benefits all-tool carriers bring to the jobsite. Remote-controlled operation enables workers to remain a safe distance from common hazards, including falling debris. Depending on the model, this could be up to several hundred feet away. Operation is much simpler and far less labor-intensive as well. This helps prevent potential injuries and eliminatesany fatigue-related issues. Additionally, these machines are most often electric-powered, eliminating harmful emissions – one of the most serious safety concerns in confined-space jobsites. Finally, drilling and blasting, though one of the most common methods used in tunneling, may be restricted

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A Brokk 160 digs the shaft on the Euclid Creek Storage Tunnel Project. The scope of this project entails reducing the number of combined sewer overflows to Euclid Creek and Lake Erie by re-routing the overflow systems into the new water storage tunnel.

at times due to safety or security reasons. All-tool carriers offer an alternate method to perform a similar function.

These machines also address the logistical issues of typical tunneling projects. Because the environment is confined, the compact nature of all-tool carriers is a major advantage, and allows them to get into areas inaccessible to other machines. For example, Brokk Inc., a manufacturer of remote-controlled all-tool carriers, offers several models that stand less than 1.2 m (4 ft) tall and 1 m (3 ft) wide. They are small enough to fit through a standard doorway.

Although they may be compact in size, all-tool carriers do not come up short on power, reach or overall performance. In fact, these machines typically deliver up to four-times the hitting power of similar class, diesel powered excavators. For example, a 4,500-kg- (10,000-lb) unit carries the same model hydraulic breaker that would normally be found on a 11,300-kg- (25,000-lb) hydraulic excavator. This remarkable power-to-weight ratio is essential in tunneling environments, as space is often a premium. Yet the material is tough enough that power cannot be compromised. All-tool carriers are also able to provide impressive reach capabilities, some up to 9 m (30 ft), further enhancing productivity by enabling access to areas inaccessible to others.

Along with power and reach, the productivity provided by all-tool carriers is unmatched by traditional methods. These machines have been shown to have an output comparable to six men. Even when precision is needed, these units are able to handle tasks traditionally performed by hand, such as lifting and holding utility pipe in place for easier installation.

The final and key aspect to the overall productivity of all-tool carriers is versatility. In the past, excavators and other machines used in tunneling typically had only two attachment options — a bucket or breaker. All-tool carriers are compatible with numerous attachments, enabling a single machine to perform dozens of tunneling applications, from breaking tough rock and clay to shotcreting.

Completing the puzzle

Not viewed as a separate piece of equipment, attachments used with all-tool carriers are much more than that. They are a key component of the all-tool carrier and essential to the machine's growing success. Some attachment and all-tool carrier manufacturers have teamed up and continuously work together to ensure that one complete solution is provided that works at peak performance every time.

A longtime and well-known manufacturer in the tunneling industry, Atlas Copco is one leading provider of attachments used with all-tool carriers. Among the most popular offerings is the hydraulic breaker. As a general rule, hydraulic breakers are the ideal choice when encountering the toughest, hardest materials, as well as in common applications, such as the creation of cross-passages and safety niches. Featuring a solid body and machined out of a single cast piece of metal, Atlas Copco SB series breakers are extremely durable and reliable. Additionally, the company works closely with some all-tool carrier manufacturers to ensure its breakers are optimized to provide maximum breaking force with every hit.

Another common attachment manufacturer used by leading all-tool carrier manufacturers is TEI Rock Drills, based in Colorado. TEI offers both standard and limited-access drilling attachments. One of the unique attributes that sets the company apart and allows it to produce some of the strongest, most lightweight attachments, is its manufacturing process. It uses patented drifters (rotary/percussion) and feed systems, resulting in a product that stands up to the most demanding underground challenges, including grouting, bolting, coring, blasting and fore-poling.

Specializing in one particular, yet highly sought after, attachment is another well-known manufacturer, Drumcutters. As the name implies, the company's expertise is exclusively focused on the manufacturing of rotary drum cutters – an attachment that is free of vibration, offers quiet operation and can complete tasks that cannot be achieved with other attachments, even hydraulic breakers. This tool is ideal for environments with softer materials where accuracy is important and vibration is not acceptable. One such application is cutting niches in concrete tunnel linings, without damaging the surroundings.

In addition to the above, all-tool carrier manufacturers offer several more attachment options for more fine-tuned tunneling work, including concrete cutters or beam grapples. These devices are best for placing utility pipes or steel structures – also referred to as "ribs" – in the upper sections of a new tunnel for water, lights, or for the formation of a safe archway.

Evidence of the growing popularity of all-tool carriers and attachments in place of traditional equipment is the contribution they are making on some of the most challenging tunneling projects in North America.

The missing link

In downtown Seattle, WA, an extensive tunneling project is under way with the construction of the University Link Light Rail. Upon completion, this 5-km (3.15-mile) light rail extension will connect some of the region's largest urban centers – downtown Seattle, Capitol Hill and the University District – with a high-speed, full-capacity light rail line. Two contractors are currently working with three TBMs below more than 91 m (300 ft) of cover on the U-Link project, one being Traylor Frontier-Kemper. This company's portion of the work includes the construction of cross-passages between the twin tunnels every 243 m (800 ft). According to Matt Burdick, project engineer, this is required in twin light rail tunnels, as it provides proper egresses in the event of a fire or other emergency situation.

Due to the severely confined nature of the space, the crew purchased two all-tool carriers to perform the cross-passage excavation. Equipped with roadheaders and rock drills, each Brokk 180 handles the material conditions – primarily dry clay – effectively breaking up the soils to be loaded and removed. Furthermore, Burdick says the machine has been beneficial in breaking through half-excavated cross-passages, cutting the manual demolition work in half.

The B180 has worked out well and boosted production on this portion of the project. In fact, Burdick said he is looking to add another Brokk to his fleet – a smaller model. With how tight and confined the cross-passages are, Burdick believes production could be further enhanced with a smaller unit.

To those on the outside, it may seem odd that a smaller unit would increase production, but Burdick pointed out the machine's exceptional power-to-weight ratio.

In addition to the benefits the all-tool carrier has provided on the cross-passages, the B180 has flexed its versatility muscles, and further proven its worth by being utilized on a variety of other tasks. It has been essential in drilling holes for spieling, which is the installation of support pieces over the crown of the cross-passage. The unit has also tackled concrete demolition with efficiency and ease.

While productivity was a key component of bringing in the all-tool carrier, safety was also high priority on this jobsite. And, according to Burdick, something the machine was able to address.

With machine locomotives running back and forth underground, it doesn't take long for exhaust and emission limits to be reached. Air quality is not only a safety concern, ordinances and emissions restrictions exist as well. Thanks to its zero-emissions operation, the Brokk machine can operate around the clock, without affecting air quality.

The U-Link project highlights both the productivity and safety benefits provided by all-tool carriers. Not to be forgotten, the compact nature is often equally as crucial in underground applications, as evidenced by a recent project in Cleveland, OH.

An alternate waterway

In 2010, contractor McNally-Kiewit began construction on a tunnel that would aid in the efforts to improve water quality in Lake Erie and Euclid Creek, OH. Known as the Euclid Creek Storage Tunnel Project, the scope entails reducing the number of combined sewer overflows to Euclid Creek and Lake Erie by re-routing the overflow systems into the new water storage tunnel. Once complete, this underground tunnel will act as a holding tank for the water plant – ensuring that no untreated water is dumped into Lake Erie. Excess water will be held in the tanks when the plant is backed up. Once the plant is up to speed again, the water will be taken from the tanks and cleaned, and finally released into Lake Erie.

While the concept of having a holding tank was relatively simple, construction of the tunnel has been a bit more intricate. Eighteen connector shafts would act as access points for water to run into the tank below. Construction of a central shaft was also needed to connect the water tank to the treatment facility. Each shaft ranges from 5 to 15 m (18 to 50 ft), which makes for a work environment too small for even a mini-excavator. William McFadden, shaft superintendent, explained additional challenges his crew faced. Ten of the shafts also had existing sewers passing through them, which limited the space even more. For example, one excavation is 7.6 m x 5 m (25 ft x 16 ft) with a 1.2-m (48-in.) sewer passing through it.

Facing these challenges, McNally-Kiewit decided to turn to an all-tool carrier for assistance – in this case, the B160 from Brokk is being used to dig shafts. A crane lowers a 1.5-m^3 (2-cu yd) bucket to remove the excess dirt and clay. While operators fill the bucket and the crane lifts it out, the B160 continues to dig – allowing shaft excavation to continue without interruption.

While McNally-Kiewit originally looked to an all-tool carrier for its compact, low-profile size, the company has realized additional benefits of the machine. Productivity, safety and precision have all been increased.

According to McFadden, in addition to the confined spaces, emissions have been an issue in the construction process of the tunnels. The machine allows the crew to dig these tunnels easily without ever having to put an operator in danger. Also, it has been strong enough to excavate even the hard clay they have been encountering.

These are just two instances showcasing the practical usage of all-tool carriers and attachments in tunneling applications. From convenience and versatility to increased safety and productivity, there's no doubt the benefits offered by these machines are going to further their growth and popularity. ■

Challenges of conveyors in tunneling

As time is costly, engineering companies have developed methods, procedures and mechanical equipment to tunnel faster. But the best excavation method will not be able to cope with the time pressure if there is not a reliable backup system. Therefore, the application of belt conveyors for tunnel boring machine (TBM) drives as well as for drill-and-blast driven tunnels assure a quick and smooth removal of excavated soil in order to enhance the efficiency of the tunneling equipment.

During the last 10 years, belt conveyor systems have achieved 'state-of-the-art' levels and have become the first choice for muck removal systems in both TBM and drill-and-blast driven tunnels. Because time has become such a key criterion in tunneling projects, it is essential that all equipment is operated so as to derive optimum efficiency and minimize costs. Efficiency also means to think about new tasks for existing technologies.

One of the key benefits of belt conveyors is that they are central to providing safer working conditions, due to the separation of TBM supply lines and the transportation of excavated soil. Therefore, fewer diesel locomotive rides are required, thereby reducing the risk of accidents. In addition, a smaller ventilation duct is required due to the fewer exhaust fumes in the tunnel atmosphere — something that also helps save money.

Conveyor systems installed in inner city tunnel projects help save space by means of vertical storage cassettes and compact on-surface installations, which allow easy transportation of muck out to the disposal area. Even bridges that enclose complete conveyor installations with walkways are p ossible setups for inner city projects, as the advantage of avoiding truck traffic cannot be ignored.

FIG. 1

Schematic sketch of MTR WIL C 704 contract, Hong Kong.

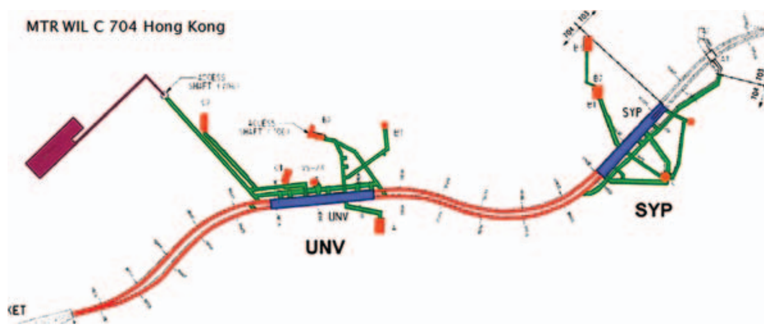
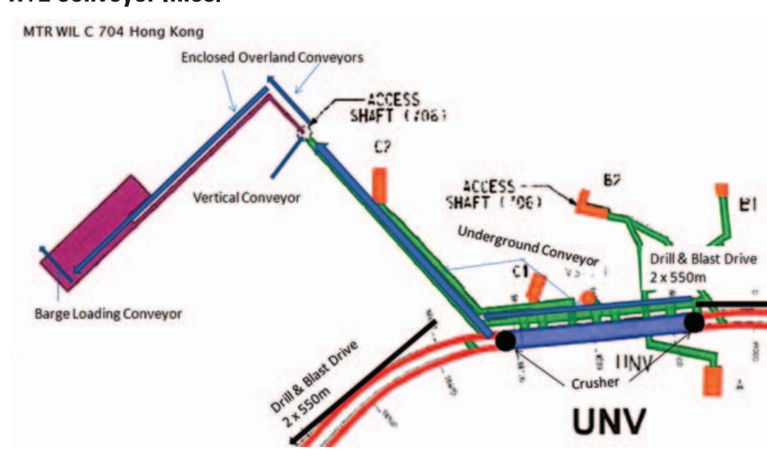


FIG. 2

H+E conveyor lines.



Marco Sonnenschein

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A conveyor setup - Inner city, Hong Kong

The Metro Line in Hong Kong was a challenging, inner city drill-and-blast project in which several conveyors were installed.

The Gammon Nishimatsu WIL Joint Venture (GNWIL JV) used a static conveyor installation for muck transportation. To transport the soil to the barge loading and stockpiling area, horizontal conveyors and a vertical conveyor form a reliable muck transport installation. The line of the JV's contract is shown as schematic in Fig. 1.

The drill-and-blast tunnels are four tubes, each 550 m (1,800 ft) in length. The excavated rock was transported by underground trucks to two crushers to prepare the rock in homogeneous chips of maximum 100 mm (4 in.) in length and 30 mm (1.2 in.) in width. From these two crushers, the installed underground conveyors were responsible for the muck removal, from underground to the barge loading at the pier.

The underground setup of the conveyor system is shown in Fig. 2 as a schematic. The two crushers are placed in big underground chambers. From there, the conveyors removed the rock where the conveyor line fed by one crusher was discharging/loading onto the other conveyor line coming from the second crusher. The capacity of the 800-mm- (30-in.-) wide underground conveyors was 400 t/h and 800 t/h (440 stph and 880 stph). The conveyors were equipped with gear motors of sizes between 37 kW and 55 kW (50 hp and 73 hp). All drives were VFD, which allowed for adjusting the belt speed if required and assured defined starting and shut down ramps. All conveyors were controlled by an S7 PLC-based SPS program, the communication between the PLC and the drives was via Profibus. The communication signal for all emergency devices was via Dubline signal. Because of the number of conveyors and the distances between the starting and end point of the conveyor lines (from underground to surface, to barge loading), the transfer points were equipped with cameras to allow people in a control room to monitor the current status.

The vertical conveyor (Fig. 3) had a 1,400-mm- (55-in.-) wide belt with corrugated side walls and cleats and two 90-kW (102-hp) drives. It was designed for a capacity of 800 t/h (88 stph) at a lifting height of 50 m (164 ft). It transported the excavated rock from underground to the surface.

The transportation of heavy equipment by truck in inner city Hong Kong was only doable at night. Due to the geographical location of inner city Hong Kong, the space for the jobsite was limited and, therefore, also for the conveyor installation. The narrow, on-surface pre-assembly space of approximately 15 m x 5 m (49 ft x 16 ft) complicated the assembly even more, compared to the dimensions of the vertical conveyor (drive station 15-m- long x 6-m- wide x 11-m- high (49 ft x 20 ft x 36 ft); return station 10.5 m x 4 m x 9 m (34 ft x 13 ft x 29 ft)). The shaft with 16 m (52 ft) diameter and 50 m (164 ft) height provided enough space for the final installation of the loading station at the bottom of the shaft. Proper assembly planning by the project management team and efficient organization of the assembly process by the supervisor and the GNWIL JV on-site led to a successful completion.

Beside the installation of a vertical conveyor, the surface installation concealed several challenges. For

FIG. 3

Vertical conveyor in Hong Kong.

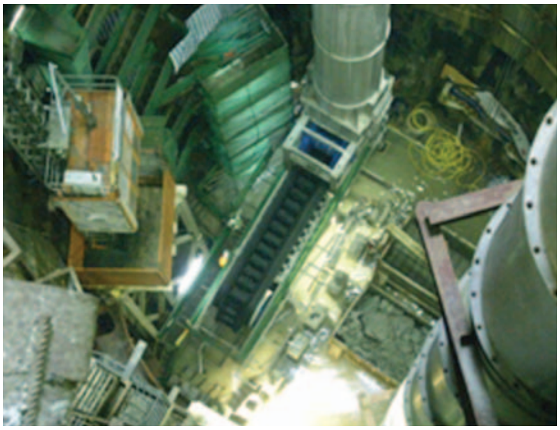


FIG. 4

Overview of an on-surface arrangement in Hong Kong.

FIG. 5

Conveyor crossing of Shing Sai Road, Hong Kong.

example, in order to reach the barge loading area, the conveyor arrangement had to cross over the Shing Sai Road, follow this road along until the discharge conveyor loads the muck onto barges (Fig. 4). Installing a bridge support system for the conveyor system with a span of 55 m (180 ft) (Fig. 5) gave the cross-section rigidity.

This was also important because of the busy traffic below the conveyor and because the installation was taking place in an inner city environment, where people were living next door to the jobsite (Fig. 7). This created numerous challenges, such as reducing emissions and noise, not to mention the need to avoid muck falling out of the conveyor onto the road below. Due to the enclosure, a noise reduction of 10 dbA to 15 dbA is possible.

The solution for reducing the noise level, avoiding the dust emission and preventing rock falling onto the road or hitting crossing vehicles or pedestrians encapsulated the whole conveyor installation. Fully enclosed bridge sections designed with walkways on both sides of the conveyor and emergency exits (Fig. 6) and enclosed drive units were the result of these environmental challenges.

FIG. 6

Emergency exit.

The bridge sections for the 800-mm- (30-in.-) wide belt conveyors were designed with different lengths between 18 m and 40 m (59 ft and 131 ft) (Shing Sai Road Crossing, Fig. 5). The overall width (3.3 m) and height (2.8 m) of these bridges provided enough space for the 800-mm- (30-in.-) wide belt installation and walkways of minimum 600 mm (23.6 in.) on both sides of the conveyor.

FIG. 7

Overland conveyance.

The encapsulated design of the bridges provided full access to the conveyor, for maintenance (Fig. 8). The personnel working on the conveyor system for maintenance were also protected from environmental influences. Following this design attitude, even the transfer point with the drive unit of 55 kW (73 hp) of the overland conveyor No. 1 was fully enclosed (Fig. 8).

Such conveyor installations in cities are complicated setups, but it was proved that the choice of muck transportation in highly populated areas has advantages that are obvious. When dismantled, the conveyor installation in Hong Kong had been in service approximately 15 months. This time of service avoided reams of truck drives for the rock transportation, avoided lots of air pollution due to truck exhaust and reduced the noise emission to a minimum.

Filling the tunnel invert by conveying the concrete

Besides the application of conveyor systems for the muck removal of tunnel drives such as drill-and-blast tunnels as well as TBM driven tunnels, conveyor systems are more flexible in use than one might think. Being faced with the demands and requirements of the customer, challenging engineering ideas are born. The already mentioned time-is-money fact leads to different ways of thinking of technical solutions. The high-speed train tunnel Atocha–Charmartin in Madrid was such a project where the customer, AVE Tunel de Serrano U.T.E (a joint venture), with the tunnel belt supplier developed the idea of using the belt conveyor installed for the TBM drive afterward for a different task.

The tunnel belt conveyor system for the 7-km- (4.3-mile) long 11.5-mm- (38-ft) diameter earth pressure balance (EPB) TBM drive was designed with a 1,200-mm- (4-ft-) wide belt and a 355-kW (476-hp) VFD main drive.

The tunnel invert had to be filled with concrete in order to prepare the tunnel for the final lining, as well as its purpose of running two rails for high-speed trains through the tunnel.

FIG. 8

Conveyor bridge from the inside of the transfer point of the overland conveyor.

FIG. 9

Main components for conveying concrete.

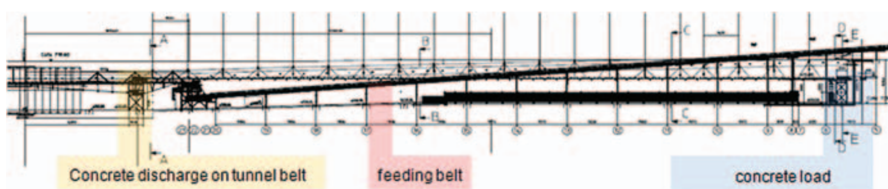
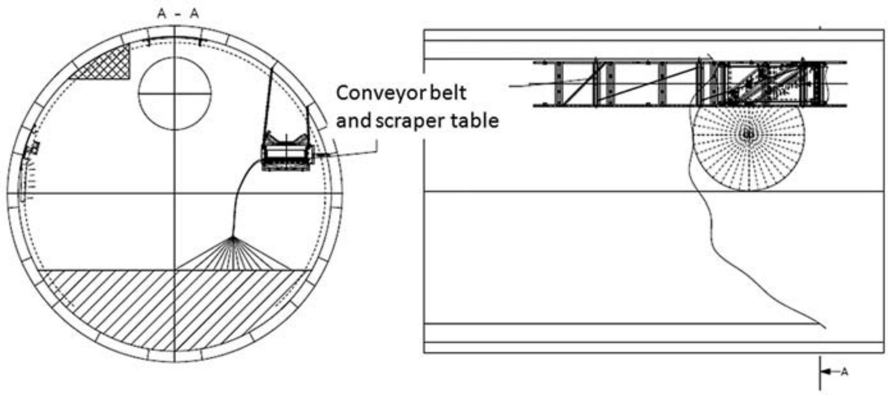


FIG. 10

Feeding conveyor with loading point onto tunnel belt conveyor.

FIG. 11

Sketch of discharging concrete.



Avoiding truck traffic and being fast with transporting the required dry concrete into the tunnel, the idea was born to use the existing conveyor system even after the TBM breakthrough and give it a different task. As the normal task of a conveyor belt for tunneling is to transport the soil out of the tunnel, the idea was to transport the required dry concrete into the tunnel by using the existing conveyor system. That means using the bottom conveyor strand (the strand running normally empty into the tunnel) to transport the concrete into the tunnel.

The conveyor setup for concrete transport consists of the main components, shown in Fig. 9, to fulfill the new task. The concrete is loaded outside the tunnel in front of the portal on a feeding belt conveyor, which had to be installed in addition to the existing system. That feeding belt loaded the bottom strand of the tunnel belt conveyor and was transported into the tunnel (Fig. 10).

Once the concrete is on its way into the tunnel, it needs to be discharged at its destination, which is a moving point as concreting works go further along the tunnel. The movable discharge was realized by a scraper table that could be pulled through the supporting structure (Fig. 11).

Once the concrete was discharged onto the tunnel invert, the concrete was distributed by front end loader (Fig. 12). This configuration was designed to transport 500 t/h (550 stph) of concrete. The invert of the tunnel, with a total length of 7,000 m (23,000 ft), was filled to the required level within two months.

FIG. 12

Concrete distribution in the tunnel.

Conclusion and outlook

Belt conveyor applications for worldwide tunneling projects have increased during the last 10 years, as productivity becomes more important and the advantages of conveyors have been proven during several projects. Every new application of a conveyor system, whether it is a horizontal tunnel belt conveyor or a vertical conveyor, hides its specific difficulties. Solving these difficulties by tailor-made technical solutions and experience gained from every project result in a continuous improvement of the belt conveyors.

As a space saving muckout system, vertical conveyors will become more important for inner city tunneling projects or elsewhere where the access to the tunnel is deep underground; e.g., in Mexico (Emisor Oriente Waste Water Tunnel) or Mumbai (Water Supply Tunnel). Mexico, with a lifting height of the vertical conveyor of 136 m (446 ft), and Mumbai, with a lifting height of 110 m (360 ft), will be the next big steps, proving the efficiency of vertical conveyor applications. The experience gained from these projects will influence the design of vertical conveyors in the future.

An extended field of application of conveyor systems in tunneling is possible by combining the core task with additional ones. To increase the efficiency of a tunnel belt conveyor, it is possible to use a conveyor as a muckout system for a TBM or drill-and-blast drive to get access to underground raw material disposal and then to use the already installed tunnel conveyor for transport of ore, coal or potash. But giving the belt conveyor system a complete different task, like transporting concrete into the tunnel by using the bottom strand of the conveyor, extends the range of application of belt conveyors and helps raise the efficiency. Choosing such an application could minimize the time until the initial investment is paid off. ■

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Gateway Tunnel project	Amtrak	Newark	NJ	Subway	14,600	24.5	2015	Under study
2nd Ave. Phase 2-4	NYC-MTA	New York	NY	Subway	105,600	20	2015-20	Under study
Water Tunnel #3 bypass tunnel	NYC-DEP	New York	NY	Water	20,000	22	2015	Under design
Water Tunnel #3 Stage 3 Kensico	NYC-DEP	New York	NY	Water	84,000	20	2017	Under design
Cross Harbor Freight Tunnel	NYC Reg. Develop. Authority	New York	NY	Highway	25,000	30	2016	Under study
Silver Line Extension	Boston Transit Authority	Boston	MA	Subway	8,400	22	2018	Under design
Hartford CSO program	MDC	Hartford	CT	CSO	32,000	20	2013	Under design
South Conveyance Tunnel	City of Hartford	Hartford	CT	CSO	16,000	26	2014	Under design
Red Line Tunnel - Cooks Lane Tunnel	MD Transit Administration	Baltimore	MD	Subway	14,000	22	2015	Under design
Red Line Tunnel - Downtown Tunnel	MD Transit Administration	Baltimore	MD	Subway	36,000	22	2015	Under design
Anacostia River Tunnel Northeast Branch Tunnel Northeast Boundry Tunnel Virginia Ave. Tunnel Expan.	DC Water and Sewer Authority CSX Railroad	Washington	DC	CSO CSO CSO Rail	12,500 11,300 17,500 4,000	23 15 23 40	2013 2018 2021 2013	Under design Under design Under design Under design
West Ashley Tunnel Project	City of Charleston	Charleston	SC	CSO	9,500	8	2012	Bid Date 12/19/12
Olentangy Relief Sewer Tunnel	City of Columbus	Columbus	OH	Sewer	58,000	14	2013	Under design
Alum Creek Relief Tunnel Phase 1 Phase 2 Phase 3 Black Lick Tunnel	City of Columbus	Columbus	OH	Sewer	30,000 21,000 25,800 33,000	18 14 10 7	2014 2016 2018 2014	Under design Under design Under design Under design
Dugway Storage Tunnel	NEORSD	Cleveland	OH	CSO	16,000	24	2013	Under design
Doan Valley Storage Tunnel	NEORSD	Cleveland	OH	CSO	9,700	17	2015	Under design
Westerly Main Storage Tunnel	NEORSD	Cleveland	OH	CSO	12,300	24	2020	Under design
Lower Mill Creek CSO Tunnel - Phase 1	M.S.D. of Greater Cincinnati	Cincinnati	OH	CSO	9,600	30	2014	Under design
Ohio Canal Tunnel	City of Akron	Akron	OH	CSO	6,170	27	2013	Under design
Northside Tunnel	City of Akron	Akron	OH	CSO	6,850	24	2021	Under design
ALSCOSAN CSO Program	Allegheny Co. Sanitary Authority	Pittsburgh	PA	CSO	35,000	30	2016	Under design
Pogues Run Tunnel	Indianapolis DPW	Indianapolis	IN	CSO	9,700	18	2016	Under design
White River Tunnel	Indianapolis DPW	Indianapolis	IN	CSO	27,800	18	2016	Under design

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Drumanard Tunnel	Kentucky DOT	Louisville	KY	Highway	2,200 x 2	35	2012	Bids 10/26/12
St. Louis CSO Expansion	St. Louis MSD	St. Louis	MO	CSO	47,500	30	2014	Under design
KCMO Overflow Control Program	City of Kansas City, MO	Kansas City	MO	CSO	62,000	14	2014	Under design
Mill Creek Peaks Branch Tunnel	City of Dallas	Dallas	TX	CSO	5,500	26	2014	Under design
North Link Light Rail Extension	Sound Transit	Seattle	WA	Transit	35,000	22	2013	Under design
East Link Light Rail Extension	Sound Transit	Seattle	WA	Transit	30,000	22	2016	Under design
Chinatown NATM Station	San Fran. Muni Transit Authority	San Francisco	CA	Subway	340	60	2012	To be rebid
Third Ave. Subway Tunnel	San Fran. Muni Transit Authority	San Francisco	CA	Subway	10,000	22	2015	Under design
San Francisco DTX	Transbay Joint Powers Authority	San Francisco	CA	Transit	6,000	35 to 50	2015	Under design
L.A. Metro Regional Connector	Los Angeles MTA	Los Angeles	CA	Subway	20,000	20	2014	Under design
LA Metro Wilshire Extension Phase 1 Phase 2 Phase 3	Los Angeles MTA	Los Angeles	CA	Subway	42,000 26,500 26,500	20 20 20	2014 2015 2017	Under design Under design Under design
LAX to Crenshaw	Los Angeles MTA	Los Angeles	CA	Subway	12,200	20	2012	Bid due mid Nov.
LA CSO Program	L.A. Dept. of Public Works	Los Angeles	CA	CSO	37,000	18	2015	Under design
Freeway 710 Tunnel	CALTRANS	Long Beach	CA	Highway	26,400	38	2016	Under design
SVRT BART	Santa Clara Valley Trans. Authority	San Jose	CA	Subway	22,700	20	2014	Under design/ delayed
BDCP Tunnel #1 BDCP Tunnel # 2	Bay Delta Conservation Plan	Sacramento	CA	Water	26,000 369,600	29 35	2014 2016	Under design Under design
Kaneohe W.W. Tunnel	Honolulu Dept. of Env. Services	Honolulu	HI	Sewer	15,000	10	2013	Bid mid 2013
Eglinton-Scarborough Tunnel	Toronto Transit Commission	Toronto	ON	Subway	40,500	18	2014	Under study
Yonge St. Extension	Toronto Transit Commission	Toronto	ON	Subway	15,000	18	2016	Under study
Hanlan Water Tunnel	Region of Peel	Toronto	ON	CSO	19,500	12	2013	Pre Qual JV's announced
West Trunk Sewer Phase 1 West Trunk Sewer Phase 2	Region of Peel	Toronto	ON	Sewer	30,000 16,000	11 11	2013 2013	Ad Mid Nov. 2012 Ad 1st Q 2013
Second Narrows Tunnel	City of Vancouver	Vancouver	BC	CSO	3,600	14	2013	Under design
Evergreen Line Project	Trans Link	Vancouver	BC	Subway	10,000	18	2012	Prequalified JV's announced
UBC Line Project	Trans Link	Vancouver	BC	Subway	12,000	18	2014	Under design

Indiana establishes Center for Underground Tunneling Education and Research

by Hamed Zamenian, graduate research assistant, CEMT at IUPUI

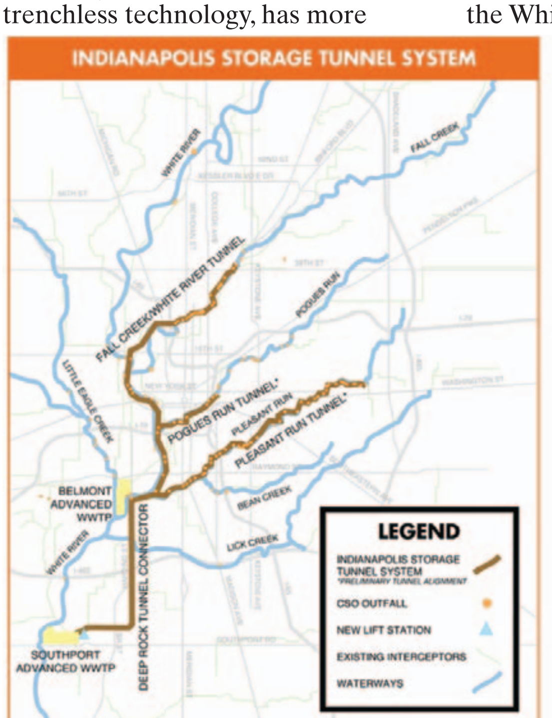
The Construction Engineering Management Technology (CEMT) program within the Purdue School of Engineering and Technology at Indiana University-Purdue University Indianapolis (IUPUI) has established the Center for Underground Tunneling Education and Research (CUTER). The center was formed in response to the 15-year combined sewer overflow (CSO) tunnel project planned for the city of Indianapolis.

CUTER's purpose is to encourage harmony between the university and industry and provide educational and research opportunities through faculty members and graduate students. Tom Iseley, CEMT professor and program director at IUPUI, and director of CUTER, wanted the university's program to be involved in large-scale tunnel projects at the local, national and international level.

Iseley, known as the father of trenchless technology, has more than 35 years of experience in the planning, designing and construction of underground infrastructure systems. During the past 15 years, he has maintained an international leadership position in trenchless technology. In 1989, Iseley established the Trenchless Technology Center, an industry-university cooperative research facility, at Louisiana Tech University, served as its director for more than five years and served as director of development for two years.

Iseley's vision for CUTER is to define IUPUI as a focal point for the tunneling industry by collaborating with other institutions and industry through construction-focused training programs and research.

The city of Indianapolis has committed to an expansive 15-year CSO tunnel project. The city's tunnel project consists of five tunnels: the Deep Rock Tunnel connector, the White River Tunnel segment, the Lower Pogues Run Tunnel, the Fall Creek Tunnel segment and the Pleasant Run Tunnel. The entire project is expected to be finished by 2025 and is anticipated to cost around $1.7 billion. The Deep Rock Tunnel connector project will include a 40.2-km (25-mile) deep tunnel system. The 5.5-m-(18-ft-) diameter tunnel, at more than 61 m (200 ft) below ground, will provide an underground storage system for sewage during heavy storms. It will have storage capacity of more than 757 million L (200 million gal) during rainy times.



Most students are unaware that tunneling is a career. Few civil engineering or construction engineering schools offer a tunneling construction program. Of the few schools that have tunneling programs, most are mining-related, rather than civil engineering or construction management. CUTER's mission is to provide a tunneling construction course for the CEMT program, which can provide opportunities for students and professionals to learn about the tunneling industry. For CUTER, collaboration with the tunneling industry advisory board is crucial to improve the CUTER concept.

The goals of this center are to become a unifying asset to the tunneling industry, to provide a premium tunneling construction program, to assist the tunneling industry at a global level and to provide students a clear career path into the tunneling industry. The Indianapolis tunnel project provides a great opportunity for undergraduate and graduate students to increase their knowledge in tunnel construction beyond design, to include project management, project procurement, safety issues and the decision-making process. CUTER is also developing an educational outreach program for middle and high schools, as well as to community organizations.

The first meeting of CUTER with the industry advisory board was held in April 2012. The attendees saw a gap between senior and young professionals because of a lack of tunneling education at schools of higher education. Safety in tunneling construction was another topic discussed. Industry representatives agreed that safety in tunneling construction is an issue that needs to be addressed and is a priority for the tunneling industry.

(Continued on page 70)

PERSONAL NEWS

Jacobs Associates has promoted three employees to the lead associate level.

RENÉE FIPPIN, PE, GE, has specialized in geotechnical and structural excavation support design. She is based out of the San Francisco, CA office and has been managing the city of San Francisco's Sunnydale Auxiliary Sewer project.

JEREMY JOHNSON, PE, is a member of the design staff in Jacobs Associates' Seattle, WA office. Johnson has performed geotechnical and structural engineering analyses for numerous projects, including the King County's Ballard Siphon Replacement project and the Fremont Siphon project.

BHASKAR THAPA, PE, is based out of the San Francisco, CA office and currently serves as the project manager on Lawrence Berkeley National Laboratory's proposed Next Generation Light Source facility.

SARAH WILSON (SME), PE, is based out of the San Francisco, CA office and currently serves as the resident engineer on San Francisco's Central Subway Tunneling project. She is responsible for administration of the $233 million construction contract for the twin tunnels, launch and retrieval structures, and station headwalls.


WILSON

Jacobs Associates has also promoted the following employees to the associate level.

BOB BALDWIN, CCM, is located in the Seattle, WA office. Baldwin's technical expertise includes contract administration and analysis, documentation and project controls, review of project records and evaluation of procurement methods.

JENNIFER JORDAN, PE, is located in the Jacobs Associates Boston, MA office. For 17 years, she has specialized in geotechnical and tunnel engineering of deep underground structures. She currently serves as senior geotechnical engineer for DC Water's Clean Rivers project.

LAURA MILES, PE, is a construction claims specialist with responsibility for contract administration, construction supervision, cost estimating, scheduling and construction claims and schedule analysis. She provides consulting services to owners and contractors for the resolution of contractual disputes in the Portland, OR office.

JOE SCHRANK, PE, is located in Jacobs' Seattle, WA office. His project work focuses on railroad tunnel rehabilitation, the feasibility and design of trenchless pipeline crossings and geotechnical field investigations. He is currently project manager for the design services during construction for seven tunnels.

The following three Jacobs employees were promoted to the senior associate level.

KEITH ABEY, PE, SE, provides critical design review, numerical modeling, forensic engineering support and advice on historic structures. Abey is currently the lead structural engineer on Sound Transit's North Link Light Rail and University Link Light Rail extension projects, including the Capitol Hill Station construction.

TED DePOOTER, PE, analyzes problem areas, works with clients and project teams to identify solutions and institutes programs to mitigate problems and enhance the performance of projects. He is the resident engineer during the construction management of the South Cobb Tunnel project.

MARK LAWRENCE, PE, specializes in the design of permanent and temporary excavation support systems. He recently provided design oversight on the tunnel final lining falsework on the Devil's Slide project, as well as design oversight on the launching and receiving shafts on the Bay Tunnel project.

DAN VAN ROOSENDAAL (SME), PE, is a geotechnical engineer who serves as the New York City project manager for the Rondout-West Branch Bypass project. He also supports other projects, including the completion of geotechnical evaluations on the District of Columbia Water and Sewer Authority's deep soft ground tunnels and management of the design-build effort for the Trans Hudson Rail Tunnel. ■


VAN ROOSENDAAL

CUTER

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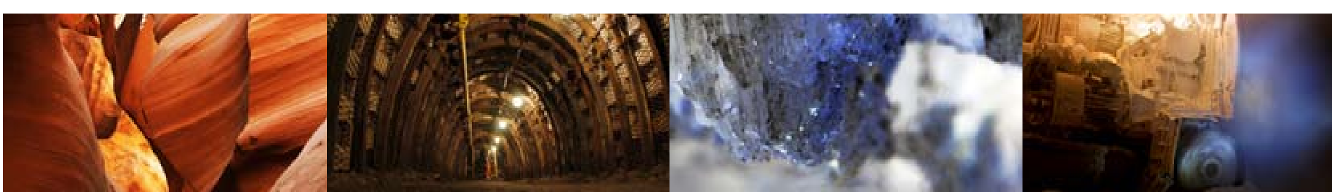
Industry representatives are eager to see how CUTER can fill the gap in the area of safety.

The next meeting of CUTER will be held early in 2013. At this meeting, CUTER hopes the tunneling industry will contribute to the short- and long-term plans for the center and will get involved in finalizing the tunneling construction course. The center appreciates the tunneling industry advisory board members' collaboration and is looking for hands-on type people with tunneling experience to improve the CUTER concept.

For more information, contact Tom Iseley, director of CUTER, at dtiseley@iupui.edu or 317-278-4970 or Hamed Zamenian at hzamenia@iupui.edu. ■



January 2013

18, Beavers Award Dinner, J.W. Marriott at LA Live, Los Angles, CA. Contact: The Beavers, 2053 Grant Road, PMB-370 Los Altos, CA 94024, phone 605-694-4834, fax 605-694-4836, e-mail info@thebeavers.org, website www.thebeavers.org.

23, The Moles Award Dinner, Grand Ballroom, New York Hilton, Manhattan, NY. Contact: The Moles, 577 Chestnut Ridge Road, Woodcliff Lake, New Jersey 07677, phone 201-930-1923, fax 201-930-8501, e-mail carty.moles@verizon.net, website www.themoles.info.

February 2013

11-14, Microtunneling Short Course, Golden, CO. Contact: Microtunneling Inc., Timothy R. Coss, P.O. Box 7367, Boulder, CO 80306, phone 303-444-2650, fax 303-444-0889, e-mail timcoss @ microtunneling.com, website www.microtunneling.com.

March 2013

3-7, NASTT's 2013 No-Dig Show, Sacramento, CA, Contact: Benjamin Media Inc., 10050 Brecksville Road, Brecksville, OH 44141, phone 330-467-7588, fax 330-468-2289, e-mail vlosh@benjaminmedia.com, website www.benjaminmedia.com.

May 2013

31- June 7, WTC 2013, Geneva, Switzerland, Contact: Swiss Tunnelling Society, c/o World Tunnel Congress 2013, Rheinstrasse 4, CH-7320 Sargans, Switzerland, phone 41-0-844-31-05-13, fax 41-0-817-25-31-02, e-mail info@wtc2013ch, website www.wtc2013.ch.

June 2013

23-26, RETC 2013, Washington, D.C. Contact: Meetings Dept., SME, 12999 East Adam Aircraft Circle, Englewood, CO 80112, phone 800-763-3132 or 303-948-4280, fax 303-979-3461, e-mail sme@smenet.org, website www.smenet.org. ■

More meetings information can be accessed at the SME website — http://www.smenet.org.

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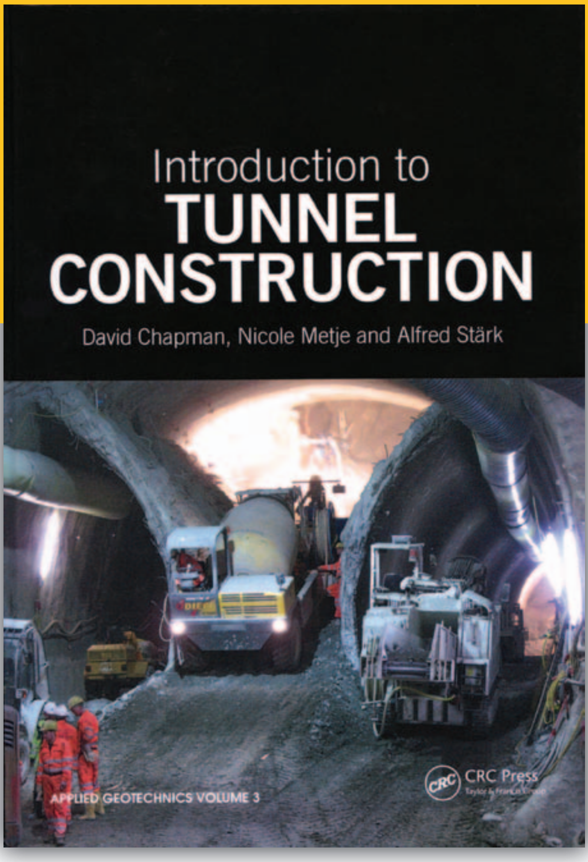
Introduction to Tunnel Construction



Introduction to Tunnel Construction

By David Chapman, Nicole Metje, and Alfred Stärk

Published by Taylor & Francis Group

2010, Hardbound, 416 pages, 3 lbs

Book Order No. 9114

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Tunnelling is one of the most fascinating disciplines within civil engineering and provides a robust solution to a variety of engineering challenges. It is a complex process, one that requires a firm understanding of ground conditions and structural issues in which engineering judgment plays an essential role. ***Introduction to Tunnel Construction*** discusses the range of topics that one would need to know in order to embark upon a career in tunnelling. It also includes a number of case studies of real tunnel projects, to demonstrate how the theory applies in practice.

The coverage includes:

- Both hard-rock and soft-ground conditions
- Site investigation, parameter selection, and design considerations
- Methods of improving the stability of the ground and lining techniques
- Descriptions of the various tunnelling techniques
- Health and safety considerations
- Monitoring of tunnels during construction

Clear, concise, and heavily illustrated, this is a vital text for final-year undergraduate and MSc students and an invaluable starting point for young professionals.

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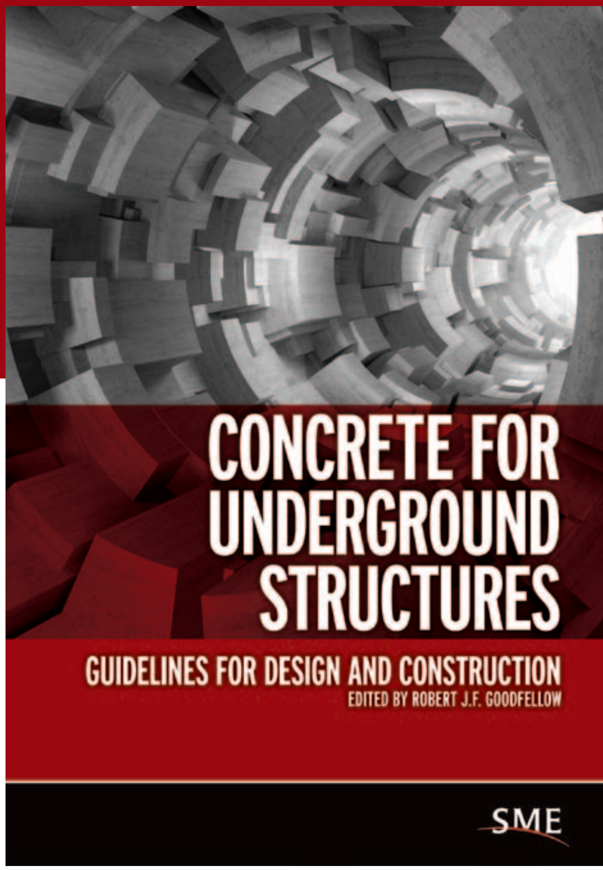

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