T&UC

TUNNELING & UNDERGROUND CONSTRUCTION

THE OFFICIAL PUBLICATION OF UCA OF SME WWW.TUCMAGAZINE.COM VOLUME 7 NO 4 DECEMBER 2013

Colorado's Twin Tunnels project

Small footprint, big challenges

Megaprojects around the world

Special Editorial Section from the publisher of *Mining Engineering*

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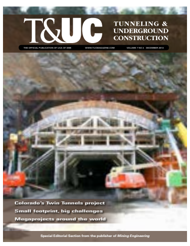
COVER STORY



In this issue — The eastbound side of the Twin Tunnels project in Colorado was widened to help alleviate heavy weekend traffic from the mountains west of Denver. The tunnel opened in December, page 61. Cover photo shows the east side of the eastbound tunnel. Construction of a water storage tunnel in Allen Park, MI presented major challenges, page 64.

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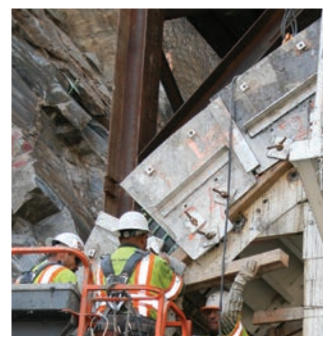


DEPARTMENTS

CHAIRMAN'S COLUMN

Generational challenges, turnover and the US tunneling industry

By recent estimates, 70 percent of Generation Y (also known as Millennials) will spend two years or less at their first job. Companies in the United States, and especially those in the underground industry, are already seeing the impacts of this job mobility. We call it turnover, and it not only adds operational costs, but also affects the cost, continuity and quality of projects. With many baby boomers nearing retirement, and large amounts of underground work in the pipeline, it is imperative that our industry find a way to retain younger employees.

With many Baby Boomers nearing retirement, and large amounts of underground work in the pipeline, it is imperative that our industry find a way to retain younger employees.

One of the major barriers to retaining employees from Generation X and Generation Y is understanding their motivations. Just as Boomers don't want to be treated like stubborn neophytes when it comes to adopting new technology, Millennials don't like to be perceived as selfish "takers" who will move on to the next company the moment it suits them. Open dialogue between employees can help these generations improve mutual understanding and provide clearer perspectives from which the best results can be achieved. For instance, a Millennial may learn to appreciate that hand calculations can be a valuable common-sense check on a computer model, and boomers can be inspired by the dedication to make a lasting contribution to the profession — even when that dedication trumps company loyalty. Understanding each other is a prerequisite to finding truly workable solutions to some of the other barriers to retention.

Another of those barriers is the expectation that an individual will provide continuity to a project by remaining in one role for its duration, whether that is five to 10 years, or as many as 20 years on some mega-projects. This is no longer a practical expectation, because many Gen Xers and Millennials are looking for variety and a faster pace of professional advancement than that to which us boomers were accustomed. With business, communication and technology moving at a faster pace than ever, it is not surprising that people expect their careers to advance quickly as well. Employers can increase their chances of retaining employees by promoting staff based on merit rather than tenure or by changing employees' responsibilities to keep them challenged. In cases where a promotion or increase in responsibility is not possible, employers may want to consider relocation. Many younger staff are not reluctant to relocate, and may even see their careers being advanced by such moves.

We also need to change our approach to professional development. Gen Xers and Millennials are highly motivated by ongoing training and increasing their skills. Rather than expecting young engineers to learn things by themselves, the way we had to do it, supervisors should proactively expose their staff to new challenges. I have found the younger staff are very willing to take initiative and learn from their mistakes once they have been given some guidance.

Finally, we should recognize that some turnover is inevitable. If

(Continued on page 4)

William W. Edgerton, UCA of SME Chairman

Delaware Aqueduct project begins in New York

An eight-year, $1.5-billion project to repair the Delaware Aqueduct in the Catskills region of New York state is now underway.

Starting the project off, crews are blasting 275 m (900 ft) down through bedrock to build a bypass tunnel under the Hudson River.

The vertical shaft in Newburgh is part of the construction of a 137-km (85-mile) tunnel that transports more than half the city's upstate reservoir water. The aqueduct leaks 57.8 to 32.5 ML (15 million to 35 million gal) of water a day, and has been blamed for chronically flooded basements in one upstate neighborhood, where homes are being demolished under a buyout program. The upstate New York project supplies water to New York City.

The multiphase project will cost $1.5 billion and eventually require the city to shut down the crucial artery for eight months or more, though city officials say the system's users shouldn't notice any disruptions, *The Associated Press* reported.

"If everything goes as planned, we expect that this will be seamless to New Yorkers," said Paul Rush, deputy commissioner of the city Department of Environmental Protection.

The massive project begins as New York City takes a series of costly steps to maintain its sprawling, aging water supply system. In November, the city activated a 13.6-km (8.5-mile) Manhattan section of its new water tunnel, which is designed to provide backup to two existing water tubes built in 1917 and 1936.

The aqueduct is a gravity-fed engineering marvel completed during World War II, but two sections hundreds of feet underground have been leaking for years.

The most expensive phase of the work involves digging a 4-km (2.5-mile) bypass tunnel running parallel to the leaky segment under the Hudson River about 97 km (60 miles) north of New York City. Blasting began in October on the first of two shafts on opposite sides of the river that will be used to transport equipment underground to dig the tunnel. Work on a second shaft in the town of Wappinger will begin before the end of the year.

The aqueduct will be shut down just before the bypass tunnel is connected to the aqueduct, probably in 2021. ■

Save the date:

George A. Fox Conference
Jan. 28, 2014, New York City, NY
www.uca.smenet.org

Anglo American launches tunnel boring machine at Australian coal mine

Anglo American's $1.95 billion Grosvenor project in Moranbah, Central Queensland, reached a key project milestone in October when its Robbins tunnel boring machine (TBM) operated for the first time.

Officially launched on site at Grosvenor, this is the first time a TBM has been used to construct a drift (or tunnel) on a Queensland coal mine, Anglo American said in a statement.

Anglo American's head of underground excellence, Dieter Haage, officially launched the TBM and said this was an important milestone in the overall delivery of the Grosvenor project, which is located next to the company's existing Moranbah North longwall mine.

"Targeting the same Goonyella Middle Seam as our Moranbah North operation, Grosvenor will be a world-class longwall mine and its delivery is a key part of our growth planned in Moranbah," Haage said.

"It is exciting to reach this milestone today after almost one-and-a-half years of construction activity," he said.

"The $40-million earth pressure balance machine will allow us to reach the coal seam early next year, bringing us that step closer to longwall production in late 2016," he said.

Grosvenor project director Glenn Tonkin said the Anglo American team was excited to be pioneering this innovative tunneling method to build the 5-Mt/a (5.5-million stpy) Grosvenor Mine.

"Similar to the TBMs that have been used to construct the road tunnels in Brisbane, the TBM tunneling method will deliver advances in safety, higher quality drifts and faster project development," Tonkin said.

The TBM will be used to build the two drifts on the project, one for the coal conveyor, which will transport coal from the underground longwall to the stockpile area on the surface, and another for people and equipment to access the underground mine once the mine is operational.

The TBM will pass beneath a steel archway roof that has been installed at the drift's entrance and begin drilling into the ground to build the 7-m- (23-ft-) diameter tunnel, descending at an angle of one in eight until it reaches the depth of the coal seam, approximately 160 m (525 ft) below.

As the TBM advances, precast concrete ring segments will be used to line the inside of the drift.

> **"The TBM tunneling method will deliver advances in safety, higher quality drifts and faster project development."**
>
> **Grosvenor project director, Glenn Tonkin**

Grosvenor site manager Greg O'Donnell said many contracting companies had worked hand in hand with Anglo American to deliver the project to this point.

"We currently have a team of about 700 people working at Grosvenor," O'Donnell said.

"I'd like to make special mention of Robbins for building and operating the TBM, Redpath Australia for assembling, commissioning and supporting the TBM mining, GHD for its assistance with the geotechnical engineering, Hutchinson Contractors for its civil work around this area and Hatch for providing general engineering procurement construction management support at site," O'Donnell said.

Once in operation, Anglo American's Grosvenor project will provide approximately 350 new jobs. ■

Chairman's Column: Industry needs young minds

(Continued from page 2)

we are all doing our best to foster a collaborative environment between generations, and keep pace with the changing face of employment, some turnover may even be beneficial. By keeping the best professionals in our industry, rather than driving them to seek employment in other industries, we help ensure that the turnover that occurs is healthy turnover, promoting the cross-pollination of ideas and helping people find work environments where they can make the best contributions.

Our firms all have different approaches to training, mentoring and promoting our staff. These different company cultures are some of the things that make our industry competitive, and, in many cases, have led to significant technological advancements in the industry. But we all need to recognize these generational differences and adjust our employment practices to accommodate them — or we will neither attract nor retain the quantity and quality of staff that we need to continue to advance the industry. ■

Marmary Metro Link opens in Turkey

The Marmaray Metro Link, a 1.4-km (0.9-mile) long tunnel under the Bosphorus straits, linking the European and Asian sides of Istanbul, Turkey's largest city, opened on Oct. 29.

Four years behind schedule, the tunnel is the first stage of the massive $4.5-billion, 76-km (47-mile) long Marmaray project. The undersea tunnel was constructed by lowering steel-lined, precast concrete sections into a trench excavated 60 m (196 ft) down on the seabed of the Sea of Marmara, where they were then buried. A further 12.2 km (7.6 miles) of on-land tunnels connect the three stations that make up the project's first phase.

The entire upgraded and new railway system will include the immersed tube tunnel, bored tunnels, cut-and-cover tunnels, at-grade structures, three new underground stations, 37 surface stations (renovated and upgraded), operations control center, yards, workshops, maintenance facilities, upgrading of existing tracks, including a new, third track on ground, completely new electrical and mechanical systems and procurement of modern railway vehicles.

The idea for a tunnel linking the two sides was first suggested by Ottoman sultan Abdoul Medjid in 1860, but the project came to nothing because of the lack of technical expertise available. It wasn't until 2004 that Tayyip Erdogan – then Mayor of Istanbul – gave the final go-ahead for the tunnel, as part of a series of lavish construction projects for the city including a third airport, a parallel canal and a third bridge.

The project has faced controversy. In May and June, Istanbul's residents protested against plans to bulldoze part of Gezi Park to make way for a huge shopping center. When police used water cannons and tear gas to clear the peaceful sit in, violent protests erupted across the country.

The project was also slowed by the discovery of 8,500 year-old archaeological remains at the site of the main metro terminus.

The decision to push ahead with the project, and a similar decision to build a third road bridge across the Bosphorus despite popular opposition, closely mirror that taken earlier this year to destroy Gezi Park. The police tactics used in June against many of the hundreds of thousands who turned out onto Turkey's streets have ensured subsequent protests have been far smaller. But that has not prevented the appearance of tens of thousands of posters calling for mass protests on both the city's European and Asian sides to coincide with the opening.

Marking the meeting point of Europe and Asia, the Bosphorus has been a flashpoint between civilizations for thousands of years.

As far back as the Roman Empire, the strait's strategic significance has been recognized – a factor that led the Roman emperor Constantine to found his new capital, Constantinople, on its banks in 330 AD. ■

Layne Christensen awarded $57 million contract for San Francisco subway project

Layne Christensen Co. announced that its Geoconstruction division received a contract from Tutor Perini Corp. to build the foundation for three underground subway stations for the Central Subway Project in San Francisco, CA.

The two-year contract, which is scheduled to commence in February/March 2014, has an estimated value to Layne of $57 million.

The Central Subway Project is the second phase of the San Francisco Municipal Transportation Agency's (SFMTA) Third Street Light Rail Transit Project. Phase 2, the Central Subway Project, will construct a modern, efficient light-rail line that will further improve public transportation in San Francisco. This new 2.7-km (1.7-mile) extension of SFMTA's Third Line will connect the 4th Street Caltrain Station to Chinatown, providing direct connections to major retail, sporting and cultural venues while transporting people to jobs, educational opportunities and other amenities throughout the city.

Layne will provide soil stabilization services to assist in the construction of the Chinatown Station, Union Square/Market Street Station, and the Yerba Buena/Moscone Station.

"The geoconstruction division has specialized in deep foundation construction for more than 40 years, successfully completing complex projects around the world," Rene Robichaud, president and chief executive officer of Layne, said. "We are honored to have been selected by Tutor Perini to participate in a project that will contribute greatly to San Francisco's economic development, and elevate the city's profile as a global hub of commerce, education and entertainment." ■

T&UC BUSINESS PROFILES

A special advertiser sponsored advertorial section

DECEMBER 2013

Underground Construction and Tunneling history is made by the investment of companies worldwide that dedicate their efforts and vision to the advancement of the industry.

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

Messinger Bearings - A Kingsbury Brand

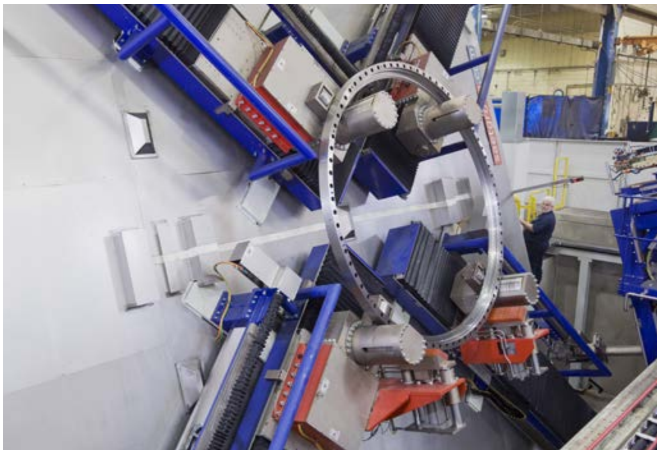
Messinger Bearings is one of an elite few companies in the world capable of producing large, custom-designed bearings for tunnel boring machines (TBMs). Messinger is addressing the challenge from end users who require new or repaired bearings of this size delivered in a reasonable timeframe.

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 focuses on providing large diameter custom bearings for unique applications, including those for 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 and heat-treating bearings of this size completely in-house using 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. Messinger is committed to supporting its customers in its core business, that is, large heavy-duty custom bearings for specialty applications in limited quantities. In addition, Messinger maintains a repair and service department that



is capable of rebuilding old bearings at a fraction of the cost of new.

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.

This is but one example of the problem-solving attention TBM customers routinely receive from Messinger Bearings -- to enable superior machine performance through expert bearing solutions.

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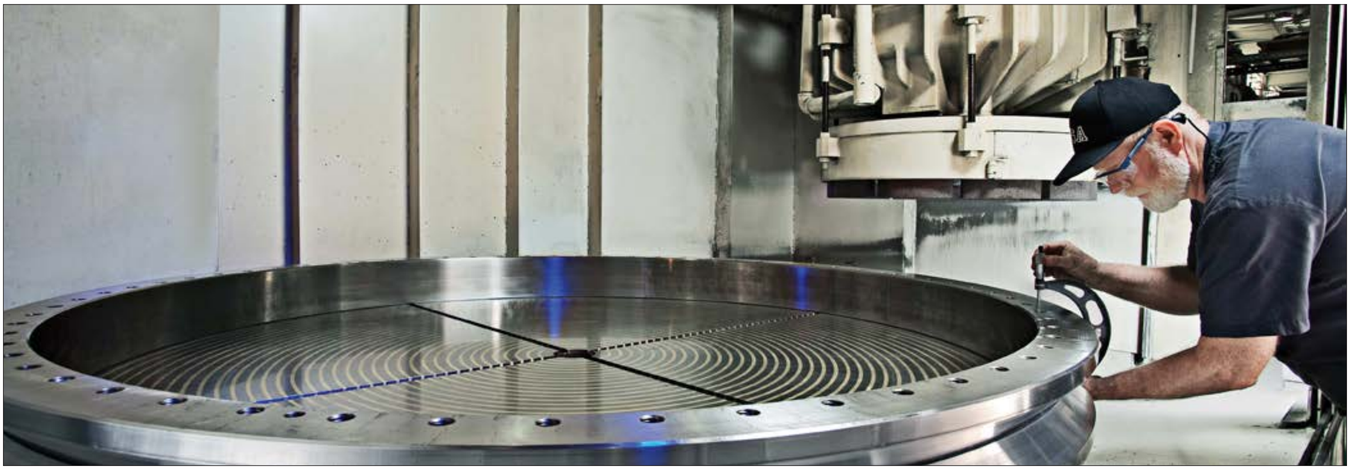

The New Standard for Tunneling

With 60 years of experience, The Robbins Company is the world's foremost developer and manufacturer of advanced, underground construction machinery. In 2013, Robbins TBMs have 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. At the Black River Tunnel in Lorain, Ohio, a massive 7.0 (23 ft) Robbins Double Shield TBM and continuous conveyer system are in the process of being assembled using the innovative method, and the machine is scheduled to launch in late 2013 (pictured top right).

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

Continued Success in Hard Rock and Soft Ground

Robbins EPBs continue to show their reliability and robustness, even in some of the world's most difficult ground conditions. In Autumn 2012, Mexico's largest infrastructure project, the 62 km (39 mi) long Emisor Oriente Wastewater Tunnel, achieved a TBM milestone. The first of three Robbins 8.93 m (29.3 ft) EPBs completed the critical Lot 1 portion of the tunnel in challenging mixed ground conditions after rescuing a Herrenknecht EPB that was stalled. At Lot 4, a successful breakthrough is rapidly approaching despite challenging geology, including abrasive basalt rock.

In Austin, Texas, USA, a 3.25 m (10.7 ft) Robbins TBM flew through limestone rock at average rates of 55 m (180 ft) per day, with several days over 60 m (200 ft) for the Jollyville Transmission Main. The Main Beam machine and a refurbished 3.0 m (9.8 ft) Double Shield TBM completed boring for the Jollyville Transmission Main in August 2013 and spring 2013, respectively (pictured below). Both machines had minimal impact on their surrounding environment while boring the new water tunnel, which lies below the Balcones Canyonlands wildlife refuge.

Robbins innovations will continue to advance into 2014, with major hard rock and mixed ground projects underway across North America. For further information on tunneling projects and groundbreaking R&D, visit www.TheRobbinsCompany.com or call +1 (440) 248-3303.

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Atlas Copco Group marks 140th anniversary

Atlas Copco CEO Ronnie Leten marked the company's 140th anniversary by ringing the opening bell at the NASDAQ MarketSite in New York's Times Square earlier this year. The bell ringing signified the beginning of the day's trading and the start of a year-long anniversary celebration for Atlas Copco. Maureen Ellis, an employee celebrating more than 40 years with Atlas Copco in the United States, joined Leten at the event, along with select customers and other company management and stakeholders.

Headquartered in Sweden, Atlas Copco began with an idea in 1873 that the country should become more self-sufficient in railroad building. As the years passed however, development, technical innovations and competition drove the company to diversify its product portfolio. In the 1950s the first major strategic international acquisition was made with the purchase of Arpic Engineering, a Belgian compressor company.

The growth of Atlas Copco is also widely accredited to the founding Wallenberg family. It is said that without the family's belief in the company and its sometimes unorthodox decisions, Atlas Copco would probably not exist today.

"From our beginning in 1873 as a manufacturer of products for the railroad industry, we have expanded and adapted to hold world-leading positions in compressed air and gas equipment, construction and mining equipment, industrial tools and assembly systems," said Jim Levitt, president of Atlas Copco North America. "The United States is the Group's largest single market and North America contributes about one-fifth of our overall revenue. The best way to celebrate 140 years in business is to acknowledge the customers that make it possible. We sincerely thank each and every one of them for their business."

Through 140 years of innovation and acquisition, Atlas Copco has grown to serve customers in over 170 countries. Atlas Copco first came to the U.S. in 1950. Today Atlas Copco has 109 locations in the United States alone, representing 1.7 million square feet of manufacturing, production, distribution and office space, employing more than 4,600 people and working with hundreds of carefully selected distributors. North America operations as a whole generated more than US$2.8 billion in annual revenue in 2012.

As part of the anniversary celebration, Atlas Copco North America donated $60,000 to New York City-based "charity: water," a global non-profit dedicated to bringing clean and safe drinking water to people in developing nations. The donation brings Atlas Copco's total charity: water giving to $161,000 since 2010, with the company's employee-run Water for All organization donating more than $239,000 since the program's inception. To learn more about Atlas Copco's employee-run Water for All charity program, please visit http://www.water4all.org/us/

Atlas Copco North America in Parsippany, N.J., Construction and Mining Center in Commerce City, Colo., Atlas Copco Rental in La Porte, Texas, and Atlas Copco Tools and Assembly Systems in Auburn Hills, Mich., all held anniversary parties to celebrate. Additional Atlas Copco business units will celebrate with customers throughout the year with local events, special offers, and rewards. Full details are available at www.atlascopco.com/us.

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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!

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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.

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

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JENNMAR Specialty Products provides custom steel fabrication services to the mining, tunneling and civil

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

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Moretrench is a member of the USGBC (United States Green Building Council) which oversees the Leadership in Energy and Environmental Design (LEED) Green Building Rating System, developed by the USGBC to provide standards for environmentally sustainable construction.

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Durable fan structures are designed for long life in the harshest and most demanding industrial applications. Both deep shaft and mining operations use a variety of New York Blower fans. Non-sparking below-ground applications use both axial and centrifugal designs for ventilation and safety exhaust-and-supply systems. Quarry trucks and draglines require cooling fans for the large DC traction motors. Crushing and grinding phases of ore processing use many types of New York Blower fans in environmental and ventilating systems. Some ore processing goes into a wet cycle where spray dryers and particle sizing systems direct products to chemical and food industries. New York Blower offers fans for all of these applications.

New York Blower has the experience, knowledge, and technology to produce what engineers and machine designers agree to be the most durable and efficient industrial fans and blowers. Today New York Blower has a worldwide presence with over 200 representatives, partners, and licensees established around the globe. We have maintained an AMCA-registered laboratory that allows us to meet the highest standard in product development and product performance testing. All of our products undergo extensive air performance, sound and quality assurance testing prior to release to the market. So when it comes time to choose the best possible air-movement solution for your construction needs, trust the industry leader.

More information about The New York Blower Company can be obtained at our website,www.nyb.com, or calling 1-800-208-7918.

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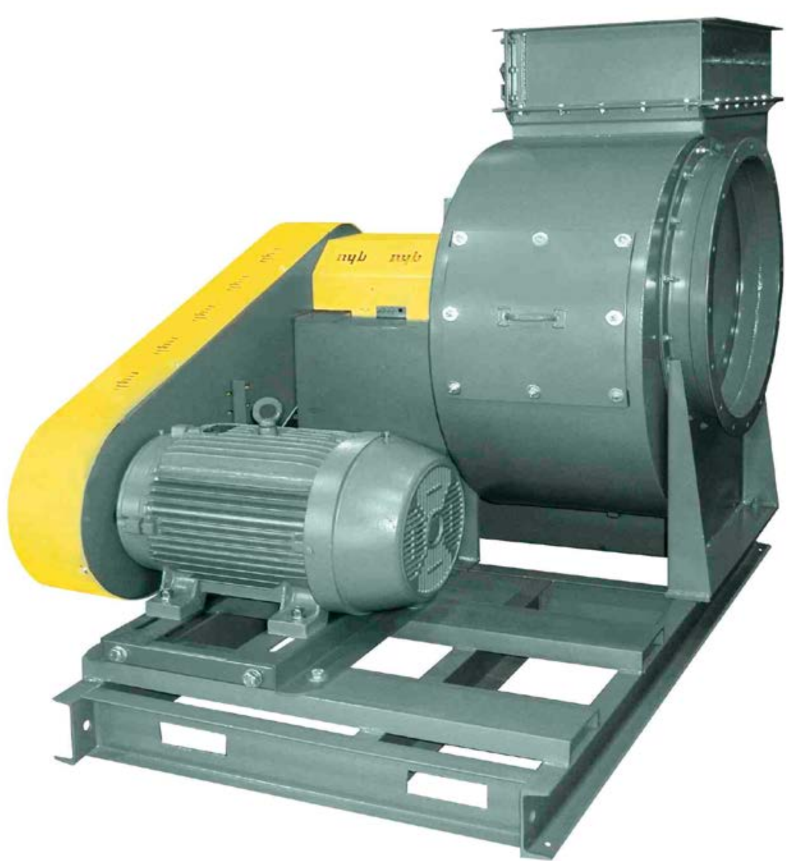

Putzmeister Shotcrete Technology, Your Worldwide Partner for Quality and Innovation

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

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

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

"In this day and age, very few companies are able to succeed in business for over 100 years," says Patrick Bridger, president of Putzmeister Shotcrete Technology. "We are very proud of our longevity, and see it as a testament to our reputation for quality, and the value we have brought our customers for more than a century."


Mixkret 4 - Low Profile Concrete Mixer

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

Throughout the years, numerous milestones have been achieved:

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


SPM 307 Nozzle Carrier

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

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

Putzmeister
SHOTCRETE TECHNOLOGY

Putzmeister Shotcrete Technology
Telephone: +1-800-553-3414
www.putzmeistershotcrete.com

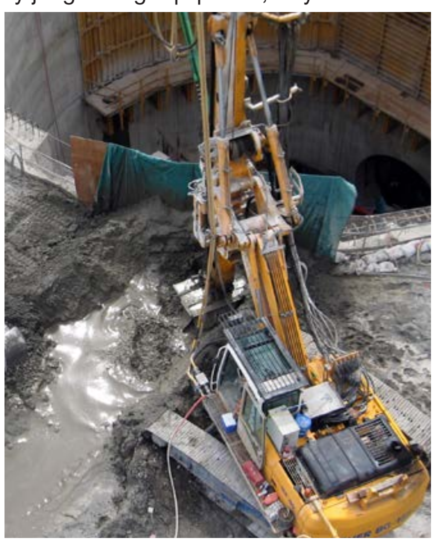

SPM 500
Dulles Corridor Metrorail

North America's Leader in Geotechnical Construction

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

Seattle, WA
Brightwater Conveyance System

Construction of the Brightwater Conveyance System required surgical jet grouting to facilitate tunneling operations. Utilizing their proprietary jet grouting equipment, Hayward Baker created soilcrete blocks outside of four deep vertical shafts to assist with both TBM and 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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www.HaywardBaker.com

HNTB

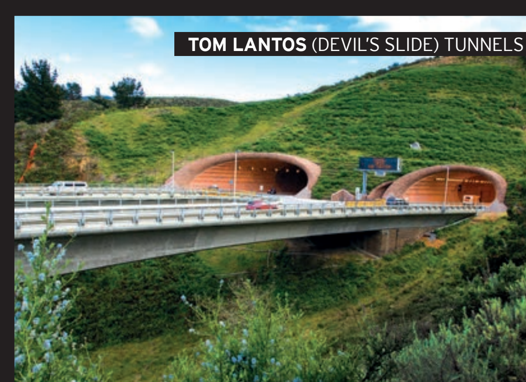
HNTB Corporation has more than 45 years of experience in the design, construction and restoration of tunnels and underground structures, including soft ground, rock and underwater crossing tunnels in the highway, transit, rail, aviation and water resources markets. Projects range from small-diameter excavations to the largest machine-bored tunnel in the world. We develop creative and effective underground solutions for our clients that minimize disruption to their surface infrastructure utilizing TBM, SEM and cut-and-cover excavation methods. Our long history in program management, design, construction and support services for tunnel structures includes award-winning work on some of the country's most complex tunneling projects.

For more information visit http://www.hntb.com/expertise/tunnels.

HNTB Corporation
5 Penn Plaza, 6th Floor
New York, NY 10001 USA
Email: nmunfah@hntb.com
www.hntb.com

COMPREHENSIVE TUNNEL AND UNDERGROUND ENGINEERING EXPERIENCE

- Winner of the 2012 International Tunneling Award Tunneling Advisor/Program Manager of the Year
- Longest road tunnel in California
- First to use NATM in California
- First tunnels to use LRFD



TOM LANTOS (DEVIL'S SLIDE) TUNNELS

ALASKAN WAY TUNNEL

- Largest TBM tunnel in the world
- Largest double deck tunnel in the world
- State of the art design and construction

For more information, please contact:

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nmunfah@hntb.com

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HNTB

The HNTB Companies
Infrastructure Solutions

www.hntb.com

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

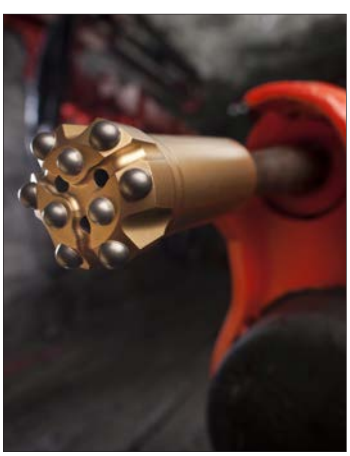
Sandvik in Tunneling

Sandvik tunneling expertise covers a variety of methods: Drill and blast, mechanical cutting and breaking. The equipment range includes tunneling jumbos, roadheaders and cutting units, bolters and bolts, drilling and cutting tools, hydraulic breakers, loading and hauling equipment, mobile crushers, and financing, parts and consumables, training, technical support, and repair and rebuild service.

The Sandvik DTi series of intelligent tunneling jumbos are fast, accurate and user-friendly. The series is available in four models for excavation of 12–211 m³ cross sections, including face drilling, bolt hole drilling and mechanized long-hole drilling.

Sandvik rock tools offer straight holes, high penetration rate and low costs per meter. As the only supplier with in-house resources for cemented carbide production and R&D as well as drill steel production and R&D, Sandvik can control the whole supply chain from raw material to finished products.

Sandvik roadheaders are extremely powerful, robust rock cutting machines that let you focus on the essential: breaking on through to the other side. These roadheaders are designed to excavate roadways, tunnels and underground chambers without using explosives that can cause harmful vibrations. This is highly valued for both environmental and safety reasons, making roadheaders extremely suitable for underground construction in urban areas.



Research & Development

In order to ensure the best solutions, Sandvik has specialized R&D centers for different fields of rock excavation. Sandvik also works in close cooperation with universities, research institutes and specialist associations everywhere in the world. As results of these R&D projects, Sandvik now offers an energy saving cutting system for roadheaders, a new roadheader type equipped with state-of-the-art profile control and automatic sequence control systems, as well as the DTi jumbos with iSURE® process optimization tool software – just to name a few.

Sandvik Cutting Technology Center runs its own in-house cutting test laboratory, addressing particular customer requirements and offers the latest solutions in mechanical cutting for all kinds of soil and rock. In addition, Sandvik has specialized R&D centers for Drilling Control, Rock Drill and Drilling Tools technologies. Sandvik is also the only manufacturer in the industry owning a unique test mine for practical testing in real life conditions.

Cleaner and safer tunneling

Sandvik focuses on continuously developing novel tunneling methods, making equipment safer, more efficient and more productive, giving results of the highest quality. As a key core value, Sandvik engineers are committed to safety, constantly developing solutions to offer a protective working environment, with efficient ergonomics. All Sandvik production operations are ISO14001 and ISO9001 certified.

Intelligent Solutions

Sandvik iSure® tunneling excavation management tool is designed for the people on site. Revolutionary in its approach - iSure® uses the most critical spot, the blast plane, as basis for the whole planning process. As a result, hole locations and blasting, are optimized. This translates into excellent accuracy, fast process and large-scale savings.

Find out more about Sandvik Tunneling offering on www.understandingunderground.com

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www.construction.sandvik.com

Itasca International, Inc.

Who is Itasca?

As the world leaders in geomechanics, hydrogeology and microseismicity, Itasca consultants solve problems in civil engineering, mining, oil and gas, manufacturing and power generation.

What Does Itasca Do?

Itasca approaches all assignments with a solid background in civil engineering and an extensive knowledge of state-of-the-art design, numerical modeling and analysis techniques. Together these strengths allow us to provide innovative, practical solutions to a wide array of projects. Civil engineering problems involving soil mechanics, rock mechanics, soil-structure interaction, rock-structure interaction or coupled rock/soil-hydro-thermal effects are the basis of Itasca's work in an extensive range of projects, including highway tunnels, deep foundations, slope stability, shoring, utility tunnels, hydroelectric plants, subway systems, dams and retaining structures. Our experience has been recognized internationally by engineering societies, universities and our own clients.

In its 30 year history, Itasca has expanded from one office in Minneapolis, Minnesota to 14 offices in 11 countries. Staff in our international offices have developed expertise particularly suited to their respective regional conditions and client needs. This allows Itasca to offer advanced, first-hand knowledge of the particular civil engineering challenges in each region and a collective pool of expertise that covers important engineering services. The diverse background of Itasca personnel ensures that we are thoroughly familiar with typical design and construction issues and uniquely equipped to attack challenging or non-standard problems, while providing practical solutions. Because civil engineering rules and techniques vary from place to place, technologies practiced in one country often are not available in another. The shared perspective developed across Itasca's international offices broadens our civil engineering capacities by bringing these innovative and emerging technologies to new geographical areas.

We also apply our software to field problems where standard technologies may be insufficient for successful problem resolution. Itasca maintains a diverse, accomplished, staff of engineers across all aspects of civil engineering from the practical to the theoretical, including coupled hydromechanical processes, soil and rock reinforcement/support and dynamic analysis. Itasca can assist clients in building and reviewing models for their own use, or we can perform the complete analysis. Itasca offers engineering during construction to check predicted performance.

Please contact us if we can assist you in the following areas:

- Large caverns in rock
- Rockfill and concrete dams
- Surface excavations
- Cut slopes
- Earth retaining structures
- Harbor structures
- Foundation design in soil and rock
- Slope stability
- Tunnel support and design
- Dynamic analysis of dams and other structures
- Evaluation of liquefaction potential
- Groundwater flow and dewatering
- Heat transfer
- Design reviews
- Soil improvement
- Monitoring and instrumentation
- Water-well designs

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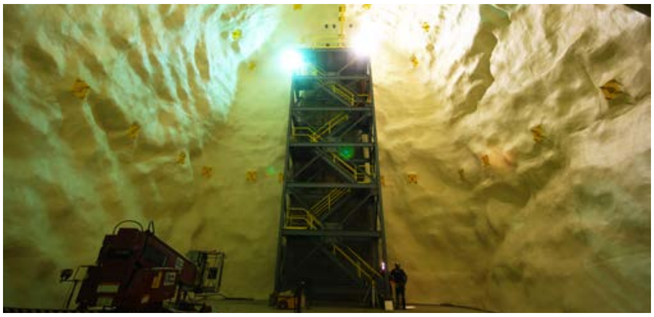
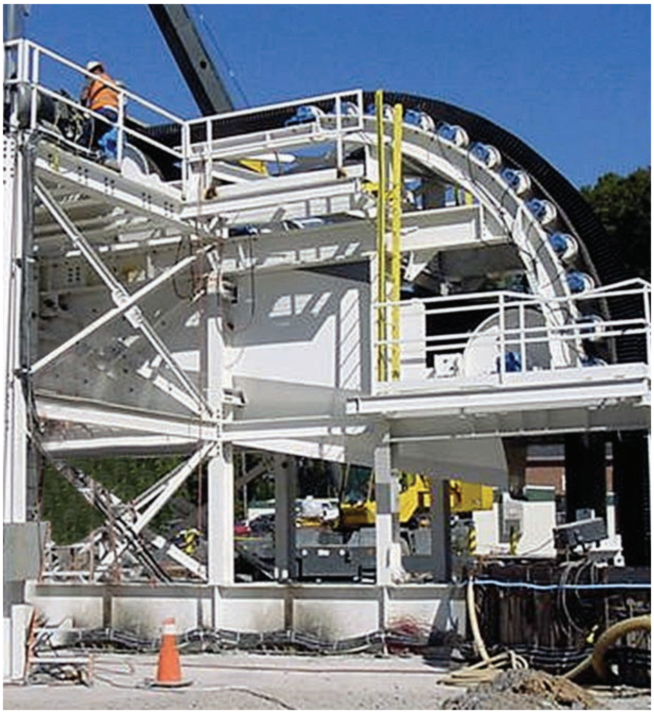


FKC-Lake Shore

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

Products/Services:

- Vertical Belts
- Skips
- Hoists
- Sheaves
- Elevators
- Cages
- Headframes
- Brakeman Cars
- Controls
- Field Services
- Wire Rope NDT



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Sterling Lumber Opens New 520,000 Square Foot Plant in Phoenix, IL

Sterling Lumber is expanding operations into their new 520,000 sq. ft., 60 acre facility in Phoenix, IL. The new facility will benefit its customers with increased production capacity, larger inventories, new manufacturing processes, cost control, faster delivery, and on-site heat treatment while continuing to provide exceptional customer service.

Sterling Lumber has four divisions: Crane & Access Mats, Construction Products, Crates & Pallets and its newest segment Temporary Road and Mat Installation. It has become a dynamic manufacturing company that provides products and services to the Transmission & Power Distribution, Oil & Gas, Wind, Coal, Hydropower & Geothermal, Heavy Construction, and Steel Industries.

The company's rapid growth during the last seven years has been achieved by manufacturing Matting for portable and temporary roads and work platforms throughout North America, as well as providing customers turnkey solutions to their Access Matting needs.

Sterling is currently consolidating three manufacturing plants and 117 existing employees into one new facility in Phoenix, IL and plans to add another 50 new employees over the next 24 months.

Long Proven History

In 1949, at the age of 41, Gerhard Sterling formed a scrap metal business in Northern Illinois. By 1970, Gerhard and his youngest son, John, had evolved the company into a successful lumber supplier.

Today, John and his four sons (Carson, Carter, Christian and Cooper) run a company built around six decades of consistency, quality and customer service. With warehousing, manufacturing, and sawmill locations in Illinois, Indiana, and Missouri, Sterling can deliver products coast-to-coast or internationally by truck, rail, or barge.

Providing Exceptional Customer Service

The key to Sterling Lumber's success has been its commitment to customer satisfaction with a personalized approach, based on timeliness, experience, accuracy and problem-solving effectiveness. The family invested into all aspects of the business and incorporated modern technology, inventory and adaptability with the company's core values of pride, hard work and trust.

Crane and Access Mats

Sterling Lumber builds the finest quality Crane Mats in the market, choosing only the best dense hardwoods from their timberland. The most important factor is the measure of safety that Sterling Lumber builds into all of their Matting products.

Products/Services:

- 30' – 40' Crane Mats
- Access Mats
- Barge Mats
- Carriage-Bolted Mats
- Excavator Mats
- Outrigger Mats
- Parts Mats
- Pipeline Skids
- Rig Mats
- Timber Mats
- Transition Mats
- Used Mats

Construction Products and Custom Crates & Pallets

Sterling Lumber keeps a massive inventory of lining lumber for earth retention walls, ground stabilization and shaft and tunnel. Lagging is available in pre-cut and standard dimensional sizes. The Sterling sawmills will prepare any specified lengths and widths required.

- Blocking Lumber & Dunnage
- Commercial Lumber
- Lagging
- Pre-made Lagging Panel
- OSB, Plywood, Forming Plywood and Sheathing
- Shaft and Tunnel Lagging
- Shielding
- Tunnel Lagging & Ties
- Wedges -- Support Saddles
- Pipeline Skids
- Timbers and Piling
- Heat Treated Lumber

Temporary Roads, On-Site Mat Installation, Extraction and Removal Service

Sterling's Matting products are used for a variety of applications from temporary roads to rig-site platforms, simplifying access to remote locations, protecting sensitive terrain from damage, and reducing reclamation costs. Sterling has the ability to customize to any environment or application while providing the most cost-effective, access solution service.

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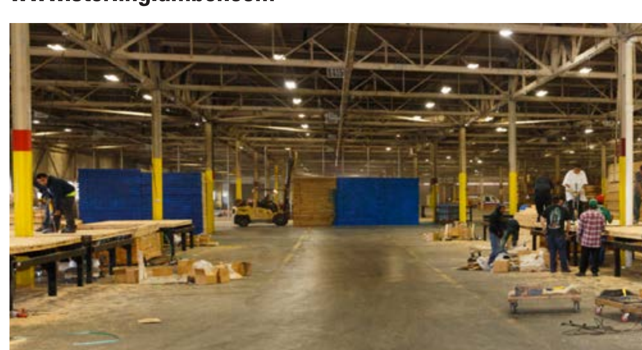

The Rewards of Reliability

Since the early 1980s, Damascus Corporation has earned a reputation for reliability and quality in its mining and utility vehicles and support equipment.

What started as a manufacturer of rock-dusting units for underground mines broadened its base by developing a family of remarkably reliable and versatile runabouts and light transporters. The company grew steadily, maintaining close contact with their customers and responding to their needs with a broadened base of dependable, robust products.

Today, under the leadership of president Eric Miller, the company produces a variety of reliable vehicles. And while the units remain popular in mining operations, demands from the industrial sector led to development of similar units for their operations. Several models are available, operated by diesel or battery power, with vehicle widths ranging from 44" to 108". Lengths vary, reaching 16' on one personnel transporter. And each vehicle incorporates storage space for tools, so vital in any industrial application.

Company president Eric Miller notes that "the growth of our product line was never haphazard. Rather it was based upon a deliberate series of innovations and improvements based upon customer feedback and modern technologies. We started our vehicle product line by small, 2-passenger, battery-powered 3-wheel personnel carriers and to larger, mid-size, 4-wheel units; we designed personnel transports for two people and progressed to 14-person diesel transporters. That's why our customers have trusted us and communicated their needs to us."

Damascus Corporation products are designed and improved to incorporate the latest technologies, while remaining within the limits of mining and industrial safety. Their service personnel and their sales force are in constant contact with their customers, and feedback flows constantly from the field to the design and development facilities. A longstanding loyalty to their customer sets them as 'a breed apart' … and they like it that way.

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www.damascuscorp.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

Xylem Dewatering Solutions

With its Godwin and Flygt products and services, Xylem Dewatering Solutions is a one-stop shop for any dewatering job, large or small. Our Great Pumps and Great People have a world-class reputation for reliability and quick response.

Product lines include Godwin automatic self-priming Dri-Prime® pumps, Godwin Heidra® hydraulic submersibles, Flygt electric submersible pumps and related intelligent control systems for dewatering applications. We are committed to delivering pumping solutions for fast-paced emergency situations, temporary rentals or permanent installations, moving water, wastewater, slurry, sludge and stringy solids.

In addition to our range of pumps for sales, we have an industry-leading rental fleet. Renting from us is beneficial because we help rental customers reduce their capital spend, service and maintenance expense, transportation and storage costs. Our large fleet and on-time performance allows access to pumps whenever needed.

Because Xylem Dewatering Solutions is a single-source supplier, with proven 24/7 parts and service availability, we offer the convenience of attaining equipment and parts with one request. To ensure customers have the right system for their needs, we offer:

- Technical application support
- Pump system design
- Engineering expertise and continued product development focused on pump performance and efficiency

We are vertically integrated, so we can develop, sell, or rent pumps for new applications whenever there is a need, and create pumping solutions with a hands-on approach. We are a distinctive brand, much like a utility company.

For more information on Flygt and Godwin products, and to find the location nearest you, visit godwinpumps.com.

Xylem Dewatering Solutions
84 Floodgate Road
Bridgeport, NJ 08014 USA
Telephone: +1-800-24PUMP4
Email: sales@godwinpumps.com
www.godwinpumps.com

The Original Tunneling Pro

Experience, innovation and hard work; it's what makes a Brokk Star. And when it comes to tunneling, August Scalici was the first.

Brokk's field sales application expert has been working on large tunneling projects since the 1980s. He was an operator on the first U.S. project ever for a Brokk, a ceiling demo in the Holland Tunnel from New Jersey to New York in 1982. He's come a long way since then, and today he's providing guidance to the Bouygues Civil Works Florida crew digging cross passages on the Port of Miami Tunnel Project with a Brokk 400.

Brokk remote demolition machines not only take people out of harm's way, they also offer diverse attachments that enable operators to complete every piece of the tunneling puzzle, from excavating to beam installation. And Scalici knows how to do it all.

"I'm an operating engineer by trade, and I was one of four operators chosen to work on the Holland Tunnel project," Scalici said. "It was amazing what we could do with a Brokk machine. I remember working eight hours and it feeling like five minutes."

After that first Brokk Job, he operated the remote-controlled machines in tunnels for nearly 20 years before joining the Brokk team as a field application specialist. He now works directly with operators, getting to know their projects, determining which Brokk machines and attachments will work best for each job, and training the tunneling teams. With his hands-on experience, he's often able to suggest solutions they may not have thought of before.

That's saying something for tunnelers who measure experience not in years or miles but in high-profile projects. And with Scalici's help, many of them are building their resumes and becoming Brokk Stars themselves.

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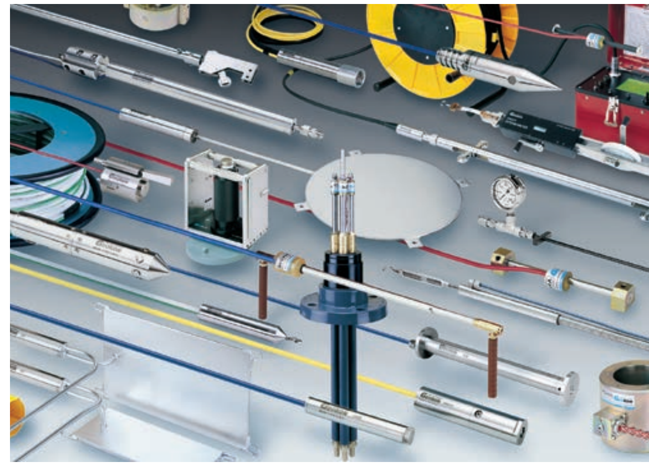
Email: info@brokkinc.com
www.brokk.com

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.

Geokon, Inc.
Telephone: +1-603-448-1562
Email: info@geokon.com
www.geokon.com

Premier Pipe Systems Manufacturer for over 85 Years

Since 1925, Naylor Pipe Company has been the premier manufacturer of Spiralweld pipe systems.

Naylor Spiralweld is available in diameters from 4” through 96” and wall thickness from 14 Ga. through 1/2” wall. The Spiralweld pipe is complemented with all types of fittings, fabrications to specification, and joint connections, including the exclusive Naylor Wedgelock Coupling, to complete your pipe system.

Naylor Spiral Buttweld pipe features two welds along the spiral seam. This creates a pipe structure in which the weld is as strong or stronger than the parent metal.

The Naylor manufacturing process creates a pipe that maintains an accurate diameter throughout its length. The uniformity of the pipe ends speed connection, whether mechanically coupled or welded.

Uniform wall thickness is assured because tolerances of steel strip are governed by the standards established by the American Iron and Steel Institute. In addition, the pipe is furnished in any required length with a cutting tolerance of plus or minus 1/8”. In addition to carbon steel, spiralweld pipe can be formed from many steel grades, including abrasion resistant, weathering (A-588) and stainless.

Every length of Naylor Pipe is inspected and where required hydrostatically tested to applicable ASTM specifications. The pipe is available in lighter weights than other pipe making it possible to save money, not only on initial cost, but also in transportation, handling and installation. By sizing the diameter of the pipe to the exact requirements, with exact lengths and factory-sized ends, the greatest economies can be realized.

Quotations are immediately available on inquiry.

Naylor Pipe Company
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Fax: 1-773-721-9494
Email: sales@naylorpipe.com
www.naylorpipe.com

NAYLOR PIPE

Vent • Compressed Air • Water Discharge • Shaft Pipe

- Diameters from 4” to 96”
- Thicknesses from .074” to .500”
- ASTM A-139, ASTM A-211
- Lightweight, Accurate Diameter
- High Salvage and Re-Use Value
- Exclusive Naylor Heavy Duty Wedgelock Coupling Reduces Connection Time
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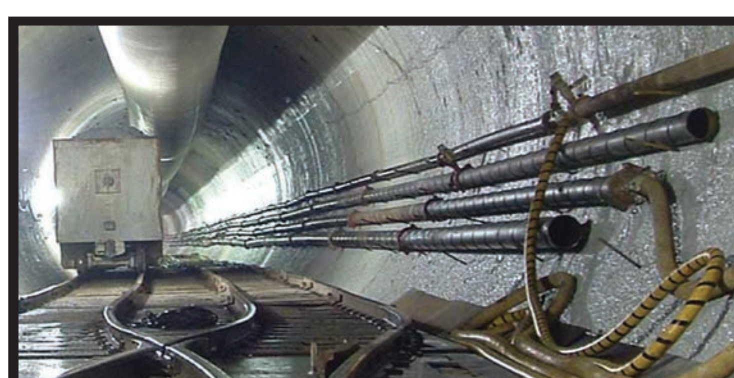

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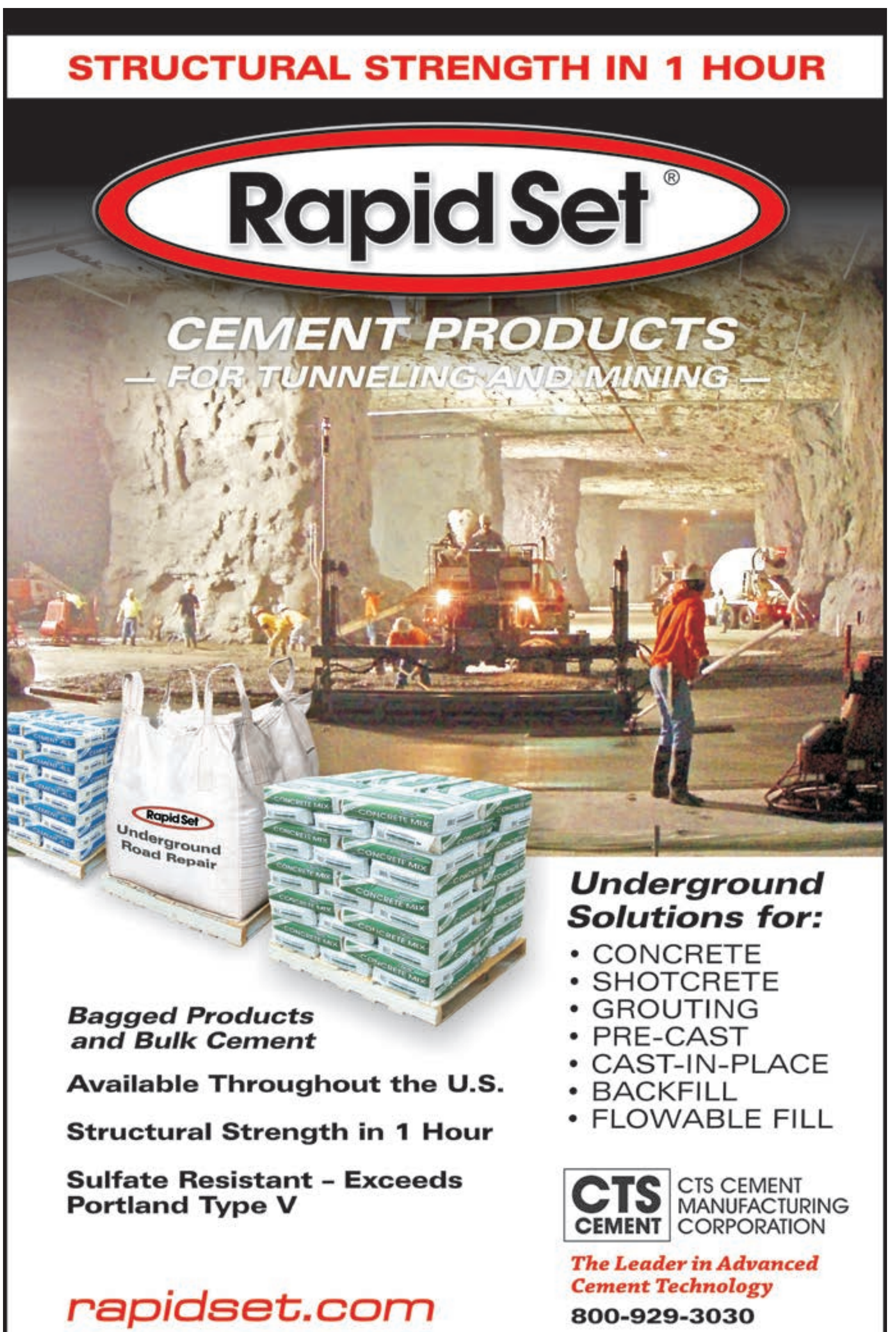
Rapid Set® Cement Products for Tunneling and Mining



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

Alpine Equipment

Alpine Equipment is the industry leader in hydraulic rock and concrete grinder attachments, roadheaders, shaft sinkers and soil remediation equipment, with over 40 years of expertise in North America. Our customers range from owner-operators to the largest tunneling firms. Alpine supplies attachments for construction, demolition, excavation, scaling, trenching, mining and tunneling. The rotary cutter heads come in range of sizes to fit on skid steer loaders, backhoes and excavators or any equipment with a hydraulic circuit. With a range of options and customizations, we can get you working more efficiently and with more precision than your current tools. Many of our customers are using the cutter head for concrete scaling projects for highway rehab or shotcrete clean up. The power, flexibility and precision of the Alpine concrete grinder enable this as a highly useful tool in a variety of jobs.

In addition to rotary cutterheads, Alpine also supplies state-of-the-art in situ soil mixing and remediation equipment. Remediation equipment includes mixing attachments and wet or dry amendment delivery systems.

With increased Natural Gas production, we have supplied the industry with mixers for solidification of drilling mud, whether on site or in container batches. The power and efficiency of our mixers have yielded significant production increases, allowing you to reduce costs and finish on time.

Contact Alpine Equipment for cutterheads, new & used roadheaders, ITC tunneling machines and soil mixing equipment.

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www.alpinecutters.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

Connecting infrastructure across the globe

Photo credit: Byron I. Lim

Founded in 1944, 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. The firm employs more than 13,000 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' 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 clientele, 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.

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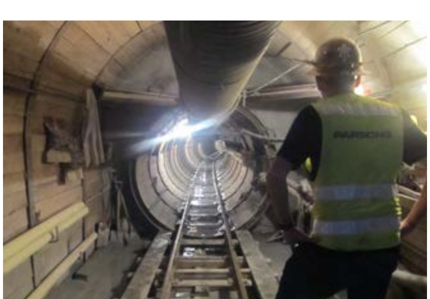

Normet in North America

Equipment, Construction Chemicals and Rock Reinforcement for Tunneling and Mining

Normet is a fast growing Finnish technology company with global operations. It provides advanced solutions for selected customer processes in underground mining and tunnelling environments. The Normet Group develops, manufactures and markets machines, services, construction chemicals and specialized rock bolts for underground processes such as robotized concrete spraying, highly mechanized explosive charging and scaling, lifting and installation, rock reinforcement and logistics.

Normet`s offering includes a comprehensive range of life time care (LTC) services for the equipment and the processes they are used for.

Normet's Multimec and Spraymec, versatile underground vehicles providing sprayed concrete for safe tunnels.

Today Normet is the global market leader in its market segment. Normet has its own sales and service companies in 6 continents, 26 countries and 39 locations.

The Group´s net sales in 2012 were close to EUR 240 million.

In North America, Normet is headquartered in Union Grove, WI, USA (Normet Americas, Inc.), and operates in Canada from Sudbury, ON (Normet Canada, Ltd.). We have sales and field service professionals in a number of locations across the continent, and operate a comprehensive parts management program with stocking in various locations to ensure an efficient means of distribution to our customers.

Normet understands not only the equipment we manufacture and the chemicals we supply but the rigors of the customers' underground processes for which they are designed.

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Normet's Charmec, the no.1 charging system.

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)
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- Road Reinforcement (Spectra® Roadway Improvement System)

Tensar International Corporation
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David R. Klug & Associates, Inc.

David R. Klug & Associates, Inc. provides international and national manufacturer representative services to the underground heavy civil and mine construction industries. The company specializes in the coordination of products, equipment and services for NATM, soft ground, precast segmental and conventional tunnel construction. This is inclusive of initial support systems, FRP bolts and soft-eye structures, high performance ultrafine cements, flexible membrane waterproofing systems, final lining reinforcement products, steel moulds, connectors and gasket sealing systems for one pass precast tunnel linings, tunnel profiling / scanning equipment and associated site services, design and supply of project specific material handling systems, and complex final lining forming systems.

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BROOKVILLE Partners With Seattle Region's S.H.A.F.T. School to Educate and Train Tunneling Workers

Brookville Equipment Corporation recently partnered with the Northwest Laborers-Employers Training Trust at their Elma, Wash.-based Safety & Hazard Awareness for Tunnels (S.H.A.F.T.) School through the provision of a 15-ton tunneling locomotive. The BROOKVILLE diesel-powered locomotive will be used in simulated haulage applications by the training school. The loci is an industry standard transportation tool and will allow students hands-on training during their coursework at the school.

Northwest Laborers-Employers Training Trust (NWLETT) developed the S.H.A.F.T. program with input from multiple industry influencers to feature both practical and classroom training for areas such as a comprehensive tunnel safety class, tunnel rail, shoring and utilities installation, overview soft ground TBMs, and locomotives.

"Brookville is committed to safety – it's the cornerstone of each product we manufacture. We are proud to partner with S.H.A.F.T. to provide practical safety and operational training to tunneling professionals," said Michael White, marketing manager, Brookville Equipment Corp. "We are hopeful it can make a positive contribution to S.H.A.F.T. and for the industry as a whole."

Brookville Equipment Corp.
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www.brookvillecorp.com

SURECRETE INC.

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Surecrete Inc. specializes in furnishing bagged cementitious materials, mixing and placing equipment, and related accessories to the heavy civil tunnel, geotechnical and mining markets. Our product lines include Nittetsu Super Fine ultrafine cement, rheology modifiers, specialty admixtures, and a complete selection of packaged wet and dry shotcrete, concrete and grout mixes. We also represent several major equipment manufacturers specializing in the mixing and placing of shotcrete, concrete and grouts. For more information, visit our web site at www.surecrete.com

Concrete materials for Chester Creek Dam, Metlakatla, AK

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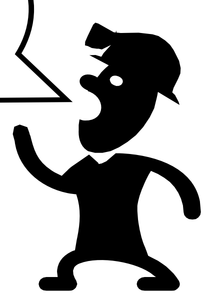

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- Amtrak Thames River Bridge Replacement, New London, CT

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Euclid Chemical

Euclid Chemical serves the tunneling industry with new and innovative products developed for annulus grouting, soil conditioning and precast segments. Euclid Chemical has been involved several large tunnel projects throughout the Americas and continues to be the innovative leader in this market segment. Euclid Chemical staff has been influential in the design of successful annulus grout mixes for several tunnel projects. For any underground concrete application, The Euclid Chemical Company offers superior products and customer service to the tunneling industry.

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McDowell has been a leader since 1968 in providing the Underground Mining sector with their new and used heavy equipment requirements.

With more than 100 employees, 5 shops, close to 75,000 sq. ft. of working space, McDowell is now synonymous with mining and to prove it, it maintains the largest stock of used, rebuilt and new equipment. Clients can access rebuilt, reconditioned or “as is” equipment for an outright purchase or rental.

A new exchange parts program offers clients the flexibility of exchanging core parts for rebuilt ones immediately, thus saving down time or inventory expenses.

Auditing, commissioning and consignment are also offered by McDowell for clients’ surplus equipment. Our search to acquire additional late model equipment is ongoing.

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The most extreme tunneling and underground construction sites demand the most dependable, durable ventilation equipment available today. Since 1926, ABC Industries, Inc. has been a leading provider of high quality, customized ducting solutions to many of the largest mine and tunnel operations in North America and around the world. ABC's complete line of MineVent® and TruOval MineVent® layflat blower tubing, MineDuct® wire-reinforced exhaust ducting, RigiDuct® filament-wound fiberglass ducting, brattice, fly pads, blast curtains, fans, and accessories offer underground professionals a complete solution for ventilation products. As tunneling and underground construction continue to evolve, ABC proactively collaborates with industry professionals to engineer unique, high quality ventilation products to exceed the industry's needs tomorrow and beyond.

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Announcing Doctor Mole Incorporated

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

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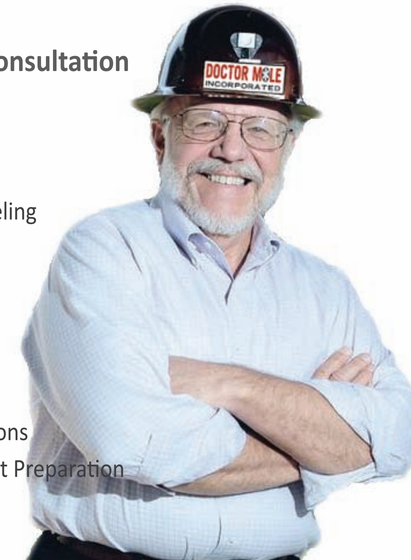

For more information contact:

Gary Brierley

gbrierley@drmoleinc.com or 303.797.1728

Custom Equipment Design Specialists

Kelley Engineered Equipment, LLC was founded in 2007 by Brian and Cindy Kelley. The firm is located in Gretna, Nebraska and has a growing staff of mechanical engineers, control system engineers, designers and drafters with extensive experience in tunneling and mining equipment design. Brian has 25 years of tunneling equipment design experience at Robbins, Kiewit and Kelley Engineered Equipment. Mechanical Engineering PE licenses are held in Nebraska, New York, California, Texas, and Washington State. The company specializes in custom tunneling equipment design, including lifting systems, mucking systems, gantries, pipe carriers, trailing gear, custom attachments, conveyors, lift cars, equipment modifications, ventilation personnel access systems and more. Kelley Engineered Equipment has a growing line of standard products including mobile reelers for wire rope and conveyor belt, hydraulic drive pulleys and material handling/storage bins and more.

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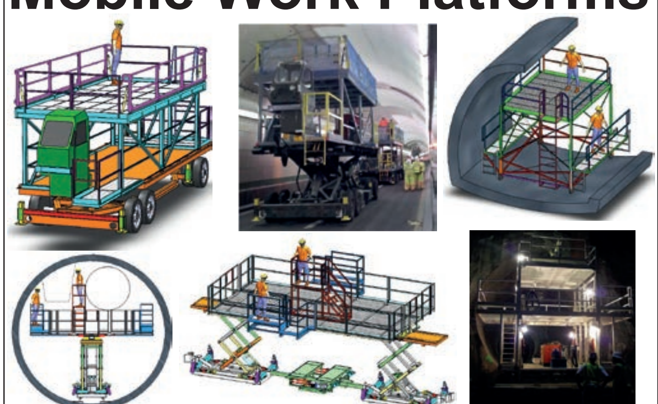
Mobile Work Platforms



Kelley Engineered Equipment, LLC has proven experience in the design of custom mobile work platforms for construction operations. Our mobile platforms can be provided with lift decks, and self propelled, steerable drive systems. We can integrate nearly any construction tool or material handling system you can envision, into powerful and productive machines which will provide your personnel with safe access to the most challenging work zones. Take a look at our web site www.keellc.com to see some of the mobile work platforms we have designed and let us prepare a conceptual design and proposal for you the next time you are in need of a mobile work platform.

Kelley Engineered Equipment, LLC

11281 S. 232nd St.
Gretna, NE 68028
PH: 402.267.0143
www.KEELLC.com

New Irvington Tunnel Holes Through!


Photo: San Francisco Public Utilities Commission/Katherine Du Tiel

After more than two years of digging, miners at the New Irvington Tunnel used a roadheader to punch through hard rock from one tunnel heading to another. This is the last of the four reaches to be mined, signifying the end of excavation and marking an important milestone. The project is located between Fremont and Sunol, California, and is a part of the San Francisco Public Utilities Commission's $4.6 billion Water System Improvement Program, which is now 70 percent complete. The 13-foot-diameter, 3.5-mile-long tunnel is being constructed parallel to the original tunnel. Jacobs Associates was the lead designer for the tunnel, shafts, and portals, and is providing design support during construction. The contractor for the project is Southland Contracting/Tutor Perini, and Hatch Mott MacDonald is the construction manager.

Jacobs Associates
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HIC Fibers is selling direct in North and South America

HIC Fibers, Inc. has opened offices in Los Angeles, California for North America and Lima, Peru for Central and South America.

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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.

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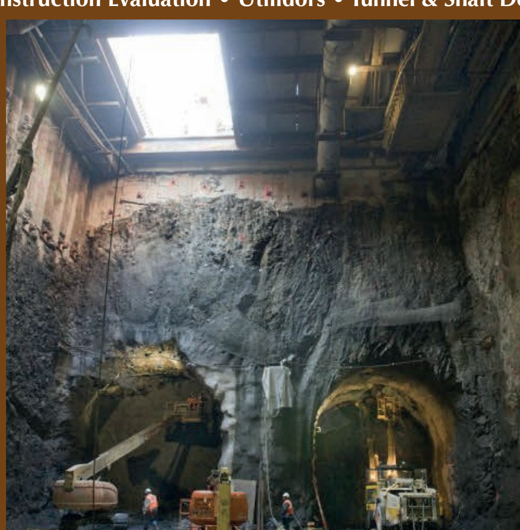

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Mueser Rutledge Consulting Engineers (MRCE), founded in 1910, is a leading engineering firm focused on the below-ground disciplines of geotechnical, marine, and structural / foundation engineering.

Providing design solutions for tunnels and shafts is one of MRCE's specialties, involving the firm in a wide range of tunnel projects in both soft ground and rock for railroads, highways, subways, pedestrians, utilidors, CSOs, interceptors, as well as water and wastewater treatment.

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

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Brierley Associates

Brierley Associates exists to partner with clients and peers on projects for underground facilities through leadership, honesty, and innovation. Brierley Associates offers a full range of geotechnical/underground engineering design and construction consulting services with a focus on tunneling and excavation support for projects throughout the United States and abroad. Brierley staff has expertise in all types of ground conditions utilizing a complete array of ground support and tunneling technologies. Brierley Associates has a strong history of providing quality services on major projects for water conveyance tunnels and tunnels for subways, highways, railroads, and other specialized design applications. Current tunnel projects include: Liberty University, Twin Box Vehicle Tunnel and I-70 Twin Tunnels Widening Project.

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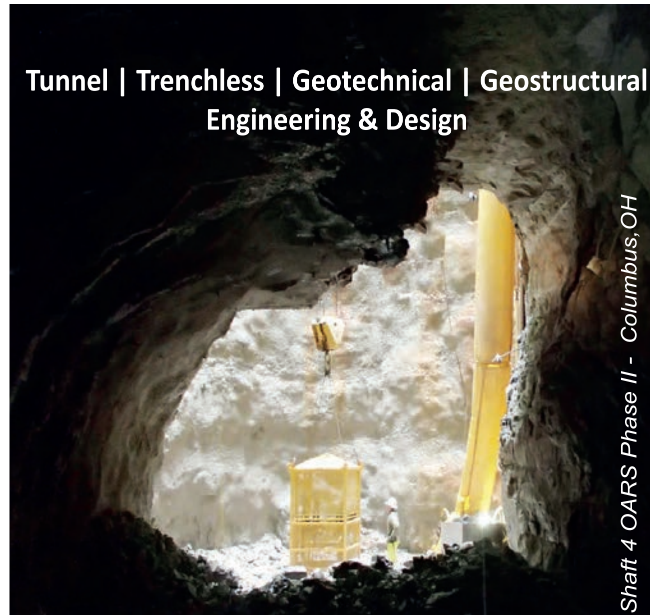

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Dā-mite Rock Splitting Mortar from the Daigh Company, Inc.

Daigh Co. is the supplier of Dā-mite Rock Splitting Mortar. Dā-mite is used to fracture rock and concrete in "no-blast" conditions. Dā-mite is an ideal and effective tool for fracturing mass rock, boulders, trench rock, dimensional stone, concrete and reinforced concrete. "Dā-mite is mixed with water and placed in the appropriately placed predrilled holes, where it sets and expands, fracturing the rock/concrete". No license required. There are four grades of Dā-mite, providing enough versatility to be utilized in drilled hole diameters from 1 in. to 2 ¾ in.

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FEATURE ARTICLE

Colorado's Twin Tunnels project helps alleviate heavy mountain traffic

The Twin Tunnels, east of Idaho Springs, CO, are a major bottleneck for motorists going to and coming from the mountains. The Twin Tunnels project will add a third lane to each tunnel, helping to alleviate traffic congestion.

Interstate 70 running into the mountains west of Denver, CO is the main access to the state's numerous ski areas and other tourist attractions. As such, the highway is a vital part of Colorado's economy.

Due to the mountainous terrain in which it winds, I-70 is limited to two lanes in either direction. And, during the past few decades, the volume of traffic has increased to the point where motorists encounter major delays, particularly on Friday evenings and Saturday mornings heading west from Denver, and then again on Sunday evenings heading east.

In the past, those delays occurred mostly during the ski season. However, many of the mountain towns have been successful in turning their resorts into year-round vacation destinations. A good move economically, but the pressure added to I-70 has caused even greater traffic delays, sometimes to the point where some Front Range residents avoid trips to the mountains.

Steve Kral, Editor

The Interstate 70 traffic problem is one that the Colorado Department of Transportation (CDOT) has been wrestling with for years. Long-term, the agency is entertaining proposals to alleviate traffic congestion from Denver to Vail, about 160 km (100 miles) west of Denver. In meantime, though, CDOT has completed a tunneling widening project near Idaho Springs that will go a long way in relieving traffic problems at one of the major bottlenecks on I-70.

Twin Tunnels project

The Twin Tunnels are located about 1.6 km (1 mile) east of Idaho Springs, itself located about 55 km (35 miles) west of Denver. Built in the 1960s, each tunnel is two lanes running parallel to Clear Creek.

In 2012, CDOT awarded a construction manager/general contractor (CM/GC) contract to widen the eastbound tunnel from two lanes to three, along with widening and straightening out I-70 on both sides. The Kramer/Obayashi Joint Venture was the contractor. Atkins and Parsons Brinckerhoff were the tunnel designers. Brierley Associates performed contractual reviews, cost engineering and scheduling, and provided CM services during construction.

Work on the eastbound side began in March 2013

Work on the eastbound side of Colorado's Twin Tunnels project was completed in December 2013.

and was completed in December 2013. In October 2013, CDOT initiated plans to widen the westbound tunnel during the 2014 construction season.

Work began by detouring eastbound traffic around the tunnel along County Road 314. This provided the contractor with several hundred feet of yard/laydown area at both ends of the tunnel. The work schedule called for three, eight-hour shifts a day, six days a week.

Portal development took place with two crews on both ends of the tunnel at the same time. Portal work, rock excavation, initial support work, and placement of reinforcing steel and final tunnel lining were done concurrently. The existing tunnel liner consisted of 460 mm (18 in.) of reinforced concrete. The old liner was removed using 1,015-mm (40-in.) saws, cut longitudinally and radially. The cut concrete was removed by a Liebherr R932 Litronic tunneling excavator equipped with a hydraulic impact hammer.

Geology

The bedrock at the Twin Tunnels is metamorphic gneiss, biotite gneiss and hornblend gneiss. The quality of rock improves moving west to east. The first 30 to 45 m (100 to 150 ft) of tunnel from the west side (driving east) encountered a zone containing fault gouge, soft seams, play crushed rock and some veins of pyrite. This slowed tunneling from that end.

Tunnel excavation

Once tunnel excavation began, two structural steel canopies were erected at each end for three reasons:

- They provided protection from rock falls throughout tunnel construction.
- The canopies supported steel blasting mats that were hung from the frame. Rollers attached to the flanges of the trolley beams allowed the mats to be moved and act like curtains during blasting.
- Once excavation was completed, the steel-framed canopies were used to lift the final tunnel-lining rebar cage off of the rebar gantry and onto the final tunnel-liner framework.

A series of tunnel support steps for each section of the tunnel, depending on the geology, followed excavation. Equipment involved included a Fletcher J-251-LS single-boom jumbo used for rock bolting, along with a Reed B20 shotcrete pump with a Shotcrete Technologies Shot-Tech 32.3 robotic arm.

Blasthole drilling was accomplished by the Atlas Copco E2C Boomer drills. Length and depth of the blastholes varied with each round. Mucking was accomplished using two Volvo L250 loaders and a Caterpillar D9R dozer.

Shotcreting

The geocomposite drain board material that was installed throughout the tunnel was J-Drain 200. This dimpled, impermeable polymeric sheet with a layer of nonwoven filter fabric was designed to retain smaller materials so that they could not pass into the drainage core.

Continuous drain board coverage was used at both portals of the tunnel. A layer of 6 m (20 linear ft) of continuous drainage was added near the west portal during construction when heavy rainfall occurred and water was apparent.

A second type of drain board was 0.9-m- (3-ft-) wide drain board strips that covered the perimeter of the tunnel profile. These strips were spaced every 6 m (20 linear ft) throughout the tunnel. All of the drain board was fastened to the walls using Hilti soft material attachment fasteners, which were pinned through the board and into the shotcrete wall.

A smoothness criteria of shotcrete was used to install the geocomposite drain board. This was so the drain board could be fastened tight to the walls and prevent anything from protruding through the drain board material. Each drain board strip throughout the tunnel required a smoothing shotcrete strip to cover rock, dowels and WWF. Where continuous drain board was to be installed smoothing shotcrete was also required to cover installed dowels, channels and steel sets.

There were areas where overbreak was encountered due to blasting and less stable ground. And, after MC channels were installed, there were large voids behind the channels that needed to be filled prior to final liner concrete installation. So supplemental smoothing shotcrete was also used in these areas. Smoothing shotcrete was placed by hand from a man lift instead of using the shotcrete robot.

Final tunnel lining

The final tunnel liner was cast-in-place, double-mat-reinforced concrete, using two sets of 12-m- (40-ft-) long rebar gantries and two sets of concrete formwork. The tunnel walls and arch were 460 and 610 mm (18 and 24 in.) thick, as-designed, depending on location along the tunnel.

The inner layer of reinforcing was epoxy coated, while the outer layer was black bar. In the 460-m (18-in.) mats, longitudinal bars were spaced on 305-mm (12-in.) centers. The radial bars were on 230-mm (9-in.) centers. In the 610-mm (24-in.) mats, the radial bars were spaced on 150-mm (6-in.) centers. The longitudinal bars remained on 305-mm (12-in.) centers. The required 28-day concrete compressive strength was 4,500 psi. The finished tunnel cross section is 16-m-wide x 12-m-high (53 x 40 ft).

The rebar cage for each pour was constructed outside of the tunnel portals on the rebar gantry and later moved into the tunnel by a rail that had been laid on a mud mat through the tunnel. To ready a form for a pour, the rebar gantry, with the completed rebar cage, was moved under the structural steel frame at the portal, where the rebar cage was lifted off the gantry using chain falls. The gantry was moved out from under the frame, the concrete form moved under the frame and the rebar lowered onto the form. The form was then pulled on the rail into place for the next pour.

The first 12-m- (40-ft-) long concrete pour was made near the center of the tunnel, with each subsequent pour moving eastward and westward from the first pour. Each form had 24 doors and 20 guillotine valves. Holes near the crown of the forms allowed for future contact grouting. The forms were preplumbed (piped) with concrete delivery piping to allow the concrete to be placed starting at the lowest level of placement doors and moving upward using the rows of placement doors and guillotine valves.

Contact grouting and portal structures

After the forms were stripped, each pour of the cast-in-place concrete tunnel liner could be contact-grouted. Contact grout holes were located at the approximate 11, 12 and 1 o'clock positions near the crown of the tunnel. There were four contact grout holes at each clock position spaced on 1.5-m (5-ft) centers along the tunnel. There were 12 contact grout holes per 12-m (40-ft) pour.

The grout mix was portland cement and water mixed at a 0.45 water-cement ratio. Before the start of contact grouting, each of the 12 contact grout holes had a mechanical packer installed. The grout was pumped through each packer, one at time, until refusal was reached. Refusal was defined as one gallon or less of grout for one minute at full injection pressure (25 psi) measured at the packer.

View of the eastbound tunnel looking west.

The portal structures were cast-in-place reinforced concrete. They extended from the last final tunnel lining pour to outside the tunnel. The east portal structure extended 12 m (40 ft) from the last tunnel pour, and the west portal structure extended 39 m (130 ft) from the last tunnel pour.

Cycle times

The quality of rock on the east portal (driving west) was more competent than on the other end of the tunnel, allowing for longer rounds and less time being spent installing initial support. This allowed crews on the east end to post faster advance rates. The east portal crew drove about 140 m (460 ft) in 102 days, or 1.4 m/d (4.5 ft/day). The average cycle time for the east portal was less than two days per round. The best cycle was 24 hours.

The poor rock quality on the west portal (driving east) slowed tunnel driving. The west portal crew drove about 53 m (175 ft) in 98 days, or about 0.5 m/d (1.8 ft/day). The average cycle time for the west portal was about 3.5 days per round, the best being 36 hours.

The next phase of the Twin Tunnels project will be the widening of the westbound tunnel to three lanes. That is scheduled to begin in the spring of 2014. In addition to widening the tunnel, a large amount of blasting on the east and west sides of the tunnel will be required in order to widen I-70 to three lanes.

Acknowledgments

The author thanks Ray Henn, of Brierley Associates, for providing much of the information for this article. The author also thanks the Kramer/Obayashi joint venture for the visit to the project. A paper on the Twin Tunnels project, authored by Henn and others, will be presented at the 2014 North American Tunneling conference, June 22-25 in Los Angeles, CA. ■

FEATURE ARTICLE

Small footprint, big challenges: Design and construction of the Allen Park storage tunnel

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The Allen Park Sanitary Sewer Overflow (SSO) Tunnel and relief sewer project, located in the city of Allen Park, MI, is a long-term corrective action designed to bring Sanitary District One's sanitary system into compliance with its 2005 consent order and service contract with the Detroit Water and Sewerage Department (DWSD). The $20 million project is intended to reduce Allen Park's wet weather discharges to DWSD, reduce bypass pumping to the Ecorse Creek and limit the future risk of basement flooding by providing storage during wet weather events and eliminating hydraulic bottlenecks in the sanitary sewer system.

FIG. 1

Project alignment and overview.

The tunnel is sized to transport and store 507 million L (1.34 million gal) of wet-weather flow. The tunnel will convey flow to a new 0.24 L³/s (8.4-cfs) submersible dry-weather/wet-weather lift station at the north tunnel connection on Outer Drive near Baker College's campus. Flow will be carried to a new 355-mm- (14-in.-) diameter force main that will outlet to an existing trunk sewer outlet north of Outer Drive. This arrangement replaces the existing 457-mm (18-in.) gravity sewer that was unable to deliver the maximum outlet capacity to the Outer Drive Lift station without significant surcharge upstream.

Designed to be empty during dry weather and smaller wet weather events, it is estimated that the tunnel will convey wet weather sanitary flow an average of 10 times per year. Approximately three times per year, the excess sanitary flow entering the tunnel will exceed the downstream pump station capacity and the flow will be temporarily stored in the tunnel until it can be dewatered. The tunnel will need to be flushed with flow stored in upstream portions of the system one to four times a year to prevent the buildup of solids and gasses that can generate excessive odor and degrade the tunnel lining.

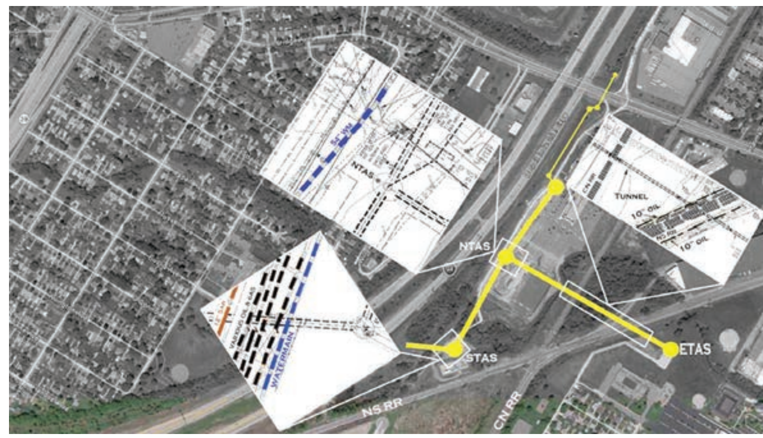
Project description

Located within the Ecorse Creek Watershed in an urban area congested with existing utilities and structures, the 1,250-m (4,100-ft) long tunnel was designed and constructed to minimize impacts on surrounding areas while meeting the requirements of regulatory agencies, property owners and other entities. To facilitate the proposed storage and conveyance improvements, while delivering a sustainable and environmentally sound project, tunneling and other trenchless methods were selected by the project team. The overall alignment crosses an interstate highway, I-94, Canadian National and Norfolk Southern railroads, gas and oil pipelines owned by various utilities, a 1.4-m (54-in.) DWSD transmission water main, a natural drain at two locations, as well as a residential area and Baker College's campus. The alignment even included a mining shaft located in the shadows of the famous Uniroyal Giant Tire, a local landmark that consists of the repurposed Ferris wheel attraction from the 1964-1965 World's Fair in New York.

A dynamic mix of five different trenchless construction and rehabilitation methods were used to complete 2.4 km (1.5 miles) of sewer, minimizing impacts on existing structures and residential, commercial and environmental properties. A tunnel boring machine (TBM) was used to install 928 m (3,045 Lft) of 2.4-m (8-ft) diameter tunnel sewer in primary and secondary lining. A 609-mm (24-in.) diameter, 213 m (700 Lft) section under the interstate highway was constructed using microtunneling methods (MTBM). Pipe bursting was used to install a 122-m (400-ft) section with only one service connection to increase the sewer diameter from 381-457 mm (15-18 in.). A combination of directional drilling, slip-lining and opencut techniques was used to install 396 m (1,300 Lft) of 355-mm (14-in.) force main. The alignment also included opencut construction of 241 m (790 Lft) of 2.4-m and 1.5-m (8-ft and 5-ft) diameter sewer and 442-m (1,450-ft) of 457-mm (18-in.) diameter upstream relief sewer improvements. The overall alignment of the soft ground tunneling portion, along with an aerial view of the surrounding setting is shown in Figs. 1 and 2. Individual tunnel runs are described below.

FIG. 2

Critical utility crossings.



Run 0 (North tunnel access structure [NTAS] to Westerly Tail Tunnel): To accommodate the tunnel locomotive and muck cars, a tail tunnel was constructed by hand mining and placing liner plate 3 m (10 ft) in diameter through the secant pile shaft wall, extending 11.5 m (38 ft) from the west face of NTAS. This run was constructed below and perpendicular to a 1.3-m (54-in.) DWSD water transmission line.

Run 1 (NTAS to ETAS): This run progressed east out of NTAS to the East Tunnel Access Shaft approximately 419 m (1,375 ft) in length with an invert approximately 9 m (30 ft) below ground surface. This run consists of 3.6-m (12-ft) diameter rib and lagging primary liner, with a 2.4-m (8-ft) diameter secondary liner, that traverses below a primary Wayne County Drain (Ecorse Creek), five tracks of railroad and a 254 mm (10 in.) diameter oil pipeline.

Run 2 (Pump station access shaft [PSAS] to NTAS): This run is 94 m (309 ft) long, parallel to the 1.3-m (54-in.) DWSD transmission main, approximately 10.6 m (35 ft) to the east. Consistent with Runs 3 and 4, the tunnel has a 3.6-m (144-in.) rib and lagging primary liner with a 2.4-m (96-in.) reinforced concrete pipe as the secondary insertion.

Run 3 (NTAS to south tunnel access shaft [STAS]): This run crosses beneath Ecorse Creek and the retention pond of Baker College's storm system. The 259-m (850-ft) tunnel run is also approximately 10.6 m (35 ft) deep, and is comprised of a 3.6-m (144-in.) rib and lagging primary liner with 2.4-m (96-in.) reinforced concrete pipe as the secondary liner.

Run 4 (STAS to the east junction chamber [EJC]): This tunnel is constructed below the 1.3-m (54-in.) DWSD water main, oil pipelines, high-pressure gas mains and a 304-mm (12-in.) sanitary sewer in which there was 1.5 m (5 ft) of clearance between each of the utilities. Cover over the tunnel crown ranged from 1.3 to 5.8 m (4.5 ft to 19 ft).

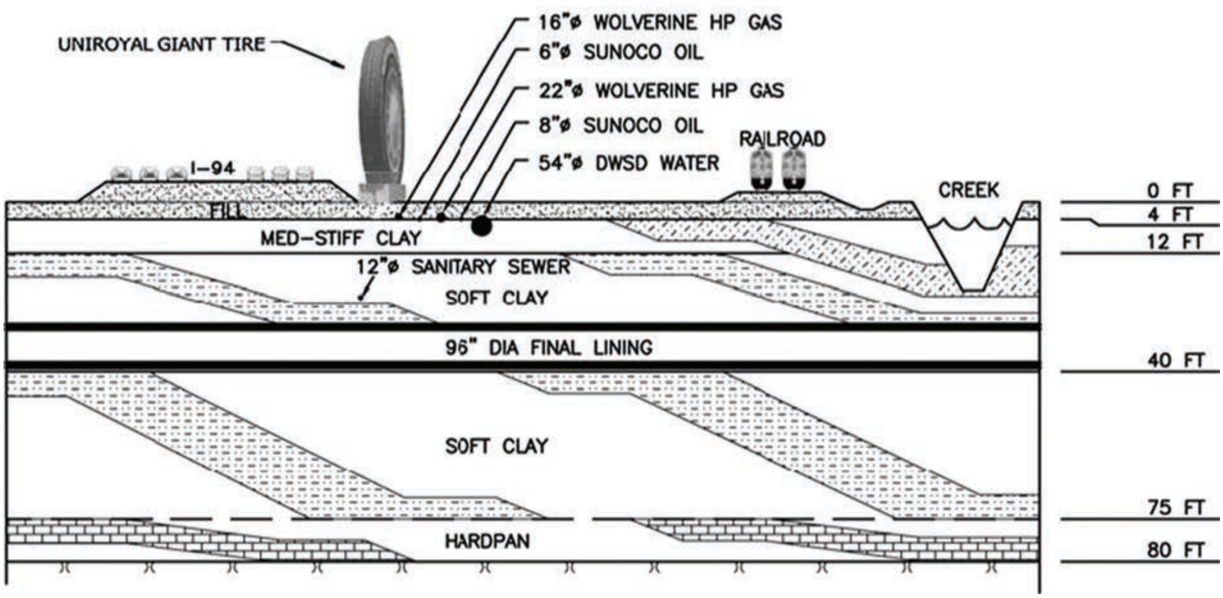
Run 5 (EJC to the west junction chamber [WJC]): This 244-m (800-ft) run crosses beneath seven lanes of I-94 with a depth of 12-13 m (40-45 ft) and was constructed by microtunneling with a 1.3-m (54-in.) steel primary liner and a 0.6-m (2-ft) diameter secondary liner. This was a late design change dictated by the governing highway agency. The mining shaft for this run was located approximately 9 m (30 ft) from the Uniroyal Giant Tire, one of the world's largest roadside attractions.

Runs 6 and 7 (WJC to west tunnel access structure [WTAS] to west diversion chamber [WDC]): These runs comprise 237 m (780 ft) of 1.5-m (5-ft) diameter concrete pipe approximately 9 m (30 ft) deep constructed by cut-and-cover methods between Ecorse Creek and Rogers Elementary School.

Run 8 (WDC to Sanitary MH 14-3): Pipe bursting of 381-m (15-in.) vitrified clay with an existing CIPP liner upsizing to a 457-mm (18-in.) PVC C900 fusible pipe. The length was 137 m (450 ft), approximately 5.8 m (19 ft) deep.

FIG. 3

Generalized soil profile.



Runs 9 and 10 (MH 14-3 to diversion chamber 14-1 at intersection of Russell and Larme streets): Upsize existing rear yard 304-m (12-in.) sanitary to 457-m (18-in.) pipe of 293 m (962 ft) in length on south side of Shenandoah and Russell streets with complete street replacement. Required to be completed between July 5 and Aug. 31 while Rogers Elementary was closed.

Run 11 (PSAS going north toward existing sanitary MH 228): Directional drilling of a portion of the new pump station's force main (193 m or 632 ft) with subsequent placement of 355-mm (14-in.) HDPE pipe.

Run 12 (Sanitary MH 228 to the existing pump station): Slip lining of 533-mm (21-in.) sanitary sewer with 55 m (183 ft) of 355-mm (14-in.) HDPE beneath the major thoroughfare of Outer Drive.

Subsurface conditions

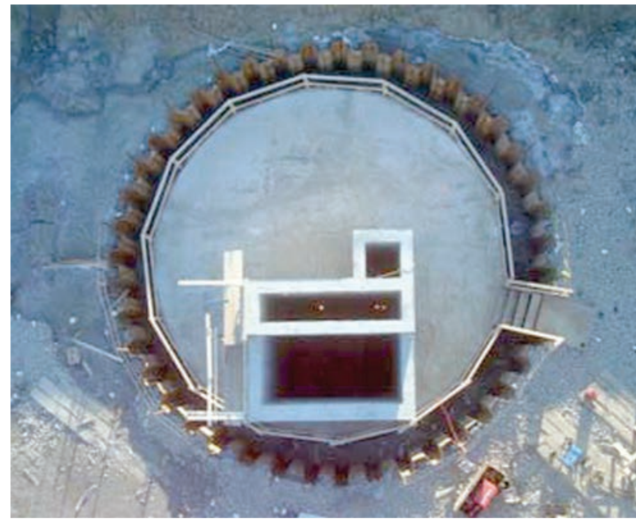
The subsurface stratigraphy along the proposed tunnel alignment is relatively uniform (Fig. 3), consisting of a thin layer of variable surficial fill extending from the ground surface down 1-1.6 m (3-5.5 ft). Below the fill layers are natural soil deposits consisting of a thin desiccated layer of medium to stiff silty clay that extends 3.8 m (12.5 ft) below ground surface, underlain by a thick layer of soft to medium silty clay that extends below ground surface ranging from 20-23 m (67-77 ft). The deep portion of the soft to medium clay strata contained occasional thin granular stratum consisting of silt and silty sand. The unconfined compressive strength of the soft to medium clay, which comprises most of the tunnel alignment, varies from approximately 1,200 lb/sq ft near the top of the deposit, to less than 600 lb/sq ft for the lower portion of the strata. The soft to medium clay layer is generally underlain by a thin layer of hard to very hard silty clay hardpan that extends to the limestone bedrock 25-27 m (83-90 ft) below ground surface. The long-term, static ground water is typically 4.5-6 m (15-20 ft) below ground surface. Low levels of hydrogen sulfide gas are typically within the substrata throughout the alignment.

Design considerations

Shafts. To accommodate the variety of subsurface improvements, the project required construction of seven shafts, ranging from 3.6-m- (12-ft-) diameter for the smaller sanitary sewer improvements, to 12-m- (40-ft-) diameter for the pump station mining shaft. The shafts ranged in depth from 5.4-18 m (18-60 ft), with the deepest shaft required for the permanent structure of the dewatering pump station. Rigid mining shafts were specified for three critical locations to minimize potential for ground movement during tunneling operations. The contract included provisions for the use of secant piles, diaphragm slurry wall or sinking caisson methods of shaft construction at these locations. Detailed performance criteria including minimum structural requirements and ground deformation limitations were also included. However, the contractor was required to ultimately select and take design responsibility for the temporary support of excavation.

FIG. 4

Each shaft location presents unique challenges.



Primary and secondary tunnel lining. A two-pass tunnel liner was specified that required steel ribs and timber lagging for the primary liner and 2.4-m (96-in.) reinforced concrete pipe for the secondary liner. The contract requirements for the primary tunnel lining included minimum rib spacing, as well as structural and dimensional properties of lagging to mitigate potential difficulties encountered in previous tunneling projects in the area's soft ground. Secondary lining consisted of 2.4-m (8-ft) long sections of ASTM C76, Class IV, Wall B, reinforced concrete pipe, fitted with cast-in-place fittings in the pipe wall as necessary for the proper application of grout between primary liner and secondary liner. ASTM C443 gasketed joints with grouted inside annulus were specified to ensure a water-tight sanitary storage vessel and a smooth finished surface to allow efficient transport and effective tunnel flushing. Maximum allowable ground water infiltration was specified to not exceed 20 gal/in. of diameter, per 152 m (500 ft) of pipe, per 24 hours for the individual runs.

Settlement tolerance. Strict requirements for geotechnical instrumentation and monitoring were specified to further manage owner risk by monitoring soil movement and utility settlement/heave from shaft, tunnel and cut-and-cover construction activities. A specific action plan was developed to respond to ground movements encountered in the field, to mitigate risk of settlement and/or damage to the critical utilities and infrastructure within the tunnel zone of influence. The specifications identified a maximum allowable surface settlement of 25 mm (1 in.) and maximum allowable heave of 12.7 mm (0.5 in.). Where the tunnel crosses the MDOT right-of-way for Interstate 94, the maximum allowable surface settlement was further restricted to 12.7 mm (0.5 in.). The contract was required to restore the site to pre-existing

TABLE 1

Summary of TBM performance.

Run	From-To	Linear ft. mined	Actual yd^3 mined	Total days of operation	Total days mined	Linear ft./day	yd^3 mined/ day	Avg. settlement per run
#1	NTAS-ETAS	1,357	6,092	41	36.5	37.1	166.9	0.84″
#2	PSAS-NTAS	309	1,322.5	23	17	18	77.7	1.48″
#3	NTAS-STAS	770.3	3,148	21	19	40.5	165.8	0.06″
#4	STAS-EJC	396.5	1,677	15	15	26.4	11.8	0.21″

FIG. 5

Secant pile shaft and TBM prior to insertion.

grades and profile and repair any damage should these threshold values be exceeded.

Boulders. Historical data indicated that boulders were likely to be contained within the silty clay throughout the tunnel alignment. The contract documents advised the contractor that cobbles and boulders may be encountered at the tunnel face. The tunneling specifications indicated that boulders less than 609 mm (24 in.) in the average of three dimensions as measured protruding into the bore would be incidental and required that the mining machine include provisions for removal of boulders at the tunnel face. In addition, a contingency bid item was included to cover unforeseen physical conditions that might be encountered during construction. These measures ultimately minimized changed condition claims from the contractor during tunneling operations.

TBM features. Face stability analyses indicated that a tunnel mined in the soft to medium clay strata using open face mining would result in overload factors from 6 to 9. This indicated a marginally stable tunnel face that may be subject to excessive squeezing. Based on other underground projects in the area, however, it was believed that the clay soils would be capable of short-term self-support even with overload factors up to 10. As such, it was determined that a conventional mining shield with positive face control would be suitable for installation of the primary lining. The specifications required the selected TBM be compatible with anticipated ground and ground water conditions, capable of providing full-face support and equipped with face closure doors. The face was to be accessible through the cutter head for removal of obstructions.

Construction and performance

The construction contract was awarded on Oct. 14, 2009, and mobilization commenced in early November 2009. The first mining shaft (NTAS) construction commenced May 5, 2010, and was completed by the end of June 2010. The TBM was assembled and mining of Run 1 began on Aug. 6, 2010.

Third party coordination and community relations. During the preliminary phases of construction, extensive coordination with the various utilities, railroads, transportation agencies and other impacted property owners was undertaken to ensure that the work progressed according to the project schedule.

Community relations. To minimize public inconvenience due to construction activities and ensure appropriate precautions were taken to protect public lives and property, several public outreach meetings were conducted to present the schedule and scope of activities near residential areas. As work activities were ready to commence in a given area, a door-to-door campaign was instituted to remind residents of pending work that would include street closures, equipment deliveries and heavy truck traffic at muck haul routes.

School influences. The construction schedule was controlled indirectly by the needs of three schools within the project area. Rogers Elementary School at the west end of the project was impacted by the installation of 457 mm (18 in.) sanitary sewer and associated excavation and paving work. Additionally, the haul route for Runs 7 through 10 traversed the area adjacent to the school and through the surrounding residential area. To avoid conflict with school traffic, the contract specified that the

FIG. 6

Mining operation with effective boulder removal.

work be completed between July 1 and Aug. 31, 2010.

A mining and access structure (ETAS) on the project's east end served as the retrieval shaft for Run 1. This structure was situated on Inner City Baptist School's property, on the east end of the school's junior varsity soccer field. Decommissioning of the mining shaft, construction of the permanent 10 m (30 ft) diameter, below-grade flushing chamber and restoration of the playing field was required to be complete for the fall 2011 season.

The most crucial coordination necessary for project progress was with Baker College. The site included the main mining shaft (NTAS), the pump station shaft (PSAS) and the south tunnel shaft (STAS). Access to the site, as well as the muck hauling route, was along the campus' entrance drive. The work site temporarily occupied approximately 6.5 percent of the campus parking area, which typically accommodates 1,000 students daily. Daily coordination and routine meetings with Baker College representatives took place to ensure that the safety and activities of the students and administrators were not adversely affected.

Transportation agencies. During the FHWA and MDOT review of the final design documents, a decision was rendered that required approximately 243 m (800 ft) of the 2.4-m (8-ft) diameter storage tunnel to be downsized to 0.7-m (2-ft) finished diameter, so that storage would not occur within the right-of-way. The excavation was further limited to 1.3 m (4.5 ft), and a jack and bore operation was proposed and accepted by MDOT. The design was revised by addendum, adding two additional shafts and permanent structures to accommodate the transition in pipeline size. Ultimately, the contractor proposed a 1.3-m (4.5-ft) microtunnel (MTBM) approach and successfully worked with MDOT to revise the permit for the crossing (Fig. 4).

Railroad crossing. Based on the permit for crossing the Norfolk Southern Railroad right-of-way, fixed steel liner plates that bolt together when tunneling under track were required to be used as the primary liner. Because this method often results in greater settlement, as the plates cannot be expanded to meet the ground beneath the TBM, and the operation proceeds more slowly, the contractor proposed to use steel channel lagging and steel ribs instead. It was demonstrated to the railroad decision-makers that steel rib and lagging materials would provide a greater degree of protection against above-ground settlement during construction and ultimately, the rib and steel lagging alternative was accepted.

Shaft selection and construction. For the rigid shaft locations at the pump station (PSAS), NTAS and STAS, the contractor used 10-m- (33-ft-) diameter shafts comprised of secant piles with reinforced-concrete ring wales. The contract required 1 m (3 ft) minimum diameter for secant piles; however, the contractor successfully proposed the use of 0.7-m (2-ft) diameter piles, with the secondary piles reinforced with HP12 x 53, and concrete ring wales.

The secant pile shafts were installed using the continuous flight auger method. Initially, grout was maintained at a constant pressure of approximately 25 psi and injected at the base of the auger stem during withdrawal. Because the excavated clay soils exhibited better strength properties than anticipated, the contractor attempted excavation of the piles without grouting the hole during the drilling process. It was determined through observation and measurement that the excavated piles indeed held up without appreciable deformation and the remaining secant piles were constructed in this manner, with the open holes ultimately being filled with grout or structural concrete by pump and tremie tube.

As the excavation of the rigid shaft for the pump station progressed, many of the 24-m- (80-ft-) long piles were not within vertical tolerance within the lowest one-third of the excavation. The use of smaller diameter piles compounded the effect of this problem. This required modification to the ring beam design and resulted in encroachment into the clear working diameter of the shaft. Upon completion of the excavation, three-dimensional laser scanning was used to document the as-built shaft conditions and determine what modifications to the permanent structure would be necessary (Fig. 5).

Flexible shafts consisting of steel sheet piling and reinforced concrete ring beams were used for the ETAS mining shaft and the MTBM mining shafts. The contract specifications had less stringent requirements for these locations due to their proximity to adjacent utilities or infrastructure.

TBM selection and performance. The contractor used a 4-m- (12-ft-) diameter, Lovat model ME 142/150 PJ/RL TBM, which is a bidirectional rotary head, soft ground machine. The machine incorporated a fully enclosed forward shield and a soft ground cutterhead equipped with spade/ripper type teeth and flood control doors at its face. Muck removal was accomplished by a 300° muck ring, mounted in the center of the forward shell, which transferred muck through pressure relief gates to a conveyor in open mode or to a screw conveyor in closed mode, and ultimately transported to the rear of the machine by conveyor for final removal by muck carts and locomotive. Sawdust obtained from a local producer was used to condition the soft clay at the tunnel face.

Production rates. The typical mining operation included two shifts of nine hours per day. When mining within the zone of influence for the railroad and critical utility crossing, the work proceeded 24 hours per day, using two working shifts of 12 hours. Maintenance was generally performed on Saturdays when no mining was taking place. The average downtime over the duration of the project for maintenance or repairs was approximately 45 minutes per day (Table 1).

As would be expected, the production rates varied considerably between the four major runs of the 3.6-m (12-ft) bore, with the higher production rates occurring during the longer runs of tunnel. The average production rate for the TBM-mined tunnel was 9.2 m/d (30.5 ftpd). The best production day was 22 m (72 ft), while the worst day was 1 m (3 ft), with only a single set installed due to mechanical failure and subsequent repair of the rib expander.

Boulders. During the mining operation, the excavated material was primarily soft clay that was conditioned with sawdust, to allow efficient removal from the face (Fig. 6). Cobbles were routinely encountered and easily removed by cutterhead and conveyor. Throughout the project, 13 boulders ranging in size from 304-812 mm (12-32 in.) in average dimension were encountered during mining. Since the contract required that boulders less than 609 mm (24 in.) were to be considered incidental to the project, only one boulder encountered resulted in additional cost to the project.

Settlement analysis. Due to the location of the tunnel with respect to critical utilities and infrastructure, a detailed instrumentation and monitoring plan was developed during the design phase and identified in the contract documents. Instruments included inclinometers, tell tales, monitoring point arrays and deformation monitoring points installed at critical utility locations, shaft locations and rail/highway crossing. The monitoring program was designed, installed and maintained by the owner, with daily communications transmitted to the contractor to allow appropriate action to be taken should threshold levels of deformation be encountered.

The frequency of monitoring varied, but typically consisted of weekly measurements of ground deformation in the vicinity of shafts, and daily measurement of monitoring points and arrays within the vicinity of the tunnel face. The tunneling induced settlement measurements ranged from 1.5-158 mm (0.06-6.24 in.), the largest occurring due to significant ground loss that occurred at the tunnel eye when the TBM was launched from the shaft for Run 3. The average measured surface settlement for the project was 24.6 mm (0.97 in.), which equates to approximately 2 percent of the excavated volume.

Measurements indicated that the largest surface settlement occurred during the maintenance shifts, when the TBM was not advancing. Twenty-four-hour tunneling operations were used to minimize settlement in critical locations, particularly the railroad crossings. The maximum settlement of the seven sets of tracks that were crossed for this project was found to be only 2.3 mm (0.09 in.).

Other trenchless methods. The project consisted of a variety of trenchless methods to not only incorporate existing utilities into the improved sanitary system, but also to accomplish the existing system tie-in without interrupting the 24-hour-per-day, seven-day-a-week capability of the pump stations. The following is a commentary on these trenchless methods, including location, success thereof and issues encountered, as well as significance to the project:

Run 5 (243 m (800 ft) long, 1.37 m (54 in.) diameter, MTBM): The contractor proposed an alternate to the proposed 1.2-m (48-in.) boring and jacking method that is shown in the contract documents for the crossing of I-94. This alternate eliminated a bore pit and a manhole in the median and consisted of increasing the casing diameter to a 1.37-m (54-in.) 0.563 w/steel casing placed using a purpose built Akkerman 1.37-m (54-in.) microtunnel machine. The MTBM used a rotating wheel to loosen and remove the spoil. This change was advantageous in that it was performed with a manned machine and operator at the face, monitoring the soil conditions constantly, as well as being articulated and steerable and guided by a laser guidance system. This change was accepted by MDOT, the owner assumed an appropriate credit to the contract and the run was completed within the specified allowable settlement tolerances of less than 12.7 mm (0.5 in.).

Run 8 (137 m (450 ft) long, 457 mm (18 in.) diameter, pipe bursting): This portion of the project proved to be extremely difficult and quite problematic to the contractor. With the depth and upsizing required, the burst could be classified as "challenging," according to Tables 1 and 2 Project Classification as depicted on pages 20 and 21 in NASTT publication "Pipe Bursting Good Practices." The contractor incurred excessive overburden pressures on the C-905 PVC pipe due to delays in shaft preparation. This resulted in exceeding the maximum pulling pressures of the pipe (greater than 58.2 t or 64.2 st). This necessitated some unexpected additional excavation and restoration in the work area. Nonetheless, the work was completed, upsized and the sewer flow was re-established through the pipe until the new pump station was ready.

Run 11 (192 m (632 ft) long, 355 mm (14 in.) diameter, directional drill): This portion of the new force main was designated to be constructed by slip lining 355 mm (14 in.) PVC C-905 through the existing 533-mm (21-in.) sanitary sewer. The contractor proposed to change the force main to a direction drill using 355-mm (14-in.) HDPE with tracer wire to be placed approximately 2.4 m (8 ft) above the existing line. By using this approach, the temporary bypass line and pumping of the existing sanitary line could be eliminated, as the extent of the tie-in on the new main was significantly reduced (Run 12). This change resulted in a credit to the owner and eliminated the MDOT-mandated 30-day maximum period for the temporary bypass line that was to be installed along the east guardrail of the Outer Drive bridge along I-94. This work was accomplished successfully within several days.

Run 12 (56 m (183 ft) long, 533 mm (21 in.) diameter, slip lining): The slip lining and ultimate tie-in of the new system was successfully completed during a three-day weekend. The existing flow in the sanitary sewer was stored in the wet well of the new pump station and its contents pumped into the new discharge manhole upon completion of the tie-in of the new force main.

Conclusion

In addition to the typical engineering and construction challenges associated with underground construction, the Allen Park Storage Tunnel project, nearly a decade in the making, required thorough coordination with multiple federal, state and local agencies, two railroads, three schools and several bustling residential neighborhoods to achieve success. The proactive and coordinated approach to informing and interfacing with the community and the other third-party stakeholders, was well-received and resulted in well-informed project participants who worked together to see this project through completion without significant changes, delays or disruptions.

Detailed, performance-based specifications provided for successful risk management through the design and contracting phase, yet allowed the contractor adequate flexibility in determining the most appropriate and cost-effective approach to perform the various types of shaft, tunnel and other trenchless installations. A collaborative effort between the contractor and owner/engineer during the preconstruction activities ensured that the project performance expectations with respect to shaft and tunnel construction, and settlement limitations were understood and achieved. Ground deformation was successfully minimized in the vicinity of the critical utility, railroad, and highway crossings, resulting in no adverse impact to any of the project stakeholders.

The project alignment, dictated by the constraints of the existing infrastructure, at the surface and below, required detailed engineering solutions and precise construction to successfully utilize the underground space for the much-needed sanitary storage and conveyance improvements. In addition to successfully achieving the technical goals of the project, substantial completion was achieved in January 2013, ultimately meeting the project's schedule and budget. ■

Acknowledgments

The authors thank the city of Allen Park for its permission to publish this paper, as well as Jason Yoscovits, who served as the full time inspector for the duration of the project, for his input regarding performance and execution of the work.

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FEATURE ARTICLE

Alaska Way visit highlights Megaprojects conference in Seattle

When defining a "megaproject," one need only to look at Seattle, WA's State Route 99 Alaskan Way Viaduct replacement project. This $3.1-billion project is one of the largest of its kind in the world, and includes the use of the world's largest tunnel boring machine (TBM).

However, for as large as the Alaskan Way project is — especially given the size of the TBM being used — there are several other megaprojects underway around the world. Each has its own challenges that require innovative design techniques and financing arrangements, as well as variations on established tunneling technologies.

So it was that 266 tunneling and underground construction professionals — owners, contractors and engineers — convened in Seattle in November for the Cutting Edge Conference on Megaprojects. This was the second joint meeting between the Underground Construction Association of SME and the *North American Tunneling Journal*. The first joint conference took place in April 2012 in Miami, FL and attracted 238 attendees. A third joint conference, to be held in 2014, is in the planning stage.

The key reason Seattle was chosen as the site of the megaprojects conference is the Alaskan Way Viaduct project. Before the conference began, many of the attendees were able to visit the project and get a close look at Bertha, the Hitachi Zosen earth pressure balance TBM that is boring the tunnel. In addition, the conference included an exhibit that attracted 20 industry suppliers, up from 10 the previous year in Miami.

Some attendees were able to get a close look at Bertha, the largest TBM in operation in the world.

Steve Kral, Editor

The 25 presentations during the two-day conference covered all aspects of the tunneling and underground construction of megaprojects. Topics included the Alaskan Way Viaduct project; considerations for procurement and contracting; political risk, financing and insurance; international megaprojects; risk and risk sharing and project delivery. Each session concluded with panel discussions.

Technical program

The opening session of the conference included five papers related to the Alaskan Way project. The project involves replacing the old viaduct on State Route 99 with a single-bored tunnel in downtown Seattle. The tunnel part of the project consists of a design-build contract worth $1.34 billion.

The Hitachi Zossen TBM — the largest TBM currently operating in the world — is boring 2,826 m (9,273 ft) of tunnel at a diameter of 17.5 m (57.35 ft). This will involve excavating about 765,000 m^3 (1 million cu yd) of material, according to Juan Luis Magro, of Dragados USA. A southbound off ramp and a northbound on ramp will require the excavation of about 413,100 m^3 (540,000 cu yd) of material for slurry walls, secant piles and concrete slabs, he said.

In his paper, "TBM Design and Construction Overview," Magro outlined the TBM's dimensions, cutterhead configuration and other key features. The machine's length is (368 ft), plus backup. Total thrust is 392,000 kN, while its maximum torque is 147,000 kN-m. Its total weight is 7 kt (7,700 st), with installed power of 22,600 kW.

Bertha's cutterhead configuration consists of 101 fixed precutting bits, 260 cutter bits, 32 scraper bits and 45 emergency bits. Also included on the cutterhead are 49 atmospheric interchangeable disks and precutting bits, along with four copy cutters.

Magro went on to explain how the TBM was built at a drydock in Japan and then shipped to Seattle. He also discussed its assembly once it reached the project site.

Other papers in the opening session that discussed various aspects of the project included "Financing and Procurement of the SR99 Tunnel," by Linea Laird; "The Singleton Bore Solution: A Stakeholders Perspective," by Bob Donegan; "Design Challenges and Solutions," by Sanja Ziatanic and "Logistical and Construction Challenges," by Greg Hauser.

International megaprojects

The Airport Link tunneling project in Brisbane, Queensland, Australia is a private-public partnership, design-build project worth about US$5.1 billion. The project was actually three projects in one — the northern busway, Airport Link M7 and the airport roundabout, according to Hannes Lagger, of Arup, in his paper "Four Billion in Four Years: Brisbane Airport Link, Australia's Megaproject." It was completed in a record four years.

The Airport Link is a tunneled highway toll road located in the northern suburbs of Brisbane, Lagger said. The link connects the Brisbane central business district and the Clem Jones Tunnel to the east-west arterial road that leads to Brisbane Airport.

The Airport Link and the northern busway were built at the same time and required 15 km (9.3 miles) of tunneling, with 8 km (5 miles mined by TBM. This included 6.4 km (4 miles) of twin tunnels, six underground caverns, busway tunnels and connecting ramps, and 25 bridges.

Two 3.6-t (4-million st) TBMs, costing about US$45 million, were the largest such machines (12.48 m or 41 ft outside diameter) ever used in the Southern Hemisphere, Lagger said. They averaged about 50 m (165 ft) a week. During construction, 17 roadheaders operated concurrently in the mined tunnels.

Other papers presented in the Internatioal Megaprojects session included "Crossrail — Europe's Biggest Megaproject," by Chris Dulake; "Experiences from the World's Largest TBM: Excavation of the Sparvo Twin Highway Tunnels," Jens Classen (he renamed the paper to "Second-Largest TBM," following the Alaskan Way Viaduct project); and "Planning of Hong Kong's Tuen Mun to Chek Lap Kok Highway Tunnel Link," by Bob Frew.

Political risk, financing and insurance

Large construction projects, or megaprojects, have been around for longer than most people think, according to Alistair Biggart, an independent consultant. In his presentation, "Success Factors for Megaprojects," he cited the pyramids in Egypt, around 2500 BC, as one of the first megaprojects. Other earlier megaprojects cited included the Suez Canal (1869), the Manchester Ship Canal in the U.K. (1890) and the Panama Canal (1904-1913).

More recent megaprojects include the Mangla Dam in Pakistan (1961-1967), the Channel Tunnel in the U.K. (1987-1994) and the Channel Tunnel Rail Link in the U.K. (2008). Each of these projects, and others that Biggart cited, involved new technology, new risks and new ways of mitigating risk and cost.

Taking a look at political risks in megaprojects, Biggart addressed a long list of political factors that delay or stall projects. Some of these included weak funding, high interest rates, unreasonable labor disputes, environmental clearances and objections, and an unreasonably long time scale due to the above factors.

On the other hand, there is an even longer list of factors that can lead to project success, he said, including ongoing political support for projects, robust funding and budget/cost control, practical and buildable designs, and contractors fulfilling design intent.

A few of the keys to a successful project are having a good overall plan and staying with it, and creating a robust schedule and budget, Biggart said. Planners need to make sure there is compatibility between the ground and the TBM and tunneling lining. This is more important with mega TBMs, he said.

Other papers in the Political Risk, Finance and Insurance session included "Political Risks for Megaprojects," by Art Silber; "Insurance and Surety: A Contractor's Perspective," by Tammy Pike; and "Attracting Private Investment for Megaprojects," by Nick Hann.

Other technical sessions

Considerations for Procurement and Contracting. The four presentations included: "Alternative Procurement and Contracting for Megaprojects," by John Reilly; "The Planning and Development of Large Tunnels in the Bay Delta Conveyance Program," by Gordon Enas and John Bednarski; "Port of Miami PPP Perspectives: Lessons Learned," by Louis Brais; and "Contract Risk Reviews: Getting It Right Before Tender," by Patricia Galloway.

Risk and Risk Sharing. The four papers included "Risk Matters in Megaprojects," by Bob Goodfellow; "Lump Sum vs. Target Practice: Risks and Chances for Large Tunnel Contracts," by Gerhard Urschitz; "Managing Risk on LA Metro's Megaprojects," by K. Murthy; and "Risk Allocation on Design-Build and PPP Projects," by Randy Essex.

Project Delivery. The four papers in the session included "Mega Considerations in Program Management: Coordinating Multiple Interfaces on East Side Access," by Andy Thompson; "Fast Track Delivery of the Los Angeles Regional Connector Project," by Bill Hansmire; "The Evolution and Delivery of a Mega Waste Water Program: The Cleveland Experience," by Kellie Rotunno and Doug Gabriel; and "Challenging Conditions on Mexico's Megaproject: Pushing the Limits at the Emisor Oriente Waste Water Tunnel," by Marco Antonio Lara. ■

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Gateway Tunnel	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	MDC	Hartford	CT	CSO	32,000	20	2014	Under design
South Conveyance Tunnel	City of Hartford	Hartford	CT	CSO	16,000	26	2015	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
Purple Line - Plymouth Tunnel	MD Transit Administration	Baltimore	MD	Subway	1,000	30x40	2015	Under design
First St. Tunnel	DC Water and Sewer Authority	Washington	DC	CSO	2,800	20	2013	Skanska-JayDee Awarded
Northeast Branch Tunnel Northeast Boundary Tunnel	DC Water and Sewer Authority	Washington	DC	CSO CSO	11,300 17,500	15 23	2018 2021	Under design Under design
Olentangy Relief Sewer Tunnel	City of Columbus	Columbus	OH	Sewer	58,000	14	2014	Under design
Blacklick Creek San. Interceptor Tunnel	City of Columbus	Columbus	OH	Sewer	24,000	10	2014	Under design
Alum Creek Relief Tunnel Phase 1 Phase 2	City of Columbus	Columbus	OH	Sewer	30,000 21,000	18 14	2015 2017	Under design Under design
Dugway Storage Tunnel	NEORSD	Cleveland	OH	CSO	16,000	24	2014	Under design
Doan Valley Storage Tunnel	NEORSD	Cleveland	OH	CSO	9,700	17	2017	Under design
Westerly Main Storage Tunnel	NEORSD	Cleveland	OH	CSO	12,300	24	2020	Under design
Shoreline Storage Tunnel	NEORSD	Cleveland	OH	CSO	16,100	21	2021	Under design
Southerly Storage Tunnel	NEORSD	Cleveland	OH	CSO	17,600	23	2024	Under design
Big Creek Storage Tunnel	NEORSD	Cleveland	OH	CSO	19,500	20	2026	Under design
Ohio Canal Interceptor Tunnel	City of Akron	Akron	OH	CSO	6,170	27	2014	Under design
Northside Interceptor Tunnel	City of Akron	Akron	OH	CSO	6,850	24	2021	Under design

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
ALCOSAN CSO Program	Allegheny Co. Sanitary Authority	Pittsburgh	PA	CSO	35,000	20	2016	Under design
Lower Pogues Run	Indianapolis DPW	Indianapolis	IN	CSO	9,700	18	2018	Under design
Fall Creek	Indianapolis DPW	Indianapolis	IN	CSO	19,600	18	2016	Under design
White River Tunnel	Indianapolis DPW	Indianapolis	IN	CSO	27,800	18	2016	Under design
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
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	2013	Tutor-Perini Awarded
Third Ave. Subway Tunnel	San Fran. Muni Transit Authority	San Francisco	CA	Subway	10,000	22	2015	Under design
L.A. Metro Regional Connector	Los Angeles MTA	Los Angeles	CA	Subway	20,000	20	2014	Awaiting Award
L.A. Metro LAX to Crenshaw	Los Angeles MTA	Los Angeles	CA	Subway	12,200	20	2013	Walsh/Shea Awarded
LA Metro Westside 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	Bid date 12/14/13 Under design Under design
Speulvada Pass Corridor	Los Angeles MTA	Los Angeles	CA	High/Trans.	55,500	60	2017	Under study
JWPCP Effluent Outfall Tunnel Project	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	2015 2017	Under design Under design
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	Bid date 01/22/14
Second Narrows Tunnel	City of Vancouver	Vancouver	BC	CSO	3,600	14	2013	Under design
UBC Line Project	Trans Link	Vancouver	BC	Subway	12,000	18	2015	Under design
Northern Gateway Clore Tunnel Hoult Tunnel	Enbridge Northern	Kitimat	BC	 Oil Oil	 23,000 23,000	 20 20	 2014 2014	 Under design Under design

UCA AWARDS

UCA issues call for award nominations

The Underground Construction Association will present the UCA awards at the 2014 North American Tunneling conference, June 22-25, in Los Angeles, CA. The awards are:

- Outstanding Individual.
- Project of the Year.
- Outstanding Educator.
- Lifetime Achievement Award.

The nominations for the awards will be reviewed by the UCA Executive Committee during its January meeting, and the committee will vote on and approve the award nominees. The recipients' photos and biographies will appear in the March issue of *T&UC*.

Guidelines and nomination forms are available on the UCA of SME website, uca.smenet.org. Please submit your nominations by Jan. 6, 2014 to Mary O'Shea at oshea@smenet.org. ■

PERSONAL NEWS


CASTRO


KAPLIN


COCHRAN

Jacobs Associates has formed a new business division, Jacobs Associates Construction Managers (JACM). The division will focus on heavy civil and underground construction projects and provide specialized services. JACM will be led by **RAFAEL CASTRO** (SME), a principal with Jacobs Associates. **JOHN KAPLIN** and **JUDY COCHRAN** (SME) have also joined the new JACM division. Kaplin works in the areas of agency construction management, construction management at risk, lump-sum bidding and design-build project targets. He is a certified LEED AP professional with advanced knowledge and experience in green building practices. Cochran joined the Seattle office as a lead associate. She has 25 years of construction management experience, primarily on large waste water projects. Much of her career has been spent working for King County Wastewater Treatment Division in Washington. She is a project management professional and an executive committee member of the Underground Construction Association of SME.

Brierley Associates recently relocated associate partner **SEAN HARVEY** (SME) from the Moraga, CA office to the Woodland Hills, CA office. Harvey assisted with the establishment of Brierley's first California office in 2010. He is a certified engineering geologist in California and a licensed professional geologist in California and Wyoming. Recently, he served as the lead contractor SEM tunnel geologist during construction of the Caldecott Fourth Bore tunnel project located in the San Francisco Bay Area.

Skanska has hired **MIKE SKOV** as business development director for the Rocky Mountain District of its civil business unit. Skov has experience in projects throughout the Rocky Mountain region, and he has done significant work in Canada and Latin America.

MIKE MOONEY, P.E., a professor at the Colorado School of Mines, has been appointed as the Grewcock University Endowed Chair in Underground Construction & Tunneling. Mooney will lead the university-wide Center of Excellence in Underground Construction & Tunneling. He has 18 years of academic and consulting experience in heavy civil engineering and construction. His expertise lies in soft ground tunnel design and construction, ground improvement, instrumentation/monitoring of construction systems, nondestructive imaging techniques and intelligent geoconstruction processes.


MOONEY

Jacobs Associates has announced the following promotions to associate level.**THOMAS W. PENNINGTON** (SME), P.E., is based out of the San Francisco, CA office. He has 12 years of underground engineering experience, including subsurface investigations, geotechnical site characterization, tunnel and shaft design, slope stability analysis, and risk management. He currently serves as a project engineer on the Kaneohe/Kailua Sewer Tunnel project in Oahu, HI.


PENNINGTON

JEFF PETERSON is the firm's safety manager and currently serves as resident engineer on the con-

(Continued on page 77)

INDUSTRY AWARDS

The Moles and The Beavers honor industry achievements

RONALD E. HEUER (SME), a geotechnical consultant, and **JOHN L. KOLAYA**, president and chief operating officer of Yonkers Contracting, have been selected for top honors by The Moles, one of the industry's foremost construction organizations.

Heuer began his professional career in 1969 working for A.A. Mathews. From 1975 through 1978, he served as an associate professor of civil engineering at the University of Illinois and became an international geotechnical consultant for underground construction projects. He has worked on several hundred underground projects and has earned the industry-wide respect of engineers, geologists, contractors and owners.


HEUER

Kolaya began his career in 1970 with Thomas Crimmins Contracting in New York City. In 1979, he became general superintendent. Kolaya joined Yonkers Contracting Co. in 1987 and was promoted successively to vice president of construction, executive vice president and, in January 2013, to president and chief operating officer. Kolaya served as the president of The Moles in 2004.


KOLAYA

The Beavers

HIRO ONOZAKI, 2013 President of The Beavers, has announced the recipients of the 2014 Golden Beaver Award. The awards will be presented at the organization's 59th annual awards dinner on Jan. 17, 2014 in Los Angeles, CA.

The 2014 Management Award will be presented to **SCOTT S. LYNN**, chief executive officer of Atkinson Construction in Broomfield, CO. He joined Atkinson Construction in 2003 as president, leading an effort to rebuild one of the industry's premier contracting companies.


LYNN

The 2014 Supervision Award recipient, **DAROLD (SCOTT) HANSON,** has spent the bulk of his 47-year career managing challenging marine construction projects in the Pacific Northwest. Hanson has managed projects for Reidel International, General Construction and Kiewit Infrastructure West. He served as the substructures project manager for the $1.2 billion skyway section of the East Span Replacement of the San Francisco-Oakland Bay Bridge.


HANSON

The 2014 Engineering Award will be presented to **F. DAVE ZANETELL**, who recently joined Edward Kraemer & Sons after a 25-year career with the Federal Highway Administration (FHWA). Zanetell supervised more than 250 projects and served as FHWA project manager for the Hoover Dam Bypass Bridge.


ZANETELL

The 2014 Service and Supply Award recipient is **JANICE L. TUCHMAN**, editor-in-chief of the *Engineering News-Record* (*ENR*). Tuchman started as an assistant editor in 1976 and was promoted to managing editor, executive editor and, ultimately, editor-in-chief in 2001. She helped guide *ENR* into the digital era. Tuchman is the third *ENR* editor to receive the Golden Beaver Award. ■


TUCHMAN

PERSONAL NEWS

(Continued from page 76)

struction management team for the Washington Suburban Sanitary Commission's Bi-County Water Tunnel. **GRANT FINN**, P.E., is based out of the Seattle, WA office and has more than 13 years of civil engineering experience, with a focus on structural design for underground engineering projects. **ANDY MENCKE**, P.E., is based out of the Seattle office and is currently serving as a project engineer on Sound Transit's Northgate Link Light Rail Extension in Seattle. **KEN SPARKS** is based out of the Seattle office and specializes in schedule development, maintenance and management. **JOHN YAO**, P.E., is based out of the Pasadena, CA office and is currently serving as project manager for engineering support services on the construction of the Cross-Town Tunnel Rehabilitation project for DC Water. **ERIC WESTERGREN** is based out of the Boston, MA office and has more than 20 years of experience in the construction of heavy civil projects projects. ■

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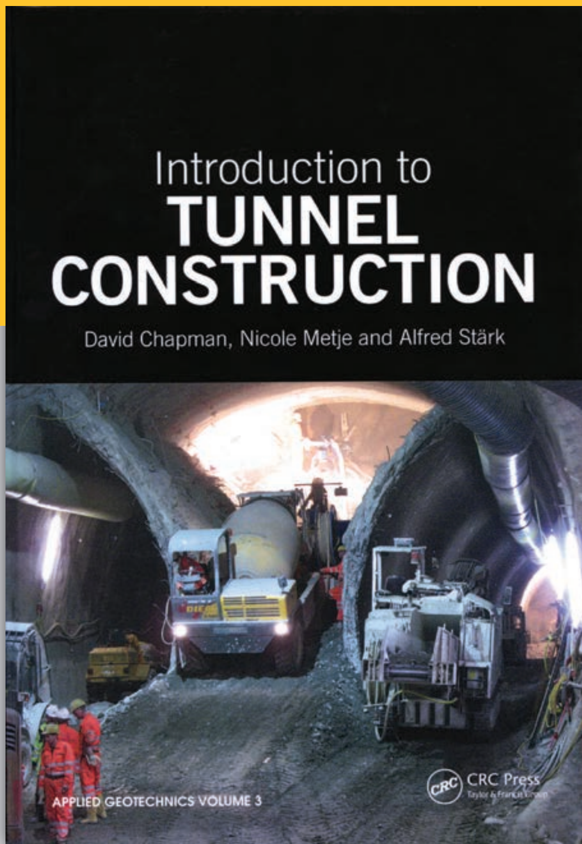
Introduction to Tunnel Construction



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

$160 Member / $140 Student Member / $180 Non-Member/List

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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