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TUNNELING & UNDERGROUND CONSTRUCTION

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Construction instrumentation

Cutting Edge

Confessions of a millennial

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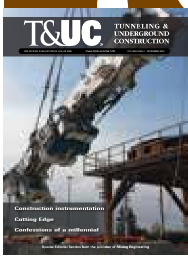
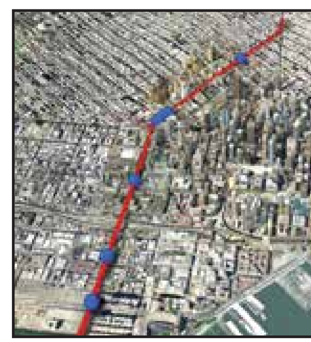


In this issue — Phase 2 of the San Francisco Municipal Transportation Agency's Third Street Light Rail project will extend the Phase 1 segment from the Embarcadero line at Fourth and King streets along Fourth Street to Market Street, page 59. Robbins' main beam TBM began work at the Mid-Halton Outfull project in Ontario, page 10. Photo courtesy of Robbins.

CONTENTS

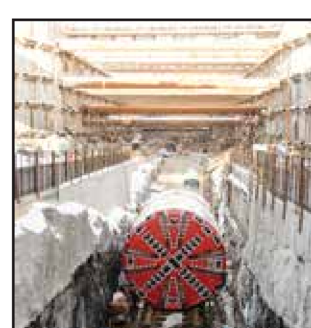
FEATURE ARTICLES

59
Central subway tunnel construction instrumentation: Lessons learned, San Francisco, CA
Kenneth A. Johnson, Michael V. Wolski and Ryan O. McCarter



71
Cutting Edge heads to Denver for fourth installment
William Gleason

73
Confessions of a millennial on the job site
Erica Fredericksn



DEPARTMENTS

2 Chairman's column

4 Underground construction news

75 Tunnel demand forecast

76 UCA of SME news

77 Classifieds

78 2015 T&UC Editorial Index

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CHAIRMAN'S COLUMN

Underground construction: A local activity, a global business

As I write this article, I'm attending the ITA's 2015 Tunnelling Awards Conference and Banquet in Hagerbach, Switzerland. This event recognizes outstanding tunneling and underground projects from around the world.

This year, four U.S. projects were shortlisted for possible winners. You can see those projects and their participating companies, and the various categories, on page 8 of this magazine.

Unfortunately, the awards don't go far enough to recognize the impact that the United States and UCA of SME member companies have on the global tunneling industry. While we can be proud of these projects, and we should be, there are consultants, equipment manufacturers and owners from around the United States who are recognized around the world for their expertise and reliability on projects near and far.

However, the ITA does offer us a chance to learn from projects outside of the United States, in physical environments different from ours, in regulatory environments different from ours, with workforces and equipment different from ours. Access to that pool of international knowledge and experience, and making U.S. knowledge available to companies around the world, are the prime reasons the UCA of SME is so involved with the ITA.

As I mentioned in my previous column, the United States is hosting the ITA's flagship event, the World Tunnel Congress (WTC), in San Francisco April 22–28, 2016. (You can register at www.wtc2016.us.) This is a clear example of the overlapping relationship between the United States and the world. The world is coming to San Francisco, and the U.S. underground construction and tunneling industry has a chance to see the world.

As people who focus on incredibly complex projects, often costing billions of dollars, working with local owners and communities, we can sometimes forget that ours is an industry with local projects taking place all over the earth, sometimes facing challenges very similar to ours. Events like the ITA Tunnelling Awards Conference and Banquet and WTC aren't just opportunities for celebration. These are the places where the best and the brightest of the industry share ideas and make us all more effective in our businesses.

Be sure to stay engaged with the UCA of SME as a member, and take advantage of the channel that UCA of SME offers to the ITA and its global leaders.

WTC update: The Young Members of the UCA of SME have created a special, one-time scholarship program for students to attend the WTC in April. The scholarship is intended to help defer the cost of travel for students who are planning a career in civil engineering or underground construction. If you know of students or programs that might want to take advantage of this program, be sure to visit the web site at www.wtc2016.us.

WTC registration update: By the time you read this, the online WTC registration page should be working properly. If you've had any troubles trying to register earlier, please revisit the website and register today. And be sure to secure your hotel reservation at the same time.

I look forward to seeing you in San Francisco April 22-28 at WTC2016. ■

Artie Silber,
UCA of SME Chairman

Next phase of Second Ave. Subway project falls victim to budget cuts

New York's Metro Transit Authority (MTA) board passed a five-year, $26.1-billion capital improvement program that's about 10 percent leaner than its original plan.

In order to make the budget work, the MTA cut a billion dollars from the next phase of the Second Avenue Subway, about two-thirds of what the agency had proposed spending a year ago. The cut reflected "funding availability and the ability to implement scope within the plan period."

Despite the cuts, MTA chairman Ton Prendergast said he was grateful and relieved to get the budget passed, *WNYC* reported.

The first segment of the Second Avenue Subway, scheduled to open at the end of next year, will go from 63rd Street to 96th Street. The agency had originally planned to pay for the tunneling north from 96th to 125th streets by 2019. But under the revised plan, that work will be deferred until 2020 or later.

MTA spokesman Adam Lisberg said the move was a practical one, not a financial decision: the agency realized it was unlikely it could get to the tunneling work during the current capital program, so it reallocated the money.

But Nicole Gelinas of the Manhattan Institute said the cut would have long-term consequences. "By stretching these things out, and sort of acting like they're doing something, it ends up costing more in the long run," she said.

She added that the MTA did not adjust funding levels for another of its ongoing megaprojects downward.

"If you look at the expansion part of the capital plan, East Side Access gets the bulk of that, and there is very little for projects that really help people who live in the city," she continued.

Funding for that project, which will bring Long Island Rail Road trains into Grand Central Terminal, is holding steady at $2.57 billion.

But the de Blasio administration took pains to stress that the revised plan did incorporate some of its priorities. In return for contributing an unprecedented amount of city money, the MTA will build a transfer between the Livonia Avenue stop on the L line with the Junius Street station on the No. 3 line in East New York. The agency will also study extending a subway line down Utica Avenue to a transit-starved part of Brooklyn, and begin planning for a bus rapid transit line on Staten Island's North Shore.

"These investments ensure that almost every MTA transit priority we outlined in OneNYC can now move forward," Mayor Bill de Blasio said in a statement, "representing a huge win for NYC riders across the five boroughs."

Another new addition to the capital plan: the MTA will award a contract to revamp the Times Square Shuttle, reducing the number of tracks it uses and making it ADA-accessible.

Next, the capital program must be submitted to a state board for review. But Prendergast's steeplechase race isn't over yet. The governor hasn't said where the state's $8.3 billion contribution is coming from, and the de Blasio administration is hoping that funding mechanisms like value capture can supply $600 million of its $2.5 billion contribution. ■

TBM operations on New Zealand motorway tunnel completed after nearly two years

The tunnel boring machine (TBM) named Alice completed its 4.8-km (2-mile) journey in Aukland, New Zealand, that will create three-lane traffic tunnels connecting Southwestern and Northwestern motorways along Auckland's 48-km (29-miles) Western Ring Route between Manukau and Albany.

The nearly two-year project is for New Zealand's longest road tunnels, each twice the length of the Auckland Harbour Bridge and overtaking the 1.97-km (1.3-mile) traffic link through Christchurch's Port Hills to Lyttelton.

The $55-million machine has doubled as a subterranean factory, lining the tunnels as it went with more than 24,000 prefabricated concrete segments, each weighing about 10 t (11 st) and churned out of a batching plant in East Tamaki, which has already been decommissioned, *The New Zealand Herald* reported.

It has been trailed both ways by an expanding conveyor belt which has carried about 800,000 m^3 (1.1 million cu yd) of spoil out of the tunnels to a drying plant, for transfer by trucks to a disused Wiri quarry.

That included a 180 ° turn in a tight space at Waterview, where 200 L (52 gal) of sheep's lanolin was used to ease the various segments of the tunneling machine around the bend. ■

State files suit against Seattle Tunnel Partners

The Washington Department of Transportation (WSDOT) filed a lawsuit on Oct. 9 against the contractor hired to dig the Alaskan Way tunnel, saying in a news release that it needed to protect its right to future claims.

WSDOT said the suit, filed in King County Superior Court, was prompted by recent court filings by Seattle Tunnel Partners, the contractor hired to dig the nearly 3.2-km (2-mile) tunnel set to replace the aging Alaskan Way Viaduct.

"Taking action to preserve WSDOT's rights in court was a necessary step," the state said.

The Seattle Post-Intelligeueen reported that the recent filings are in all likelihood a response to a suit by Seattle Tunnel Partners insurers filed in New York. That action seeks to avoid paying the $143 million in estimated cost overruns for the access pit, plus repairs necessary to get the tunnel boring machine Bertha back up and running after it broke down nearly two years ago, *Seattle PI* reported.

According to a letter sent by WSDOT to the insurers and filed with that suit, the state has already incurred more than $3 million in overruns and expects another $75 million due to the stoppage.

The state said that it would ask the court to stay its suit against Seattle Tunnel Partners until the project is finished and was asking the contractor to make the same request.

Bertha broke down in early December 2013, just 304 m (1,000 ft) into the tunnel.

WSDOT also released a new time frame for the restart of the tunnel boring machine was pushed out a month further than anticipated. On Oct. 22, the department issued a release saying mining will resume on Dec. 23, one month later than the previous scheduled restart.

"Accordingly, the tunnel opening date in the new schedule also has moved by one month, to April 2018. STP has told us the changes in the schedule reflect the current emphasis on giving crews the time they need to complete the tunneling machine repairs successfully," WSDOT said in a statement. ■

George A. Fox Conference returns to New York Jan. 26

The annual George A. Fox Conference will be held Jan. 26 at the City University of New York Graduate Center. This year the conference will focus on technological advancements in the tunneling and underground construction industries.

Talks will range from lessons learned from large tunnel boring machines to the newest technology in fire protection and to international innovations in pre-cast segmental linings.

Randy Essex, executive vice president-tunnels practice, Hatch Mott MacDonald, will deliver the keynote address to the conference.

The one-day conference will include papers on contracting models, rescue and fire life safety and will conclude with a session on new technical developments with talks focusing on innovations in pre-cast segmental linings; Instrumentation of the CSX Virginia Avenue tunel and lessons learned in large-diameter tunnel boring machines.

In recognition of George A. Fox's accomplishments in tunneling and underground construction, the UCA of SME holds this annual conference to help today's industry professionals learn from their peers about the challenges and the strategies for tunneling in populated areas.

To learn more about the conference, including how to register, please visit the conference home page at www.georgefoxconference.com/. ■

Four American projects among those considered for 2015 ITA tunneling awards

With the growth of infrastructure needs and requirements for better use of space and resources, the development of underground options have often proved to provide relevant solutions to these challenges.

As part of this endeavor, the International Tunnelling and Underground Space Association (ITA) has taken the initiative to launch its own dedicated Tunnelling Awards to identify outstanding achievements in the field of tunneling and underground space use, and provide international recognition to these remarkable contributions.

The ITA Tunnelling Awards ceremony was held Nov. 19, 2015 in Hagerbach, Switzerland.

More than 100 project and initiatives were considered in the ITA Tunnelling Awards 2015 selection, among which were four projects in the United States:

Lake Mead Intake No. 3 - Engineering: Arup and Brierley Associates; Contractors: Impregilo/S.A. Healy Joint Venture, dba Vegas Tunnel Constructors (VTC).

Second Avenue Subway Project - Engineering: AECOM (67 percent), ARUP (33 percent); Contractors: Skanska, J.F. Shea, Kiewit, Schiavone, Traylor

Indianapolis Deep Rock Conveyance and Storage Tunnel Project - Engineering: AECOM; Contractors: J.F. Shea, Kiewit, Southland

Caldecott Fourth Bore Project - Engineering: Parsons and Jacobs Associates; Contractor: Tutor-Saliba Corp.

The full list of finalists is listed on this page.

Major Project of the Year (more than euro 500 million)

- Eurasia Tunnel Project — Turkey
- Futian Station of Guangzhou-Shenzhen-Hong Kong — China
- New York City's Second Avenue Subway Project — USA

Tunneling Project of the Year (between euro 50 and 500 million)

- 1st Phase of Low and Intermediate Level Radioactive Waste Disposal Facility Construction — South Korea
- Indianapolis Deep Rock CSO Tunnel Project — USA
- Lake Mead Intake No. 3 — USA

Outstanding Project of the Year (up to euro 50 million)

- Grosvenor Decline Tunnels — Australia
- Norsborg Metro Depot — Sweden
- North Strathfield Rail Underpass — Australia

Technical Innovation of the Year

- An innovative vehicle-mounted GPR technique for fast and efficient monitoring of tunnel lining structure conditions
- Combination of techniques for immersed tunnel
- Development of the new joint (SB joint) for shield tunnels
- Monitoring tunneling induced ground displacements using distributed fiberoptic sensing
- New innovative system for layer thickness control on spray mobiles
- The evolution of the "Nazzano" method to widen tunnel without interrupting traffic flow

Environmental Initiative of the Year

- Brenner Base Tunnel - Lot Isarco River undercrossing lot — Italy
- Innovative overhead conveyor belt for urban environmental benefit — Qatar
- The Corribtunnel Project - tunneling in environmentally sensitive area — Ireland

Safety Initiative of the Year

- MineARC Systems compressed air management solution
- Safety cabin of tunneling drill
- Semiautomatic tubular steel arch: an innovation on safety

Innovative Use of Underground Space

- Reviving burial in tunnel — Israel
- Sydney Opera House vehicle access and pedestrian safety project — Australia
- Toledo Metro Station on Line 1 in Naples — Italy

Young Tunneler of the Year

- Duarte, Philip
- Karlovsek, Jurij
- Log, Sindre
- Palma, Filho Eloi Angelo
- Fortsakis, Petros
- Liu, Hao
- McCarron, Ryan
- Perez Lupi, Ponciano

World Tunnel Congress is headed to the United States in 2016

The World Tunnel Congress (WTC) is headed to the United States. Scheduled for April 22-28, 2016, the congress will be held in San Francisco, CA. So, it's time to get registered, make hotel reservations and get prepared for a week of learning, networking and socializing with your peers from around the world. Online registration is now open. Go to www.wtc2016.us.

The Underground Construction Association of SME (UCA of SME) is putting on the conference. The UCA represents the tunneling industry in the United States. It is part of an organization that includes owners, contractors, engineers and suppliers; the full spectrum of tunneling services is represented in the UCA. Members operate around the world, so there are opportunities to hear from partners, clients and prospects throughout the industry while attending the conference.

WTC 2016 is unique in that it will be held in lieu of the UCA's biennial North American Tunneling (NAT) conference. The advantage of this is that the resources, talents and participants of the NAT will now be found at the WTC in San Francisco.

Tunnelers and underground construction professionals all face common challenges, no matter where they operate around the globe. An industry united will best serve governments, companies and communities because of the knowledge and experiences they have shared.

With as many as 600 unique technical presentations, short courses and breakout sessions, attendees will have the chance to interact with more than 200 exhibiting equipment suppliers from around the world, and companies representing all types of products and services for the tunneling and underground construction industry.

The 2016 WTC program/scientific committee has developed a program that will feature more than 500 oral and poster presentations. The primary focus of the technical program is to add value to the industry through examination of the most innovative practices and products currently in use. The program committee is dedicated to shining a light on new, novel and unique innovations and projects. The emphasis is on real-life applications of techniques as applied to real problems.

Additionally, rigorous quality controls were in place to ensure top-quality papers and presentations. All final manuscripts have been peer-reviewed and will be available as electronic proceedings and/or hardcopy.

The final programming will be published in the April issue of *Tunneling & Underground Construction* (*T&UC*) magazine. That's right, the April issue. Normally published in March, this WTC issue has been moved to April to allow for more up-to-date preshow coverage.

Some of the topics at WTC16 include case histories, contracting practices, design/analysis, drill and blast, environmental and urban planning, ground improvement, hard rock tunneling and high stress tunneling, to name just a few.

In addition to the technical program, WTC16 will offer two ITA-CET training courses; Monitoring and control in tunneling and underground space use.

Monitoring and control in tunneling provides the purpose, methods and examples of monitoring the effects of tunneling, including the monitoring of tunnel machine performance, to control tunneling to achieve acceptable excavation performance with stable underground structures, and prevent damage to existing structures and utilities.

Underground space use will serve as valuable introduction for engineers, architects, planners and public administrators to the use of underground space to increase livability and sustainability in urban areas and in other key public resource regions. ■

T&UC TO BE PUBLISHED IN APRIL

The next issue of *Tunneling & Underground* Construction, normally published in March, will be published in April next year to allow for more up-to-date advance coverage of the upcoming World Tunnel Congress, scheduled for April 22-28, 2016 in San Francisco, CA.

#WorldTunnelCongress

ITA - AITES WTC 2016 The World Tunnel Congress

Well-traveled tunnel boring machine to begin work at Mid-Halton Outfall in Ontario, Canada

On July 22, 2015, a 3.5 m (11.5 ft) Robbins main beam tunnel boring machine (TBM) began a new chapter in its storied 32-year career. Originally built for the Terror Lake project in Alaska, the veteran machine has been used all over the world, most recently in Hong Kong. Including its new 6.3 km (4.0 mile) long tunnel for the Mid-Halton Outfall in Ontario, Canada, the machine will have bored nearly 30 km (18.6 miles) of tunnels since 1983.

The machine's latest endeavor will not be without challenges. The rebuilt TBM has been beefed up for high-capacity tunneling in hard rock. Geology is expected to consist of laminated shale with interbedded limestone and siltstone layers and a maximum rock strength of 120 MPa UCS.

"We have kept this a simple, streamlined main beam machine, but we modified the cutterhead with larger muck buckets, so material can be moved through it faster," explained Robbins project manager Lynne Stanziale. In addition, the TBM was outfitted with fully modernized VFDs, electronics and high-capacity gearing and motors. The back-up system was also modified to make it more mobile through two 130 m (427 ft) radius curves that the TBM will have to navigate, one in each direction.

"The concept of using refurbished TBMs bears great opportunities for value-for-money constructors," said Christian Zoller, commercial project manager for contractor Strabag. "Our TBM 'Peggie' is evidence of that — when well-maintained and professionally refurbished, the lifespan of these machines is extensive. We're pleased to see that our client, Halton Region, has the forward-oriented mindset that allows Strabag to provide its renowned high level of skill and quality, paired with the good value for money that a refurbished TBM yields."

Contractor Strabag, who has had several projects in Canada including the epic Niagara Tunnel project, is in charge of the works. In addition to the tunnel, Strabag had to construct two deep shafts for the launch and exit of the TBM. The scheme involves two sections of tunnel designed to carry treated effluent water from a treatment plant in Oakville into Lake Ontario. The completed system will upgrade water treatment capacity in the Halton Region of Ontario.

Contractor Strabag lowers the main beam of the Robbins TBM into the 62 m (203 ft) deep launch shaft.

The TBM was launched from a 12 m (39 ft) diameter, 62 m (203 ft) deep shaft and is ramping up production, having excavated more than 300 m (980 ft) by early September 2015. "An ongoing challenge associated with the tunneling on this project is the requirement to drive the TBM downhill for the first 4 km (2.5 miles) of the tunnel. Keeping the water that infiltrates the tunnel from flowing directly to the cutterhead requires significant effort," said Terry McNulty, technical project manager for Strabag.

Management of water inflows is not the only challenge. A portion of the drive will curve to run directly under Lake Ontario for 2.1 km (1.3 miles), though the tunnel is deep enough that it will remain in bedrock. Once the machine has completed its final bore under Lake Ontario, it will be backed out of the blind heading and removed from an 8 m (26 ft) diameter shaft in a local park.

"We can already see the potential performance that this TBM will have, once fully assembled and tested. We look forward to the continued support and cooperation with our partner Robbins on this endeavor," said Zoller. Though the TBM has only recently started up, crews are moving forward with a plan to line the tunnel with mesh panels and ring beams if necessary. A cast-in-place liner will follow on after tunneling is completed in August 2017. ■

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

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

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JENNMAR

The Robbins Company

Setting the Tunneling Standard

With over 60 years of experience, The Robbins Company is the world's foremost developer and manufacturer of advanced underground construction machinery. Robbins TBMs made swift headway on many worldwide projects in 2015, and will continue this progress in 2016. Innovative concepts keep expanding the company's scope, from efficient TBM assembly methods to high-performance machine designs resulting in landmark performances in soft ground and hard rock.

Committed to Partnership and Innovation

Robbins is a total supply company, offering the complete tunneling solution. Robbins can supply everything from the TBM to all supporting components, such as cutters, conveyors, field service personnel and technical support. Additionally, Robbins brings innovative solutions to each project they are involved on. One example of this is Robbins' time-saving Onsite First Time Assembly (OFTA) method, first used at Canada's Niagara Tunnel Project in 2006. 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. OFTA has been carried out successfully on multiple projects and with all types of TBMs. At the North Link Project in Seattle, Washington, a refurbished 6.65 m (21.8 ft) Robbins Earth Pressure Balance (EPB) TBM and continuous conveyor system were assembled onsite alongside Washington's busiest highway, on a jobsite the width of a city street. The machine recently has its intermediate breakthrough at the Roosevelt station site in July 2015.

In 2015, Robbins proudly announced its Crossover Series of TBMs, a line of field-tested, rugged Dual Mode-type machines. Crossover TBMs feature aspects of two TBM types, and are ideal for mixed ground conditions that might otherwise require multiple tunneling machines. The first North American Crossover TBM was launched for the Túnel Emisor Poniente II (TEP II) Project in Mexico City, a complex wastewater scheme, on August 10, 2015. Assembled using OFTA, the 8.7 m (28.8 ft) dual-mode type machine is an XRE TBM that is capable of "crossing over" (X) between two modes, rock (R) and EPB (E), and represents of the latest in Crossover technology. Designed with field-inspired features including a single-direction cutterhead, multi-speed gearboxes, and improved probe drilling capabilities, the machine is prepared for the incredibly complex ground conditions, including competent to weathered volcanic rock, clay and sand at the TEP II site.

Robbins' continuously advancing conveyors are designed to increase the efficiency of muck removal and streamline tunneling logistics. At the Indianapolis Deep Rock Tunnel Connector (DRTC) Project, a Robbins continuous conveyor system including both horizontal and vertical conveyors runs behind a 6.2 m (20.2 ft) Robbins Main Beam TBM. Additionally, the tunnel contains two uncommon 90-degree curves requiring a specialty conveyor system, designed by Robbins. After setting three world records and completing its initial breakthrough in July 2014, the machine completed its last extension tunnel, known as the Eagle Creek Tunnel, on March 5, 2015.

With major projects currently underway in North America and abroad, Robbins continues to lead the tunneling industry in innovation and partnership. For more information about Robbins and our past and present projects, visit www.TheRobbinsCompany.com or call +1 (440) 248-3303.


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Leading the Way

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

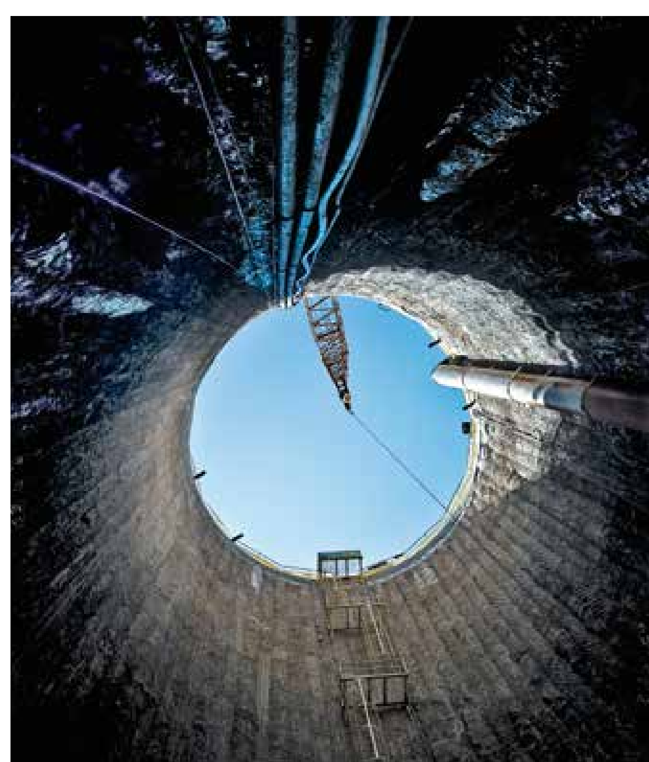
Malcolm's list of core services as it relates to tunneling includes access shafts, excavation support systems, cutoff and secant pile walls, jet grouting, deep soil mixing, cutter soil mixing and dewatering. The company has augmented its construction and engineering expertise along with a strong safety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

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

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

Look to the Blue

Malcolm Drilling
www.malcolmdrilling.com



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

Sandvik Construction
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Email: info.smc-us@sandvik.com
www.construction.sandvik.com

Local Presence. Global Competence.

DSI Underground Systems (American Commercial Division) offers a complete selection of ground control solutions for the Civil, Mining and Foundation markets. We have been a leader in the underground support business in North America since 1920.

We are a global leader in tunnel and shaft construction, focused on engineered and tailored products to support our customers and industry.

DSI is proud to bring an expanded group of products to the job site:

- **ALWAG** – Support Systems
- **Biomarine** - Tunnel Rescue Equipment
- **Boart** – Probe and Roof Bolting Equipment
- **CBE** – Segment Moulds – Precast Segment Moulds, Related Equipment and Plants
- **ChemGrout** - Grouting Equipment
- **Condat** – Ground Conditioning Chemicals and Lubricants
- **Cooper & Turner** – Bolts and Sockets for Precast Segments
- **DSI** – Steel Ribs, Liner Plates, Lattice Girders, Lagging and Miscellaneous Support Items
- **Dywidag** – Bolts and Accessories including DSI Threadbar, Friction Bolts and Omega Bolts
- **ES Rubber** – Segment Gaskets
- **Geodata** – Monitoring Equipment
- **Hany** – Grouting Systems
- **Montabert** – Excavator Drilling Attachments and Replacement Drifters
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- **Strata Worldwide** – Safety and Communication Equipment
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- **Weldgrip** – Fiberglass Bolts and Dowels
- **WIRTH** – Pile Top Rigs

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DSI

DSI Underground Systems, Inc.
American Commercial Division

Moretrench

As every tunneling contractor knows, ground loss, settlement, and groundwater inflow can be significant concerns. A problematic soils or groundwater condition known in advance can be properly addressed at the design stage. But the unexpected does happen and when it does the impact, both financially and to overall scheduling, can be devastating. In either situation, getting specialty geotechnical contractor Moretrench on board early is the best decision you can make. No one has seen more than Moretrench. We have the experience, the expertise and the techniques to resolve any geotechnical challenges your tunneling project may encounter.

Access Shaft # 3, Sistema de Potabilización Area Norte, Buenos Aires, Argentina

The Sistema de Potabilización Area Norte project will transport and treat raw water from the Paraná River, providing potable water for 2.5 million residents in Northern Buenos Aires province. When persistent soil and water inflow prevented the completion of a deep , 34-ft diameter access shaft, the prime contractor attempted various ground improvement and grouting techniques over a period of more than a year, all without success. Eventually, the shaft was filled with lean concrete above the tunnel crown so that the TBM could proceed, and Moretrench was called in to provide the watertight barrier beneath and around the newly completed TBM tunnel that would allow shaft completion. Moretrench designed a freeze system, shipped all system components from its New Jersey headquarters, and provided field engineering and on-site supervision during installation and operation. After nine weeks of freezing, closure of the barrier was verified, allowing the prime contractor to pump down the shaft, install base slab reinforcement and place the final concrete liner.

D.C. Water First Street Tunnel Project

For the 1st Street Tunnel , part of Washington D.C.'s Clean Rivers Project, mitigating surface impact during shaft and adit mining was high priority for the project team. Ground freezing meets that criterion in difficult ground better than any other method. When Moretrench was contracted to design, install and operate ground freezing systems for three deep shafts and four adits, extraordinary measures were successfully incorporated into the program. Staging for all ground freezing operations was centrally located, and brine supply and return lines from the freeze plants were run as much as 2,600 feet via utility channels. Freezing also served double duty to provide full face improvement for the adits as well as frozen soil "lagging" for the shallower structures above. These measures, together with a high degree of safety and awareness by the ground freezing team, significantly minimized community disturbance.

PSE&G Crossing 10A, Camden, NJ

With groundwater just below the surface, watertight excavations were required for the microtunneling launch and retrieval pits for installation of an electric transmission line beneath Newton Creek. However, heavy metals present in the groundwater required permitting that would not be obtainable in time to meet the tight schedule. Moretrench installed double-fluid jet grouted bottom seals within the sheetpile cofferdams, which balanced the hydrostatic pressure and eliminated the need for dewatering.

Please visit us at www.moretrench.com for more on our tunneling related solutions.

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
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LAKE SHORE
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Putzmeister Shotcrete Technology, Your Worldwide Partner for Quality and Innovation

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

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

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

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

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

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SHOTCRETE TECHNOLOGY

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www.putzmeistershotcrete.com

Kiewit

As a construction, mining and engineering leader, Kiewit is a FORTUNE 500 company with 2014 revenues of $10.4 billion. Kiewit, through its operating companies, brings a wealth of diverse resources and a track record for delivering the highest quality results — on budget and on schedule. Kiewit's size and experience provides the stability, predictability and know-how our clients and partners expect — and the flexibility and overall best value they deserve.

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

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

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

PKS Kiewit

North America's Leader in Geotechnical Construction

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

Seattle, WA
Brightwater Conveyance System

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

Brightwater Conveyance System

Los Angeles, CA
Lower North Outfall Sewer Rehabilitation Project

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

Los Angeles, CA

Metro Gold Line C800

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

St. Louis, MO
Baumgartner Tunnel Alignment

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

Big Bend Tunnel Improvement
Big Bend, WV

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

Big Bend Tunnel Improvement

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Geotechnical Construction
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Premier Pipe Systems Manufacturer for 90 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.

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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 engineering and construction firm, we deliver exceptional client service, quality results and enduring value across the entire project life cycle.

CDM Smith's underground construction staff includes geotechnical, structural, and civil engineers and geologists located 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

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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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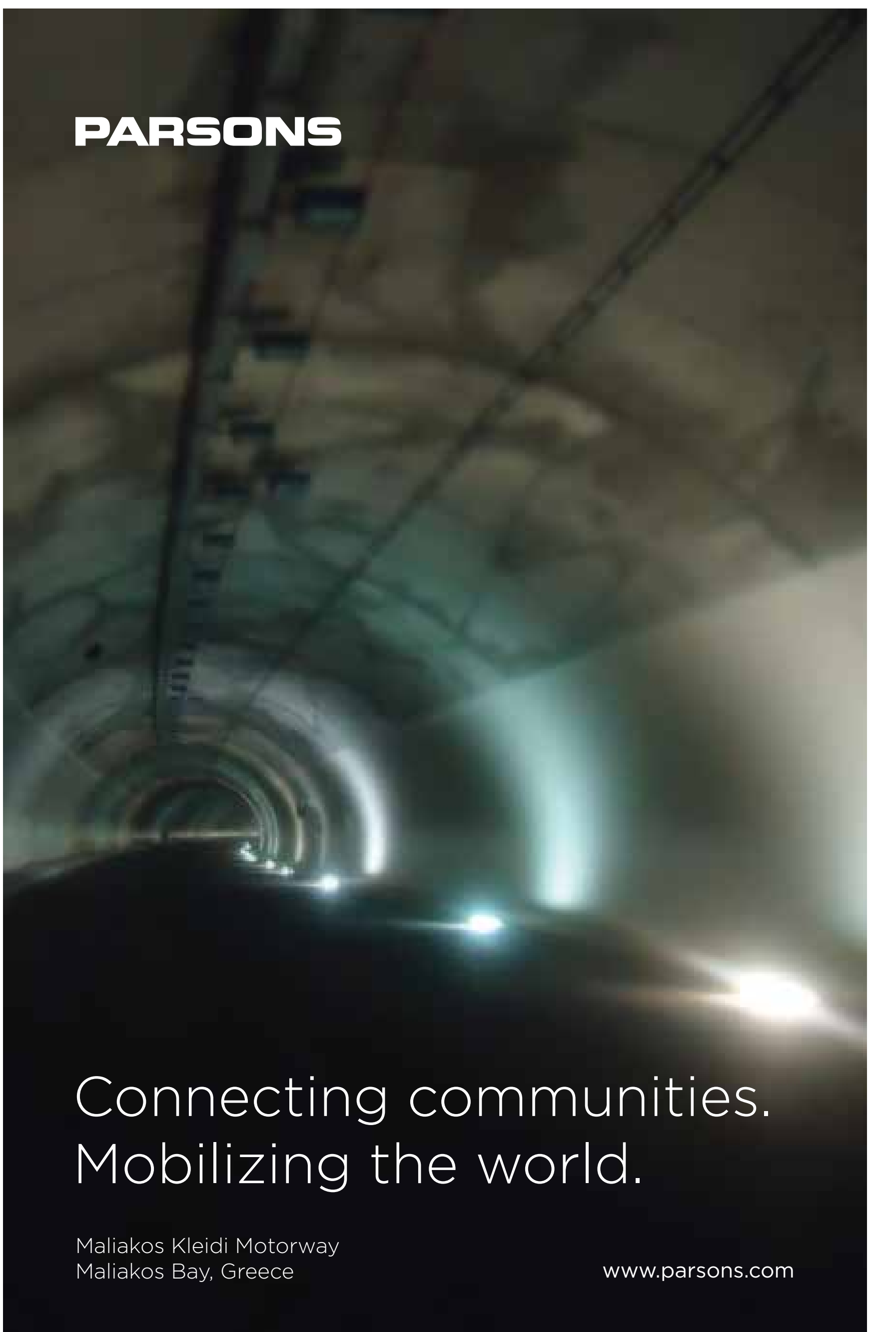
Connecting infrastructure across the globe.

Founded in 1944, Parsons is the premier source for end-to-end design-build engineering capabilities, including expert multidisciplinary planning, all phases of construction and implementation, and maintenance and improvements. The firm employs more than 15,000 professionals around the world who are prepared to meet every technical and management challenge and to persevere until the job is done.



Parsons' Tunnel Sector has contributed to hundreds of domestic and international tunnel projects, including the Caldecott Tunnel improvement project, which involves the construction of a fourth bore through the Berkeley Hills, near Oakland, California; 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; and the Maliakos Kleidi Motorway Tunnel, in Greece.

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. To minimize the risks associated with underground structures, Parsons offers a host of innovative tunneling techniques, like the New Austrian Tunneling Method, top-down construction sequencing, advanced hard-rock and soft-ground tunnel-boring machine technology, single-pass tunnel construction, and advanced tunnel waterproofing systems. 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.

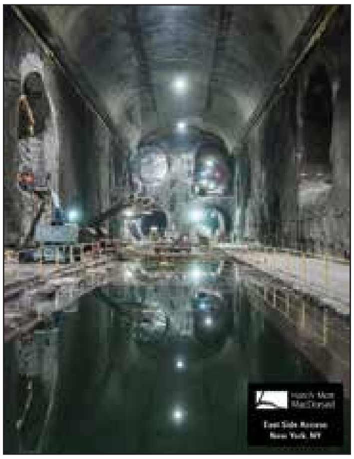
Hatch Mott MacDonald

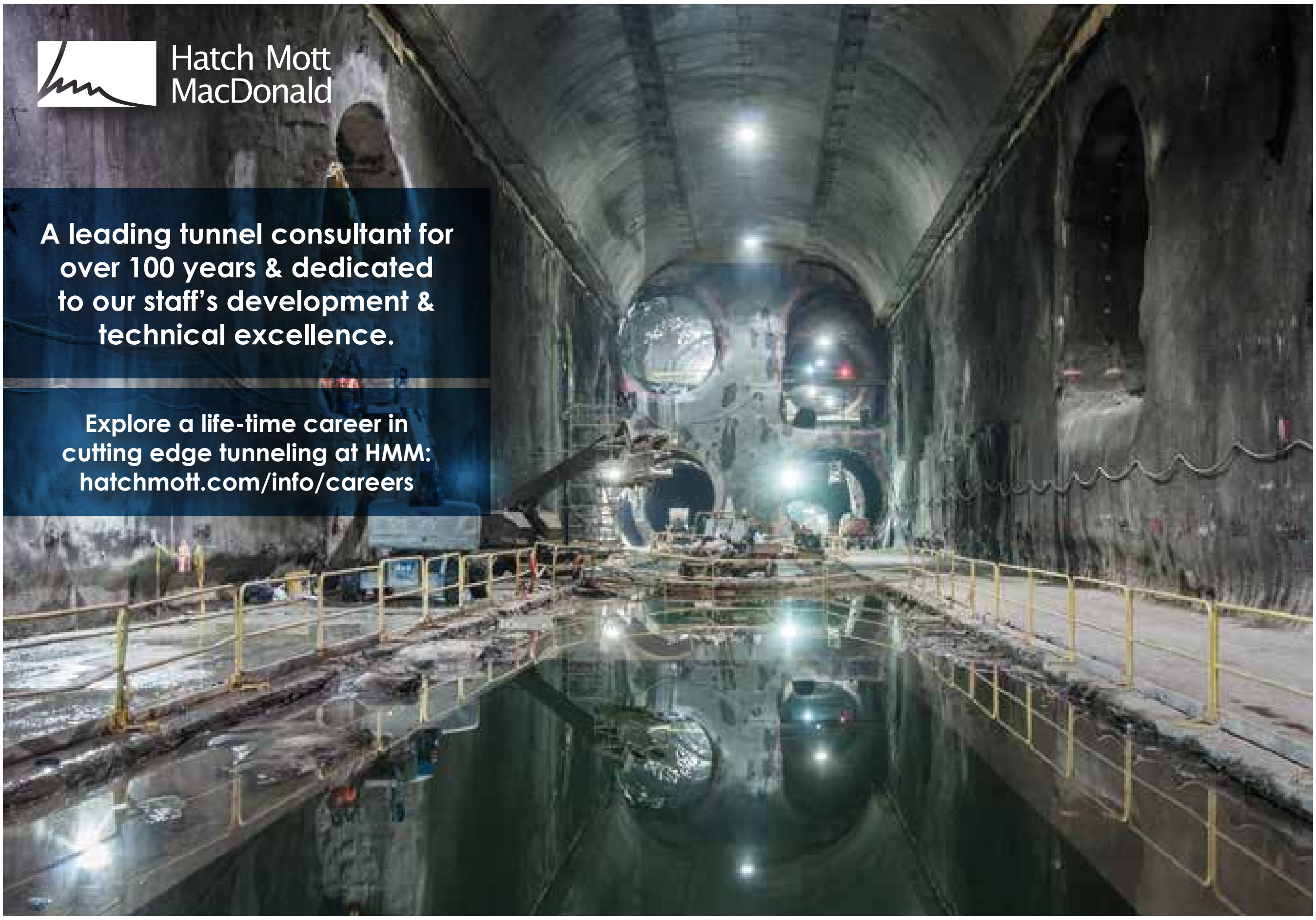
Tunnel engineering is one of Hatch Mott MacDonald's core services. For a wide-range of public and private clients, we have engineered transportation tunnel solutions for roadway, passenger rail, freight rail, subway, pedestrian, cable and communications projects. Our expertise spans a broad-range of capabilities from the planning and implementation of new facilities to the inspection and rehabilitation of existing facilities.

Our involvement in tunneling began more than a century ago, dating back to our founders' involvement with London's underground road and rail systems in 1902, and Toronto's subway system in 1954. Our association with these clients continues today – a testimony to the trust, confidence, and professional relationship we build with our clients and to the quality of our work.

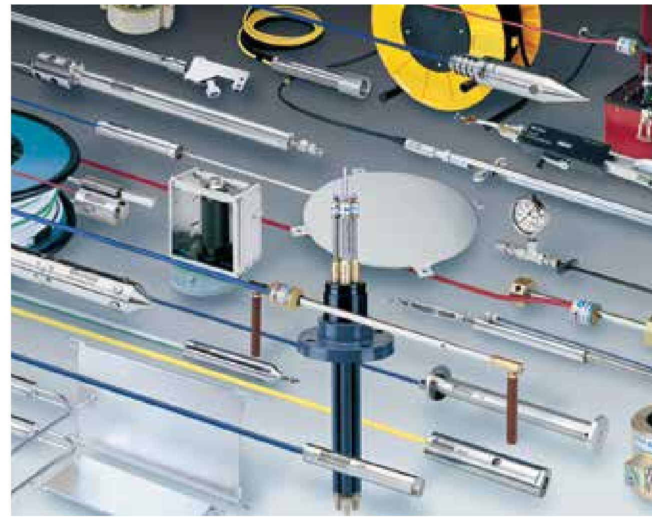
With more than 75 offices throughout North America, Hatch Mott MacDonald offers a full-range of services to handle any size project – from a small inspection assignment to world-class, multi-billion-dollar transit programs.

Our goal is to deliver client projects in an environmentally responsible manner, with value-added design and construction methods – minimizing programmatic risk along the way.





Geokon, Incorporated



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

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

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

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

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Tensar International Corporation

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

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

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

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

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HNTB: Innovative tunnel solutions for a city-centric world

The trend of people moving to more heavily populated urban areas is fueling demand for additional infrastructure in major cities that are challenged to develop adequate supporting infrastructure and facilities. Urban growth is exerting increased demand for more efficient transportation, reliable power, water and wastewater conveyance, and communication systems. Many cities are opting to add infrastructure underground. Modern technology makes that solution possible and preferable. Impressive, sophisticated underground structures can help solve current and future urban congestion and development challenges.

HNTB Corporation has more than 45 years of experience in the design, construction and restoration of award-winning tunnels and underground structures in various grounds in the highway, transit, rail, aviation and water resources markets. The firm's holistic tunneling and underground engineering services implementing state of the art techniques, and its tunnel staff are at the forefront in advancing the tunneling technologies. Among its recent notable projects are:

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

HNTB provides full service in tunneling and underground engineering including:

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

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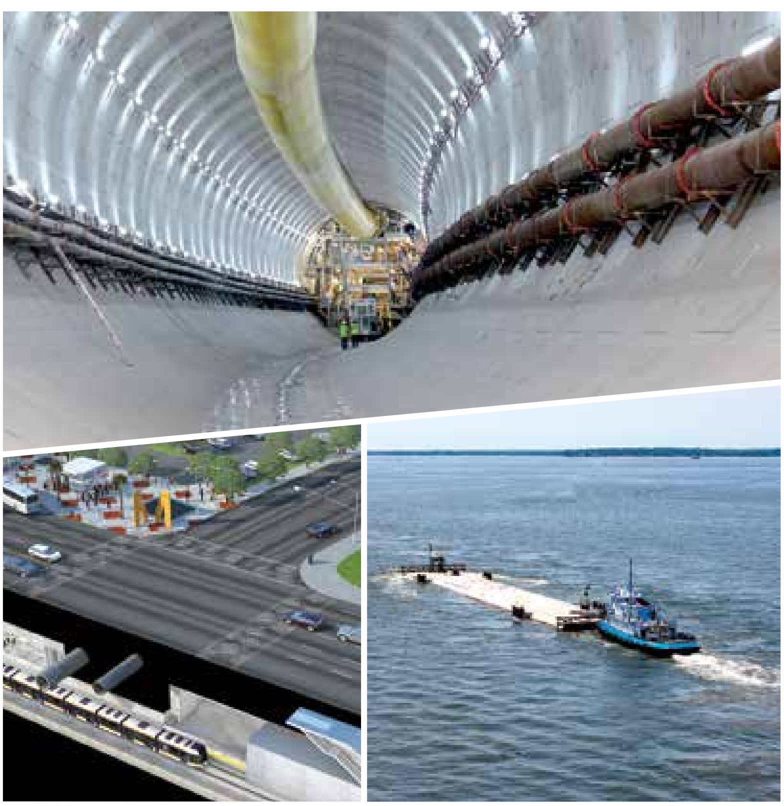
WORLD CLASS **TUNNELING**
EXPERIENCE



TOP: Istanbul Strait Road Tunnel Crossing *Istanbul, Turkey* | LEFT: Crenshaw/LAX Transit Corridor *Los Angeles, California*
RIGHT: New Midtown Tunnel/Elizabeth River Tunnels Project *Norfolk & Portsmouth, Virginia*

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T&UC

Schauenburg Flexadux Corp.

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

This cooperative approach involves combining the strengths of Protan's years of manufacturing and supply of top quality Tunnel Ventilation PVC Ducting and Technical solutions to the global mining and tunnelling industries with Schauenburg Flexadux's 40 plus years of local US Manufacturing, Supply and customer service to these industries. The major benefits of this Business Alliance is to combine the 60 plus years of Protan experience in designing and supplying lower friction Ventilation Technology with the dedicated local commitment of Schauenburg Flexadux to supply fast deliveries to meet our customers production requirements.

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

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

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

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

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

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

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PROTAN

Tunneling Ventilation

We strive to bring you the best in flexible tunneling ventilation. Our new partnership with Protan allows us to offer ventilation products with lower K factors, same great service and competitive pricing.

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F (304) 363-0875
www.schauenburg.us

A company of the SCHAUENBURG International Group

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
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www.antraquip.net

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

A Successful Project Takes All Sizes

Small Brokk Played Huge Role in POMT Cross Passage Work

New underground routes connecting Watson Island and Dodge Island beneath Biscayne Bay near Miami wouldn't have been possible without some key players, both big and small.

A huge tunnel boring machine (TBM) was the star of the Port of Miami Tunnel (POMT) project, but a strong contender for best supporting equipment was a relatively tiny machine: the Brokk 400.

While the Brokk 400 is only 14 feet long, 5 feet wide and less than 6 feet tall, it packs a powerful punch. The size-power combination was a big reason design-build contractor Bouygues Civil Works Florida used one to create cross passages between the project's twin 4,200-foot traffic tunnels, which are set to open in May 2014.

The Brokk 400, equipped with a hydraulic breaker, knocked out chunks of the concrete casing in one of the main traffic tunnels to begin one of the five cross passages in the POMT project.

Inside the passages, the machine delivered tremendous force with a hydraulic breaker to excavate hard soil, some of which was artificially reinforced with grout or through a freezing process to add stability. The next step was to place support ribs at 3½-foot intervals. The machine grasped the top section of each steel rib with a beam manipulator retooled specifically for the job, carried it to the installation point, lifted and positioned it, then held it in place while miners bolted on the lower sections.

Throughout the process, the Brokk machine enhanced safety for the miners. The remote control kept the operator away from potential cave-ins, and the electric drive ensured crewmembers weren't exposed to dangerous emissions.

All in all, the relatively small player gave a winning performance that delivered big results.

Brokk, Inc.
1144 Village Way
Monroe, WA 98272 USA
Telephone: +1-360-794-1277
Email: info@brokkinc.com
www.brokk.com

A close-up view of the beam manipulator designed specifically for the POMT project by Brokk's sister company, Kinshofer. Crews used the remote-controlled Brokk 400 and this beam manipulator to pick up and maneuver the steel support ribs into place in each cross passage.

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.

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Grindex
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Surecrete Inc.

Surecrete Inc. focuses on 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 SuperFine 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.

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Atlas Copco Innovation

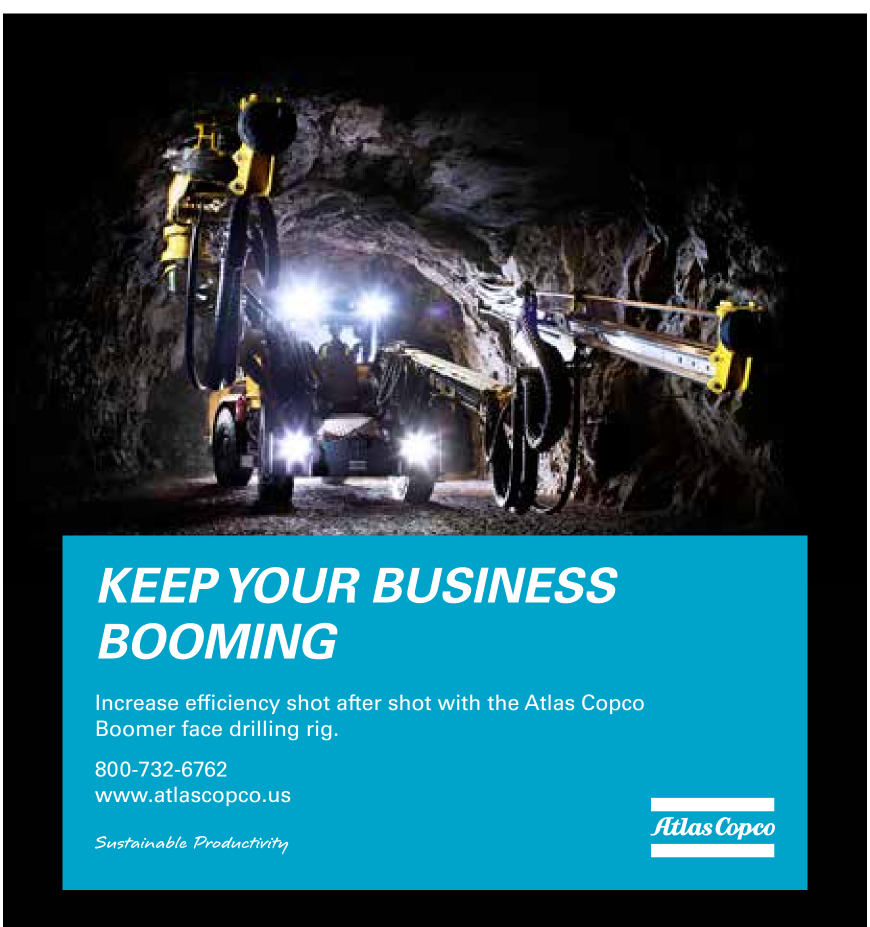
Atlas Copco innovation never stops


The Swedish Method

Founded in 1873 as AB Atlas, the company manufactured its first drill in 1898. Continuous innovation followed, and in 1936 Atlas introduced a one-man rock drill that could be equipped with a pneumatic pusher leg. This became the basis for the "Swedish method," a modern and lighter drilling technology. In the same year, the company pioneered the use of "down-the-hole" drilling. And in 1937, Atlas manufactured a rock shovel loader for the mining industry. The Atlas Copco legacy continued to grow and innovation on all product lines continues today.

The Atlas Copco mining product range includes:

- Exploration drilling equipment
- Rock reinforcement equipment
- Raiseboring equipment
- Face drilling rigs and scalers
- Underground loading and hauling vehicles
- Rock drilling tools, hammers, bits
- Blast hole drilling rigs
- Large rotary and DTH blast hole rigs
- Grouting and shotcrete
- Air compressors, generators



Lachel & Associates, Inc.

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

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

Founded in 1976 as a tunneling engineering firm, Lachel has a long history of providing tunnel design services for constructors, owners, and other A/E firms for project across the United States. Some of our recent projects include:

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

TUNNEL DESIGN SERVICES

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

- Feasibility Studies
- Alignment Optimization
- Assessment of Geotechnical Conditions
- Tunnel Initial and Final Support Design
- Numerical Methods for Design
- SEM / NATM
- Cavern Design
- Shaft Design
- Constructability Review and Cost Estimating
- Geotechnical Baseline Reports (GBRs)
- Construction Documents/ Design Reports

BROOKVILLE Exhibiting Latest Advancements in Underground Haulage and Transport Equipment at SME Annual Conference and Expo in February

Brookville Equipment Corporation will showcase its line of customizable haulage and transport equipment to the mining and tunneling industry in Phoenix from Feb. 21-24, 2016 at the SME Annual Conference and Expo, to discuss the latest product innovations and enhancement for its line of locomotives, personnel carriers, and combination vehicles.

Founded in 1918, Brookville manufactures custom battery and diesel powered rail-mounted and rubber-tired equipment for the mining and tunneling industries. Recently, Brookville has supplied equipment to some of the industry's most notable projects, including the Traylor Brothers East Side Access Project in New York City, the Stillwater Mine in Montana, and three permissible 27-ton diesel locomotives to the Walsh-Shea Corridor Constructors' Crenshaw/LAX Transit Corridor Tunnel Project in Los Angeles.

For more on BROOKVILLE's customized mining and tunneling equipment, visit www.brookvillecorp.com.

Northwest Laborers-Employers Training Trust

Northwest Laborers-Employers Training Trust -
Safety Hazard Awareness for Tunnels (SHAFT) program

Developed by the Northwest Laborers-Employers Training Trust with input from a team of industry experts and stakeholders, the Safety Hazard Awareness for Tunnels (SHAFT) program seeks to fill a void by providing quality, comprehensive safety training for both new and experienced tunnel professionals.

The curriculum is comprised of a blend of classroom discussion and use of materials and mockups in classes focusing on basic tunnel safety, rail, and utilities. Our facility, located in Elma, Washington, features a TBM mockup, loci, and access to 1,400' feet of 12' diameter tunnel, providing students with a unique, interactive educational experience.

Northwest Laborers-Employers Training Trust
+1 (800) 240-9112
www.nwlett.org

Gall Zeidler Consultants

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

The company specializes in mastering difficult ground conditions by using cutting-edge ground improvement methods such as dewatering, grouting, and ground freezing. GZ employs over 50 staff worldwide, and has a history of over 170 miles (275 kilometers) of successfully completed international tunneling projects. The company's expertise has consistently been sought after by major contractors and project owners in the industry developing tailored tunnel solutions and to assist with the mitigation of risks associated with tunneling.

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

Bradshaw Offers Innovative Tunnel Engineering and Construction Technology

Bradshaw Construction Corporation strives to apply the most appropriate tunneling technology to each project based on its purpose, subsurface conditions and surface restrictions. The company's management team is proud of its ability to construct any type of tunnel in any soil condition both above and below the water table. From small hand mined, wood-box and liner plate tunnels to large NATM shotcrete-lined tunnels; from small pilot tube guided auger bores to large rib-and-board shield and tunnel boring machine (TBM) tunnels; from conventional pipe jacking to slurry microtunneling (MTBM) to earth pressure balance (EPB) TBM tunnels; and from hand mined drill and blast to rock tunnel boring machines (TBMs), Bradshaw Construction has a solution.

For your next project, let our knowledgeable staff of tunnel engineers and construction professionals create the most cost effective, safest, and highest quality solution for your unique tunneling needs.

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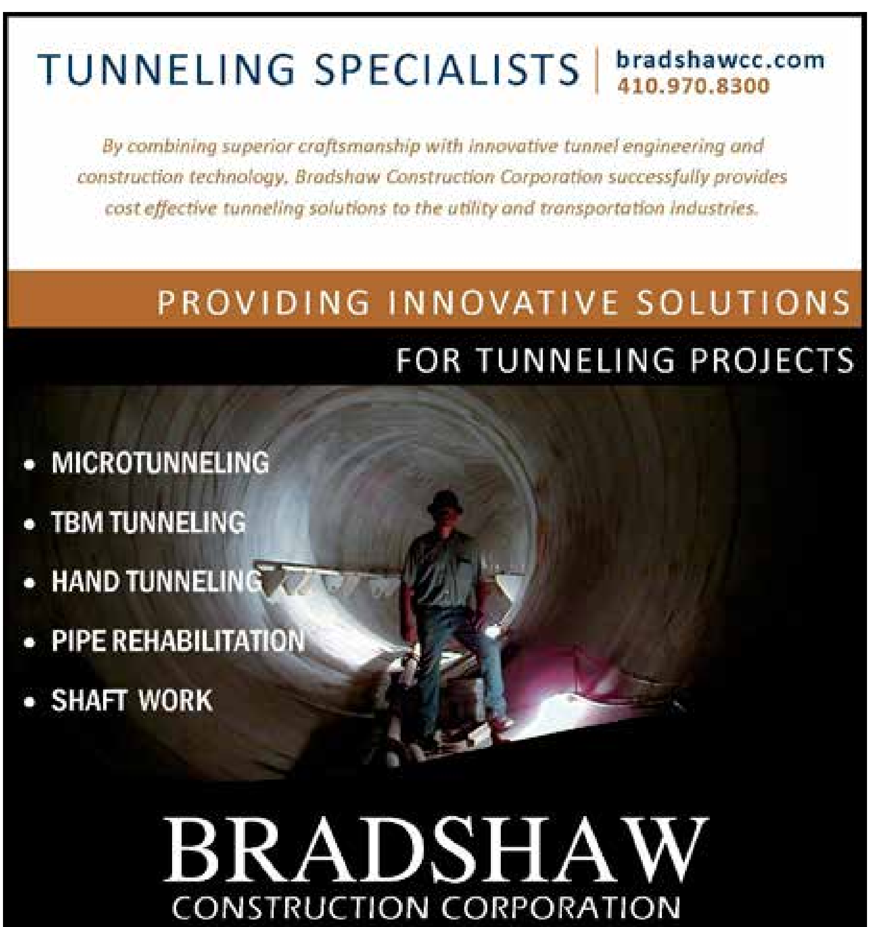

ABC Industries, Inc.

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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www.abc-industries.net

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.

David R. Klug & Associates, Inc.
6000 Waterdam Plaza Dr., Ste. 120
McMurray, PA 15317 USA
Telephone: +1-724-942-4670
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Email: dklug@drklug.com

The Heintzmann Group

The Heintzmann Group, which has been in business approximately 165 years, manufactures support systems in the tunneling and mining industries. In the last decade, we have greatly expanded our line of products, as well as our regions of service. We currently have offices located in Virginia, West Virginia, Alabama, Colorado, and Illinois. Our range of products and services include but are not limited to standing supports, pumpable roof support, arches, square sets, pre-stressing devices, heat treated beams, polyurethane grout injection, shaft rings, lattice girders, two flange liner plates and four flange liner plates.

The goal of the Heintzmann Group is to provide resources to make the tunneling and mining environments safer and to achieve the highest level of customer satisfaction by providing our customers with a variety of support options.

The Heintzmann Group
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www.heintzmann.com

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.

This marks the first time that HIC Corp. based in Korea, has opened offices with the intention of selling direct to the end user in lieu of selling strictly through distributors.

HIC Fibers has the exclusive technology and rich know-how in manufacturing of steel fibers. HIC Fibers can provide you a steel fiber of your choice in length, diameter and package.

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Advanced Concrete Technologies, Inc.
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ILF Consultants, Inc.

ILF USA specializes in tunnel and underground engineering, foundation and retaining systems for permanent and temporary works, and construction engineering services throughout North America.

Our team can assist clients with engineering solutions in energy, water, infrastructure, and natural resources markets applying cutting edge technology and providing services including; project consulting, engineering design and planning, pre-bid services, construction management, project management, and risk management/claim avoidance and mitigation.

ILF USA has expertise in design-build, P3's, and conventional contract delivery methods. Depending on requirements, we can serve as an owners engineer or as a construction engineer for contractors. For more information contact either Conrad Felice at (425) 505-2907 or James Morrison at (231) 944-9732.

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400 112th Avenue NE, Suite 205
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www.ilf-usa.com
Email: info@ilf-usa.com

Where Experience Meets Vision


McMillen Jacobs Associates is delivering University Link in Seattle as part of the NTP Joint Venture

McMillen Jacobs Associates provides design, management, and construction services for the heavy civil industry, focusing primarily on underground and water resource projects.

McMILLEN JACOBS ASSOCIATES

mcmjac.com

McMillen Jacobs Associates

New Year, New Outlook

After successfully working together for several years and gaining an understanding of each other's cultures and talents, drivers and missions, McMillen and Jacobs Associates agreed to merge in late 2014. Jacobs Associates brings 60 years of serving the heavy civil underground industry, while McMillen brings an integrated design-build delivery to the water supply and hydropower industries. By merging, we can contribute to projects at the planning stage, develop a design, and self-perform construction. Clients benefit because we understand project drivers at all stages and can provide cost-effective alternatives. We are small enough to remain focused on service and quality rather than profit centers and internal bureaucracy, but large enough to offer expanded services and a deeper bench of technical expertise. As the industry we serve continues to change and evolve, so must we. As you learn more about the capabilities of our new firm, we are confident that you will agree.


Daniel N. Adams
President

McMillen Jacobs Associates
800.842.3794
www.mcmjac.com

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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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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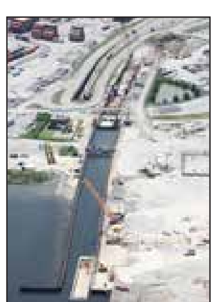

Mueser Rutledge Consulting Engineers (MRCE), founded in 1910, is a leading engineering firm focused on the below-ground disciplines of geotechnical, marine, and structural / foundation engineering.

Providing design solutions for tunnels and shafts is one of the 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.

Mueser Rutledge Consulting Engineers
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Foundation Engineering Since 1910

FEATURE ARTICLE

Central subway tunnel construction instrumentation: Lessons learned, San Francisco, CA

The Central Subway is Phase 2 of the San Francisco Municipal Transportation Agency's (SFMTA) Third Street Light Rail project and will extend the existing Phase 1 initial operating segment from its current connection to the Embarcadero line at Fourth and King streets along Fourth Street to Market Street, under the Bay Area Rapid Transit (BART) and Muni Metro tunnels and then north beneath Stockton Street to Chinatown (Fig. 1).

Total new track to be constructed as part of the Phase 2 work consists of approximately 734 m (2,410 ft) of surface track and 2,636 m (8,650 ft) of tunnels. The tunnels were constructed as twin, single-track bores by two tunnel boring machines (TBMs) (Johnson, 2014) moving north from the southern end of the launch box under the I 80 freeway between Bryant and Harrison streets. North of Chinatown Station the TBMs continued another approximately 683 m (2,240 ft) to a retrieval shaft near Columbus Ave. at Washington Square. The project also includes five cross passages to connect the two tunnels, and three underground stations (the Yerba Buena/ Moscone Station, Union Square/Market Street Station and Chinatown Station.)

Excavation of the twin tunnels was performed with two TBMs, with both TBMs driving northward from the launch box. TBM excavation was performed such that the location of the machines was staggered to separate the active excavation faces by a minimum of 91 m (300 ft) between headings. This minimum separation was maintained until the first TBM arrived at the retrieval shaft plug, at which time the separation requirement was relaxed. Excavation began with the "southbound" (SB) tunnel, which will ultimately accommodate the southbound TBM light rail trains followed by the second TBM in the "northbound" (NB) tunnel. With the completion of the drives in June 2014, cross passage excavation then began and was completed in April 2015. Overall, construction of the Central Subway tunnels was a success considering the nature and complexity of the project. Additional details of the completion of the Central Subway tunnels are presented in another paper from the RETC 2015 conference (Leong et al., 2015).

Kenneth A. Johnson, Michael V. Wolski and Ryan O. McCarter

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FIG. 1

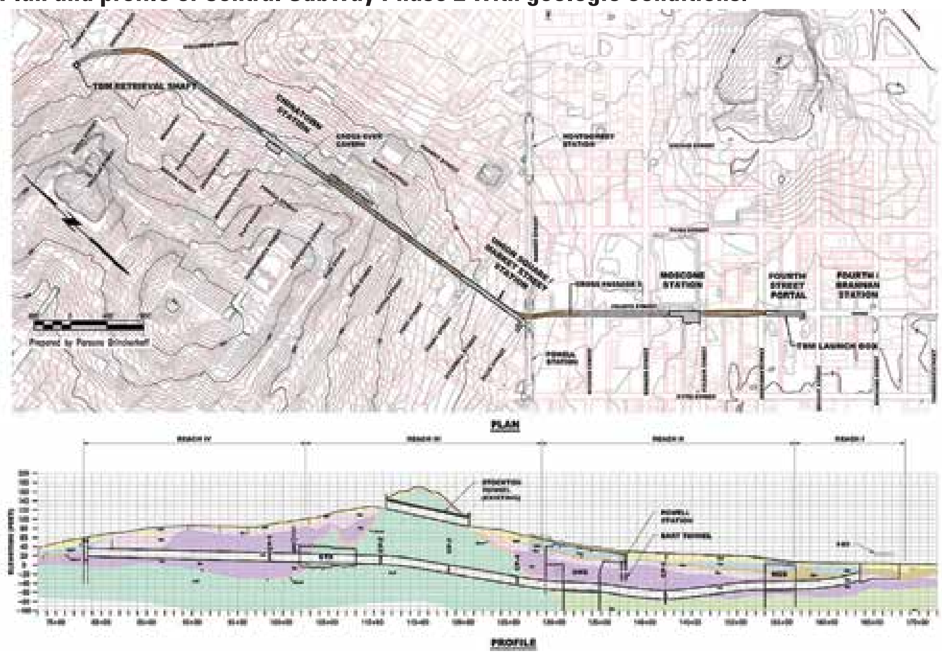
Overview of Central Subway Phase 2 alignment.

Site/geologic setting. San Francisco is located in the central Coast Ranges of the greater Coast Ranges Geomorphic Province of California. The project area lies east of the San Andreas Fault. The geology of the San Francisco North Quadrangle is characterized by recent (historical) artificial fills and Quaternary sediments (i.e., deposits that are up to 1.6 million years old) unconformably overlying bedrock of the Franciscan Complex. Bedrock is exposed locally in the isolated hills that occur throughout the city and along parts of the coastline. Franciscan rocks typically are strongly deformed (faulted, fractured and folded). In the project vicinity, Franciscan bedrock generally comprises three predominant rock types: including sandstone (typically greywacke), shale and mélange. The surficial quaternary deposits flanking the bedrock outcrops comprise colluvial, aeolian (dune) and near shore sedimentary deposits. A comprehensive summary of the geotechnical factors that influenced the tunnel design and construction is summarized in Yang and Johnson (2011).

A generalized interpreted geologic section depicting the subsurface stratigraphy along the project alignment is shown in Fig. 2. Eight geologic units were encountered on this project, with Qc and KJf being the two units within which the major portion of the tunnels were driven.

FIG. 2

Plan and profile of Central Subway Phase 2 with geologic conditions.



GEOLOGIC UNITS

Surficial Deposits

Quaternary

Qaf	Artificial Fill (Holocene): Generally consists of very loose to medium dense Sand (SP), Silty Sand (SM), and medium stiff Sandy Clay (CL); locally with miscellaneous debris (bricks, wood, metal, concrete, glass, etc.). Much of this deposit originates from the underlying Dune Sand (Qd).
Qd	Dune Sand: Generally consists of loose to medium dense poorly-graded fine to medium grained aeolian Sand (SP).
Qm	Bay Mud/Marsh Deposit: Generally consists of very soft to soft, dark greeni gray to black organic-rich Clay and Sandy Clay (CL to CH).
Qu	Undifferentiated Deposits: Generally consists of medium stiff to stiff brown Sandy Clay (CL) and medium dense to dense brown Clayey Sand (SC). May comprise colluvium, alluvium, or Colma Formation.
Qc	Colma Formation - Lower Unit: Generally consists of well-bedded dense to very dense Sand (SP to SM) with interbedded stiff to very stiff Clay and Sandy Clay (CL). Where observed in Project borings, beds range from 1 inch to greater than 2 feet thick. Color is typically brown to yellowish brown with red, orange, and gray motling.
Qo	Undifferentiated Old Bay Deposits (Qu): Generally consists of interbedded dense to very dense Sand (SP) and Silty Sand (SM) and stiff to very stiff Clay (CL); locally contains lenses of shell fragments. This unit also contain Older Bay Clay and Mud, which typically are stiff Clays and Silts that are gray to greenish gray in color.
Qcol	Colluvium: generally consists of very stiff brown to gray Sandy Clay (CL) to Clayey Gravel (GC). Appears to be decomposed bedrock/residual soil.

Franciscan Complex Bedrock

Where observed in Project borings, this unit is highly variable in composition, hardness, and strength, ranging from soft to hard and from friable to moderately strong. Observed fracture spacing varies from very close (< 0.1 ft) to close (0.1 to 0.3 ft) and, in general, the severity of weathering decreases slighty with depth.

Jurassic and Cretaceous

KJf	FRANCISCAN COMPLEX, UNDIFERRENTIATED; includes sandstone, meta-sandstone, sandstone breccia, shale, shale breccia, siltstone, claystone, mudstone, chert, serpentine, and melange.

Role of instrumentation

For the Central Subway project, the primary goals of the instrumentation program included building protection, protection of existing underground transit facilities, protection of existing utilities and documentation of construction/excavation activities, including compensation grouting. Overall, the instrumentation system was intended to:

- Provide data to support building protection program.
- Monitor ground water control programs.
- Monitor existing underground utilities.
- Monitor ground deformations related to construction and excavation activities.

Instrumentation is particularly important for this project because the tunnel alignment passes beneath the heart

FIG. 3

Typical AMTS installation.

of San Francisco's commercial and shopping districts at Union Square and in Chinatown, passing near a variety of building sizes and foundation conditions as well as numerous underground utilities and transportation facilities.

Building protection and compensation grouting. Based on estimates of tunnel-related settlement developed during the final design, a number of structures and facilities along the tunnel alignment had the potential for settlement to a degree that would be unacceptable. For the buildings that were most susceptible, termed Group A buildings, settlement mitigation methods were designed (including compensation grouting), such that protection of these structures could be maintained during construction. The actual position of grouting pipes depended on the foundation type and the relationship of the building or facility with actual tunneling activity. Examples are tunneling adjacent to pile supported foundations, tunneling beneath spread footings/mat foundations and tunneling beneath existing operating transit systems. A discussion of compensation grouting and protection of Group A buildings and the BART facilities was described in Piek et al. (2014).

Ground water control and monitoring of dewatering. Piezometers were installed along the alignment and near cross passages to provide information regarding water pressures during construction of the launch box, retrieval shaft and cross passages. Along the alignment the primary water-bearing units include the Qd, Qu and Qc deposits, and the sandy strata in Qo.

Excavation support that provided hydraulic cutoff was designed and constructed to minimize drawdown outside of the excavation to minimize the potential for dewatering-related settlement. These hydraulic cutoff systems worked well. However, there were two instances where a piezometer suggested cutoff was not performing as expected, as discussed in case study D.

Monitoring existing utilities. Monitoring and protection of key underground utilities was also a significant part of the overall instrumentation program. In addition to the use of multiple position borehole extensometer (MBX) installations, surface settlement arrays, inclinometers and utility monitoring points were installed at various key utilities that had the potential to be impacted by tunneling activities. Utilities that were monitored included water mains with diameters from 205 to 750 mm (8 to 30 in.), auxiliary water supply system (AWSS) pipes with diameters between 305 and 460 mm (12 and 18 in.), AWSS cisterns and sewer pipes with diameters between 305 and 2,440 mm (12 and 96 in.). Condition assessments were performed on large-diameter sewer pipes prior to tunneling. Utility monitoring point data indicated very small movements, typically less than 2.5 mm (0.1 in.), and at a few locations rising to 5 mm (0.2 in.).

Construction/excavation activities. In addition to the monitoring of buildings and utilities along the tunnel

FIG. 4

Typical AMTS plan.

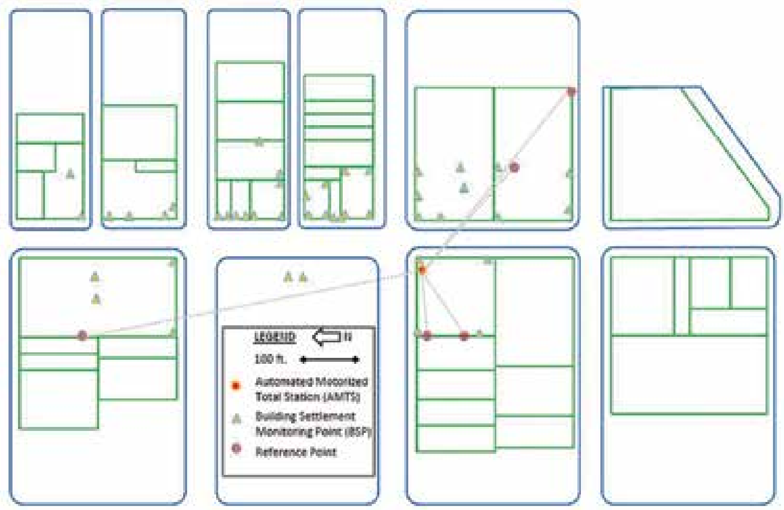
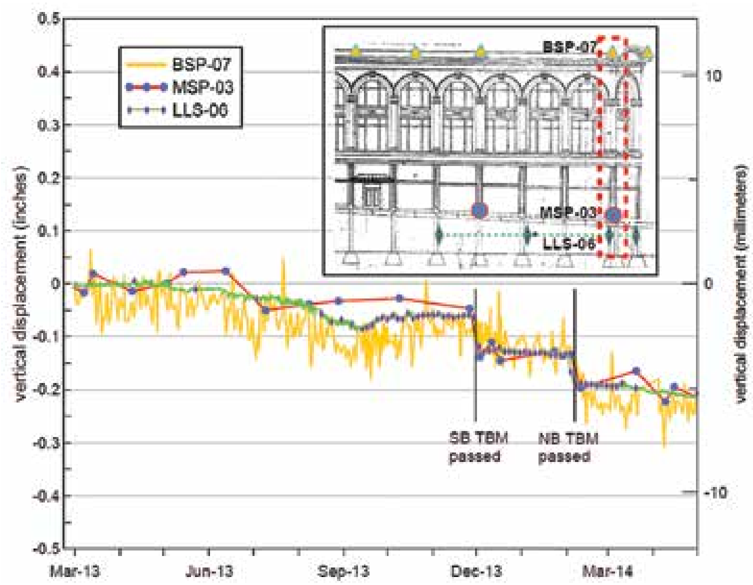


FIG. 5

Multiple instrumentation system redundancy.



alignment, structures and utilities in the vicinity of the launch box and retrieval shaft were also monitored to assess potential excavation-related movement. In particular, deep foundations for the I-80 overcrossing as well as the surrounding buildings and structures were included in the program. Instrument movements in these areas were generally below 2.5 mm (0.1 in.) and significant impacts have not been observed.

Description of key instrument systems

Instrumentation for the Central Subway project included a variety of instruments to monitor the effects of tunneling on the utilities and structures along the tunnel alignment. Recent advances in telecommunications and Automated Data Acquisition Systems (ADAS) have enabled the development of integrated systems used for real-time construction monitoring. Remote access via the internet and the use of automated alerts have simplified the task of monitoring hundreds of instruments. Following is a brief description of the major systems used.

AMTS and BSP systems. Automated Motorized Total Stations (AMTS) and Building Settlement Monitoring Prisms (BSP) are the backbone of the monitoring system used for the buildings along the alignment as well as the BART tunnels. The AMTSs are composed of an electronic theodolite with an electronic distance meter (EDM). Angles and distances are obtained by firing an infrared beam at a reflective target and processing the return. The three-dimensional location can then be calculated to determine whether the reflective target has moved in relation to a reference point. One can then extrapolate whether a structure has moved based upon the movement of the reflective targets anchored directly on the structure. The instruments installed on the Central Subway project included robotic total stations (Fig. 3) using automatic target recognition capable of accuracies of 1 arc second and 1 mm (0.04 in.) + 1 ppm up to 200 m (656 ft).

The AMTS can be placed within the settlement zone of influence and still accurately measure the deformation of the other prisms by the process of resection. The AMTS looks back to a constellation of reference prisms and recalculates its own position prior to each cycle of readings of the BSPs. A typical layout for the AMTS and constellation of references and BSPs is shown in Fig. 4. The total number of AMTS units was not specified in the contract, but it was left to the contractor to optimize the system so that the four corners of each building as shown on the plans could be monitored. A total of 629 BSP prisms were read by 17 AMTS units. The three-dimensional displacement vectors were required to have a measurement precision of 1.6 mm (0.0625 in.) for sight distances of up to 91 m (300 ft).

Conventional survey systems. Conventional surveys were utilized to provide a level of redundancy for the vertical deformation component of the AMTS/BSP systems as well as to monitor utilities, roadways, and other structures along the alignment. To provide first-order accuracy of the surveys, a series of five deep benchmarks extending to a depth of 15 m (50 ft) below the tunnel invert were required to be installed along the tunnel alignment. Specifications required that the manual surveys start and end on two different deep benchmarks and that the accuracy of an elevation measurement be plus or minus 3 mm (0.01 ft) (at 95 percent level of confidence).

The types of instruments read by conventional survey and the total number of each installed are as follows:

- Manual Building Settlement Monitoring Points (MSPs): 582.
- Surface Settlement Points/Arrays and Utility Settlement Points (SSP/SSAs and USPs): 175.
- Utility Settlement Monitoring Points (UMPs): 95.

Vertical multiple position borehole extensometers (MBXs). A total of 24 MBXs were installed along the tunnel alignment. The MBX consisted of either three or five anchors at various positions above the tunnel crown. These precise instruments provided real-time measurements of the ground behavior before, during and after the passage of each TBM.

Piezometers. Twenty-five open standpipe piezometers, located along the tunnel alignment, were installed during the exploration phases of the project and were monitored throughout the tunneling contract. One additional standpipe piezometer was drilled at the retrieval shaft. Two of the existing piezometers encroached within the paths of the TBMs and were damaged during passage of the TBMs. Another piezometer was damaged during utility work. Three vibrating wire piezometers were installed: two replacing the damaged piezometers and one installed at the retrieval shaft.

Liquid level systems (LLSs). It was specified that LLSs be installed in buildings where compensation grouting was used as a mandatory building protection system. LLSs were required to measure relative vertical displacement of plus or minus 50 mm (2 in.) with a system accuracy of plus or minus 0.3 mm (0.001 ft). The liquid level gauges used vibrating wire transducers and were monitored remotely using a data collection system. A total of 71 LLSs were installed in nine buildings.

Tiltmeters and tilt beams. A total of 10 biaxial tiltmeters were installed in six buildings for additional tilt monitoring of the structures and 14 tilt beams were installed within the existing BART tunnels to monitor rail movements. The electrolytic tiltmeters have an angular range of plus or minus 1 degree ith a static repeatability of plus or minus 2 arc seconds. In addition, a motion sensor was placed at each end of the instrumented section in each BART tunnel to record the passage of trains.

Tape extensometers. Tape extensometer readings were required at only two structures. A hook-and-eyebolt system with a digital reading tape was used to monitor the change of distance between two points with measurement repeatability of 0.25 mm (0.01 in.).

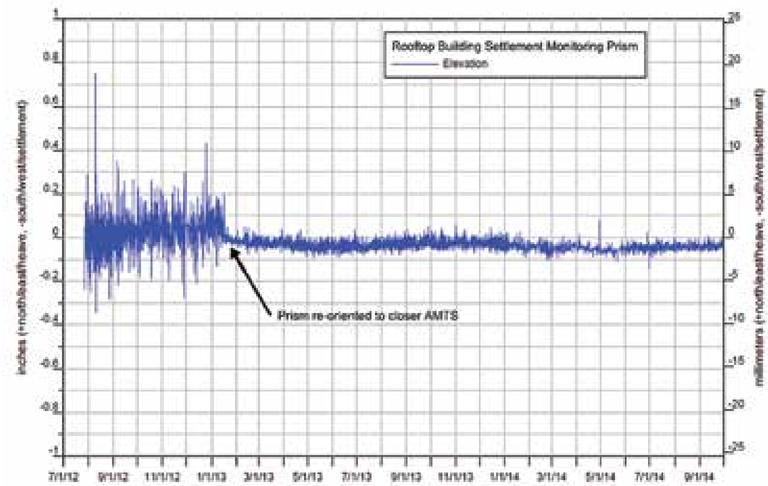
Inclinometers. Seven inclinometer casings were installed adjacent to the walls of the launch box and four were installed adjacent to the retrieval shaft. Readings were performed manually with portable biaxial inclinometer probes.

Strain gauges. Strain gauge arrays were used to monitor strut loads at each level of support: 19 installed at the launch box and 12 at the retrieval shaft. The weldable vibrating wire strain gauges were configured to be read remotely in real time.

Seismographs. Seven portable seismographs were provided for monitoring the velocities of ground vibrations resulting from construction activities. About 50 buildings along the alignment were designated as Historic Structures with a maximum vibration limit set at 3 mm (0.12 in.) per second peak particle velocity (PPV).

FIG. 6

BSP noise reduction by changing AMTS used for measurements.



Acoustic leak detection system. In addition to the monitoring of potential settlement using the UMPs, an acoustic leak detection system was specified for water mains and the auxiliary water supply system (AWSS). The leak detection system provided continuous monitoring using acoustical leak detection technology and was required to precisely locate a leak.

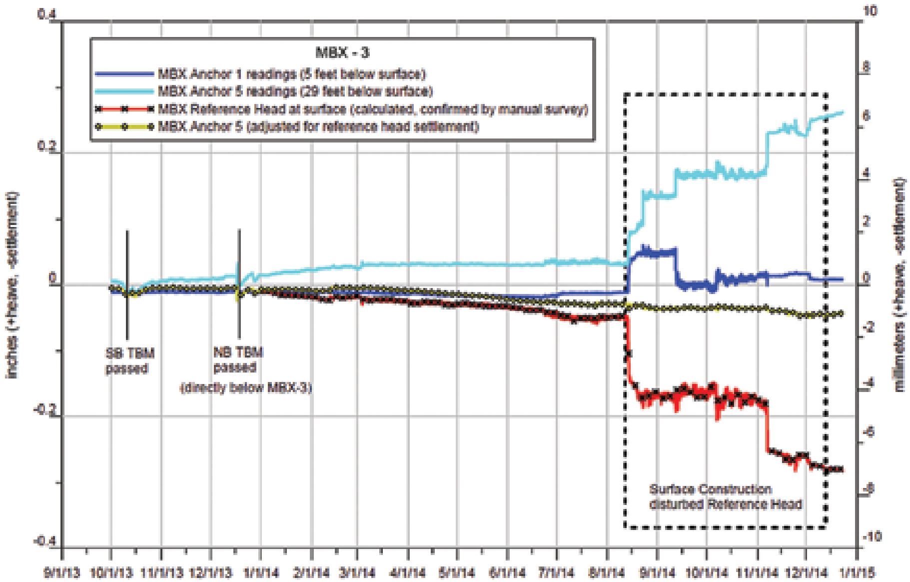
Further discussion of BSPs and MSPs. Having both the AMTS system and the conventional survey of MSPs provided a redundancy that ensured coverage of the buildings and an important verification of the monitoring results. Both systems have advantages and disadvantages. The combination of using both systems was beneficial in overcoming some of the shortcomings of either system. An example of an ideal indication of redundant instrumentation systems is shown in Fig. 5. Here, the major changes displayed by the BSP, MSP and LLS at one portion of this structure are generally quite consistent, showing contemporaneous similar movements, albeit with different levels of noise in the data sets.

The primary advantage of conventional surveys (MSPs) based on reference to the deep bench marks is that they provide verifiable deformation measurements to compare with AMTS/BSP data. However, the primary disadvantage of relying on MSPs is that it is not always possible to monitor MSPs at the back or sides of the buildings due to access constraints. For example, neighboring buildings with walls immediately adjacent on the property line prevent installation of MSPs on the back of buildings. Another disadvantage is that MSP monitoring is more labor intensive requiring more time per measurement.

The primary advantage of an AMTS system is that it is capable of frequent three-dimensional measurements

FIG. 7

MBX-3 data showing change in reference head elevation and impact on data.



viewable on the web-based program in near real time. Additionally, for this project, the AMTS was more successful in achieving coverage of all the building corners, although complete coverage was still challenging in some cases because of sight obstructions by trees, billboards and buildings with varying heights. A disadvantage of an AMTS system is that it can be adversely affected by weather conditions. For this project, the instrumentation subcontractor elected to mount the system on the rooftops rather than the building facades. This simplified coverage of the BSPs at the back of the buildings, but resulted in limitations of the prism mountings. Ideally, the prisms would have been securely anchored to structural members. However, most of the property owners would not allow any penetration of the roofing materials, so the prisms were adhered to the roofing material or metal flashing with silicone adhesive.

Much of the AMTS data displayed a significant and undesirable level of noise. Sources of noise may include the mounting details of the AMTS and prisms, lines of sight, sight distances, vibration and atmospheric conditions. Despite the level of noise, it was possible to discern a trend line through the oscillating data, but instantaneous readings were of diminished value. In some cases, the level of "noise" in the BSP readings was reduced by adjusting a prism orientation and changing the AMTS used to monitor it, as shown in Fig. 6.

The BSPs were also required to provide horizontal deformation data. The northing and or easting component of the BSP data often had a much wider noise band than the vertical deformation data. Further discussion of the horizontal measurement system is presented in Case Study C.

Lessons learned and case studies

Many of the lessons learned described in this article may seem familiar to practitioners with years of experience in the field. They are presented here to identify essential principles to be included in developing and implementing excellent instrumentation systems for future projects. Considering the case histories that follow, the importance of these principles is underscored.

Lesson 1: Which way is up? Understanding exactly what the instruments are measuring and how that information is plotted is critical for the proper interpretation of instrumentation data. Defining the sign conventions used and labeling these on the data plots will facilitate the correct interpretation. Tilt beams and tiltmeters are one example. Saying "positive to the east" does not fully define the direction of motion; "down to the east is positive" fully describes the sign convention.

Most often, settlement plots are constructed to show settlement plotted in the negative "y" direction. MBXs are basically extensometers that record the change in distance (rod length) between the reference head and anchor. The sign convention provided by the manufacturer is positive for an increase in the rod length. However, if the data are plotted with this sign convention, settlement would be displayed in the positive "y" direction. Clearly, the data reduction must incorporate and document this convention to avoid misinterpretation.

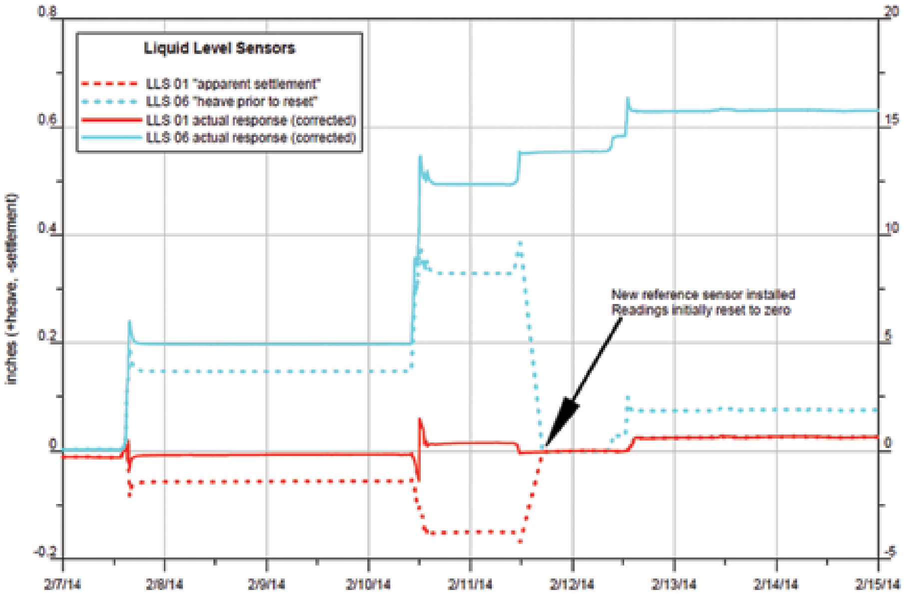
Lesson 2: Relative motion. Monitoring instruments do not measure absolute movement but, rather, a movement relative to some reference. A simple example is a conventional survey where benchmarks are used as a reference for elevation control. Ideally, the reference is fixed and does not change. MBX measurements present a more complicated example. The MBX measurements are relative to the reference head. To interpret the movement of the lower anchors during tunneling, we typically assume that the reference head is stable and that we are observing movement of the anchor and not movement of the reference head. However, as the loosening of ground around the tunnel progresses upward, we may also see movement of the reference head. Therefore, the reference head must also be frequently measured by conventional survey to determine if and how much it moved. Too often in an urban environment with paved streets, the potential for reference head movement is assumed to be negligible and carries significant possible consequences as described in Case Study A.

Case Study A: The devil is in the details. Lessons 1 and 2 are illustrated in a case study involving the MBXs. To measure the settlement trough induced by the twin TBMs, surface settlement arrays were installed along intersecting streets perpendicular to the tunnel alignment. One MBX string, consisting of three to five anchors, was also installed above the centerline of each tunnel. The lowest anchor is located about 1.5 m (5 ft) above the tunnel crown. During tunneling, movements of the lowest MBX anchors were minimal, generally on the order of a few hundredths of an inch.

After TBM tunneling was complete, MBX 3 began showing renewed movements nine months after the passage of the TBMs. All the anchors, including the lowest anchor, just above the tunnel crown, started to show a settlement trend in discrete steps with a total magnitude on the order of 6 mm (0.25 in.). Deep settlements above the tunnel raised concerns, and this response was mysterious given that no tunneling had occurred during this time period. Other construction activities in the area included slurry wall construction for a future station, which could account for deep settlements, but was considered too far away to have an effect on MBX 3. Sewer work with trenches about 3 m (10 ft) deep was also ongoing adjacent to the MBX. The trench was not deep enough, however, to affect the lower anchors of the MBX. To further investigate, other MBX data were reviewed and assumptions and sign convention were double-checked. Data reports with interpretation were submitted weekly by the instrumentation subcontractor. The MBX data plots primarily showed positive movements that were interpreted as heave. It became evident that the plots were inverted when heave-inducing activity (ground freezing) was simultaneous with a slow settlement trend at a nearby MBX. While the plots were consistent with the manufacturer's sign convention (elongation in the positive "y" direction), the plots were inconsistent with time-settlement plots of other instruments that interpreted settlement in the negative "y" direction. Therefore, the lower MBX 3 anchors were really showing heave, not settlement. In addition, since the movement is relative between the anchors and the reference head, a plot showing heave on the anchor would be consistent with settlement of the reference head (shortening). So, after inverting the plots (Fig.7), and using a survey of the reference head to correct its elevation, the mystery was solved. The trenching had settled the reference head about 6 mm (0.25 in.) and there were no deep-rooted settlement issues.

FIG. 8

LLS data for building above tunnel, illustrating the impact of reference sensor heave.

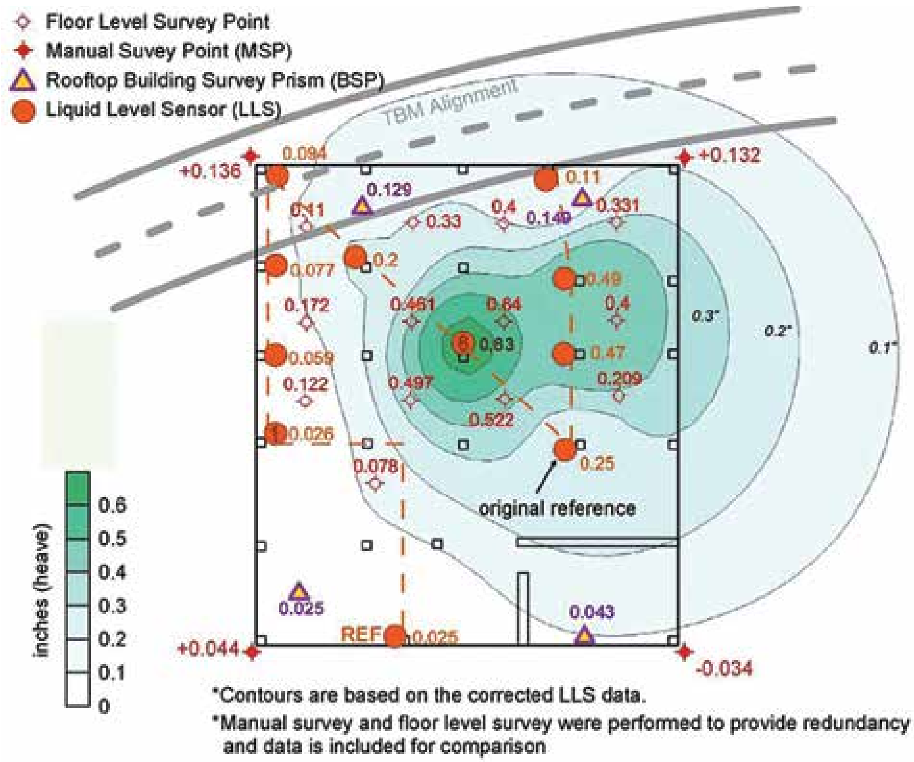


Lesson 3: Did the reference move? Similar to Lesson 2, recognizing that the potential for movement of a reference exists, how do we confirm the accuracy of the reference values? In instrumentation systems where the measurements are relative to a reference sensor, it is necessary to also tie the reference sensor back to another reference outside the zone of influence, preferably on the project datum. For example, in an LLS system, each monitoring sensor is measured relative to a reference sensor. If the reference sensor is not routinely checked against the outside reference, some uncertainty in the accuracy of the settlement measurement will be introduced. The magnitude of the uncertainty or error cannot be determined until the check is made with the outside reference. If the reference sensor is shown to have not changed, intermediate readings will be directly valid. If the reference sensor has changed in elevation, some judgment must be used to correct the intermediate readings. This is also a key issue for MBX and AMTS systems, as previously mentioned.

Case Study B: Separate LLS reference from construction work area. Lessons 2 and 3 are illustrated in a case study involving LLS. For the project, Group A buildings, such as the one in this case study, required mandatory mitigation measures, specifically compensation grouting and associated preconditioning was deemed necessary to protect the buildings from settlement during tunneling. Because of their rapid response capability, LLS instruments were specified as the primary method

FIG. 9

Floor level survey and LLS instrumentation for building above tunnel.



of monitoring. To account for daily fluctuations within the static water level of the system, all the LLSs were measured relative to a reference sensor. To account for possible movements of the reference sensor, it was required that the reference sensor also be surveyed relative to a stable point outside the zone of influence, preferably one of the deep benchmarks. However, for this location, the system was installed in the basement of a building that presented a challenge to surveying of the control. Consequently, the reference sensor was not tied to an outside reference point.

The curving path of the TBM would pass directly beneath the corner of this Group A building. The plan for compensation grouting was facilitated by drilling subhorizontal holes beneath the basement of the building from a shaft in an adjacent parking lot. A liquid level system of 10 sensors (one reference and nine monitored points) was installed and base-lined as the primary monitoring system. The deformation limit for settlement or heave of Group A buildings was specified as plus or minus 13 mm (0.5 in.) and an angular distortion limit of 1/600; the compensation grouting specification set a preconditioning target to limit heave to 3 mm (0.125 in.).

During installation of compensation grouting pipes and preconditioning, the instrumentation was closely monitored. During preconditioning, heave was observed in only three of the sensors, while a settlement trend was indicated in six of the sensors. Heave was anticipated because of the ongoing grouting, but no construction activity was occurring that could be responsible for a settlement trend, and the TBM was nowhere near the building at this point. Because the LLS measurements were relative to the reference sensor, a heave of the reference sensor would appear to be a settlement in those sensors that did not heave, or had heaved less than the reference sensor. Based on the data and the type of activity at the site, it appeared that the reference sensor was in the zone impacted by construction and a correction was needed.

Typically, the LLS sensor readings could have been corrected by simply surveying the reference sensor and adding the amount of the reference heave to each of the sensor readings. However, since the reference sensor was not tied to an outside reference, there was no direct measure of the magnitude of the reference heave. An additional LLS sensor was installed as a new reference in a location further from the grouted zone, and the original reference sensor was converted to a monitored sensor. After the new reference was installed, all the LLS sensor readings were "temporarily" reset to zero (Fig. 8) to initiate measurements relative to the new reference. Concern about the zero reset was that the readings being made from that point were no longer related to the approved baselines and that the heave experienced during precondition grouting was no longer reflected in the data set. Heaving the center of the building relative to the front also induced an apparent angular distortion, which would likely worsen with additional settlement during passage of the TBM. Therefore, an accurate understanding of the vertical deformation of the building was necessary to calculate and monitor the angular distortion.

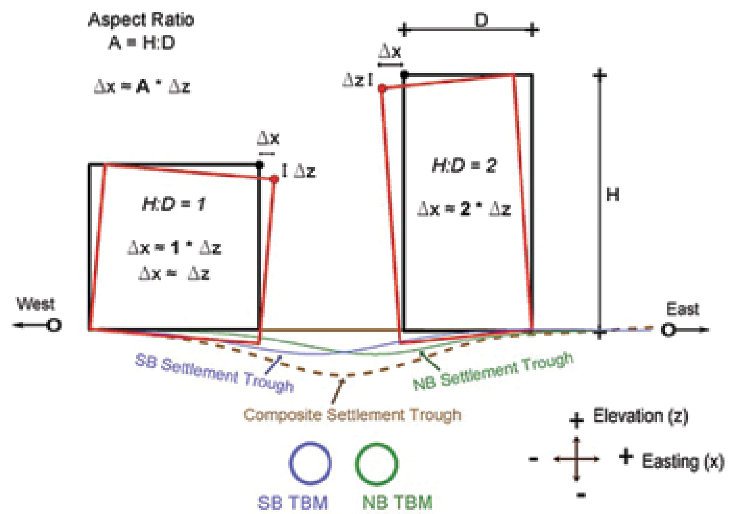
To develop a means of correcting the LLS data, a floor level survey of the basement was performed and compared to the preconstruction floor level survey required by the project specifications. The results confirmed that the floor heaved more than what was indicated by the initial LLS with a maximum of 16 mm (0.64 in.) in an area near the original reference sensor. Based on a contour map of the floor level survey results the floor adjacent to the reference sensor was estimated to have heaved 5 mm (0.2 in.). However, use of this estimated value to directly correct the LLS readings was not considered appropriate because the floor slab could have heaved differently than the columns on which the LLSs were mounted. Other instrumentation, including MSPs and BSPs, was reviewed, but these points were located near the corners of the building and were not measuring the heave experienced in the central area of the basement. Considering that the columns were lightly loaded and were founded on spread footings, and that the soil mass between the grout pipes and the column footings would tend to even out the deformation, the amount of heave experienced by the slab would likely be similar to that experienced by the columns. However, an independent measurement of the reference heave would still be necessary to confirm this assumption.

Given the lack of an external reference, an alternative method to estimate the amount of the reference sensor heave was developed by looking at the LLS data which showed an apparent settlement trend. If we assume no settlement actually occurred in any of these sensors, the magnitude of the apparent settlement would indicate the reference heave. The sensors that show the maximum apparent settlement would be the best approximation of the reference heave. Four LLS sensors, installed along the north wall of the building, experienced little to no heave and totals of the apparent settlement were approximately 5.5 mm (0.22 in.) in each sensor. This is also in close agreement with the results inferred from the floor level surveys. Where the LLS data showed heave, however, it was observed that there was some relaxation of the heave after the precondition grouting stopped. Considering that the reference sensor heave occurred over a period of several days followed by relaxation, the estimated reference "correction" was slightly reduced to account for this gradual relaxation. A reference sensor correction value of 4 mm (0.165 in.) was agreed upon. The LLS data plots were then reestablished to the previously approved baseline and the offset was added to account for the original reference sensor heave. The revised LLS survey data and the floor level survey results as well as the MSP and BSP data are presented in Fig. 9. These revised LLS data, confirmed by the floor level surveys, clearly document heave in the central portion of the building. As indicated in the figure, the BSP and MSP data did not capture the extent or the magnitude of the floor and column deformation in the building interior.

Lesson 4: Floating world: Is the measured movement real? When the data do not look right, how can we determine if the movement indicated by the instrumentation data is really representative of the structure's movement? Redundancy with other monitoring systems and the ability to verify measurements are critical in confirming whether or not the data represent meaningful movement.

FIG. 10

Typical section showing aspect ratio and settlement trough.



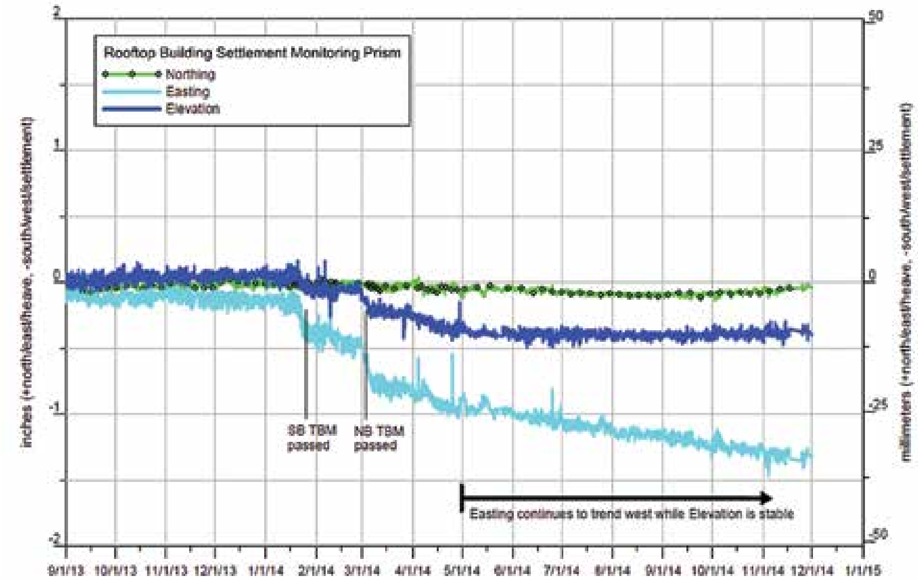
Case Study C: "Floating" systems still need to be tied down. The AMTS systems on the Central Subway project generally produced reliable vertical data to monitor settlements induced by tunneling. Noise within the reported data was very noticeable but, as mentioned previously, trends were usually discernable when a series of measurements were viewed. However, the horizontal data, particularly the easting component, showed greater variability. While not ideal, this was generally acceptable provided that the lateral movements of the structures were clearly indicated by the trend lines.

After completion of tunneling, adverse trends began to develop in several AMTS systems, indicating movements in the easting component. Given the absence of construction activity and the fact that the magnitude of the horizontal movement did not seem consistent with the corresponding vertical settlement, other explanations for these trends were sought. One possible explanation for a horizontal roof movement higher than the vertical movement may be related to the aspect ratio of the building. Since the BSP prisms are located on the rooftops, there may be an "amplification" of the horizontal movement related to the height of the building when a building is taller than it is deep. As shown in Fig. 10, if the building is twice as tall as it is deep (aspect ratio equal to 2), we would expect to see a horizontal movement at the top of the building roughly twice the measured settlement. While buildings will not generally behave as a rigid body as assumed by the example, this comparison provides a useful screening tool to evaluate the consistency of horizontal movement indicated by the AMTS system.

An example of an adverse easting trend, exhibited long after tunneling was completed, is presented in Fig. 11. The data suggest horizontal (westerly) movements of 35 mm (1.3 in.), but less than 13 mm (0.5 in.) of settlement. The horizontal movement continued even after the vertical

FIG. 11

Adverse easting trend.



settlement stopped. The project specifications limit the horizontal movement of structures to 20 mm (0.75 in.). This building has an aspect ratio of 1.0, so there is clearly more to the reported movement than consideration of aspect ratio. Other BSPs on the same building and adjacent buildings on the block showed similar movement; in addition, BSPs on the building across the street also showed a small movement in the same westerly direction. Given the well-known geometry of tunnel-related settlement, we would expect buildings to tilt toward the center of the settlement trough, with buildings on opposite sides of a tunnel showing inward movement symmetric about the tunnels (i.e., opposite directions). Having horizontal movement in the same direction on both sides of a tunnel may be better explained by a systematic discrepancy.

Figure 4 shows the layout plan of the AMTS in this example. The AMTS unit is located at the northeast corner of a building. Five reference prisms are used for control of this AMTS; one is located to the north, two to the southeast, and two to the west. The two closest reference prisms are located on the same building as the AMTS unit. Each of these reference prisms is located in close proximity to BSPs. Several of these BSPs show movement, specifically about 5 mm (0.2 in.) in the easting direction. This is a strong indication that the adjacent reference prisms used for control were not “fixed” and stable. Therefore, the adverse easting trend does not appear to be “real” movement, but is likely related to the survey control of the AMTS monitoring system. Movement of a control point or poorly constrained control (reference prisms) will introduce errors into the AMTS system.

For some project AMTS installations, it may be adequate to assume that only localized “relative” displacements are required. In these cases, at t=0 the AMTS can be set at a convenient set of coordinates (typically N, E, Elev, all = 1000.00), and the horizontal angles are set to site North (at 000° 00' 00"). The reference prisms are treated like monitoring points, and their 3-D positions are calculated relative to the AMTS and are assumed to retain those values throughout the project. This type of floating system is not tied to the project coordinate system, and is generally not independently verifiable.

For the Central Subway project, however, the specifications required that all instrumentation be georeferenced and as-built coordinates be surveyed for all instruments with an accuracy of 2.5 mm (0.1 in.). Given the floating nature of the system installed for this project, verification of BSP measurements can therefore best be obtained by performing a postconstruction survey and comparing final BSP positions with the as-built coordinates from when the system was originally installed.

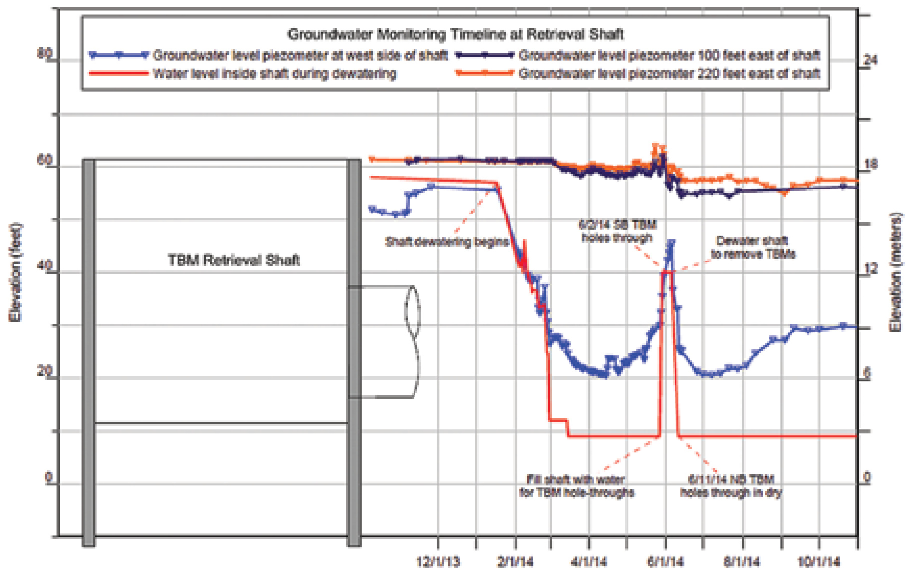
Because the horizontal AMTS data were more difficult to confirm than the vertical data, a series of steps were developed to assess where horizontal movement issues were significant and where they were not during the project.

- Compare the lateral movement with the vertical movement indicated, considering the aspect ratio of the building. Are the magnitudes reasonable?
- Compare the movements with other prisms (1) on the building, (2) on adjacent buildings and (3) across the street. Are they all moving in the same direction? Are the movements consistent with the expected deformation from construction activity?
- If not, a more detailed review of the AMTS system and data is needed, along with conventional manual surveying methods to confirm whether the reported movements are representative.

A detailed description of the resection procedures for AMTSs can be found in Bassett (2012). Bassett also provides guidance on the selection of the control, stating: “This correction [resection] is conveniently carried out by back-reference to a number of ‘fixed,’ stable locations, which are considered to be outside the influence zone of any engineering work. However, as every building is subject to daily, monthly, seasonal and yearly cyclic movements, the choice of these fixed locations must be made with considerable care. They should be on or near

FIG. 12

Water levels in the vicinity of the retrieval shaft during excavation and TBM hole-through.



the foundations of major structures and they should preferably be in the shade and not subject to external vibration."

Good quality control points are especially critical for long-term monitoring. A robust survey control for the AMTS network used nearby at the Transbay Transit Center in San Francisco, CA, is described in (Gouvin, 2014). As described in this article, "The establishment of a physical control network was invaluable to a monitoring program that required geospatial referencing, and it proved to be the best practice for verifying AMTS network measurements."

Lesson 5: Is all construction dewatering drawdown bad? Ground water control is a very common element of underground excavation projects. Significant problems can arise if ground water control is carried out in a haphazard manner, especially in a dense urban environment. For this reason, specifications typically outline limits on drawdown associated with dewatering to reduce or minimize potential adverse effects. Such precautions are generally warranted, especially when the true three-dimensional nature of ground water flow and hydrogeology is not fully appreciated.

In any excavation where the excavation support is intended to cut off or greatly reduce dewatering requirements it is critical to appreciate the three-dimensional nature of the system. This is important not only for the aquifers and aquitards included in a monitoring program, but also for the base of an excavation support wall and the bottom of dewatering wells used to lower the water table within an excavation. In cases where the dewatering well depth approaches the depth of a slurry wall or cutter-soil-mix (CSM) wall used for excavation support, the degree of cutoff is reduced, and increased drawdown outside a cutoff wall may result. Whether this amount of drawdown is problematic depends on the specific situation at hand.

Case Study D: Understanding the hydrogeology is key to good piezometer data interpretation. Launch box. Piezometers were installed outside of the excavation support within the shallow aquifer (Qc) and a deeper aquifer (Qo) to monitor water levels and potential impacts to a compressible strata overlying the shallow aquifer. Near the TBM launch box, the ground water level is less than 3 m (10 ft) bgs, which is close to sea level. Data from the piezometers showed that, while the shallow aquifer water levels remained within the design tolerance, one of the deep piezometers exhibited a larger decline of water levels related to dewatering inside the slurry wall and this decline was in excess of the tolerance. The primary reason for the tolerance level was to limit drawdown that might induce settlement in the compressible strata, thus potentially impacting adjacent buildings and structures. The water levels in the shallow aquifer closest to the compressible strata were within tolerance during this time. Additionally, the dewatering operation was a temporary construction activity that ceased after the base slab of the structure was poured and cured. As a result, the potential for dewatering-related settlement was considered minimal, and the project proceeded without delay or other mitigation measures.

Retrieval shaft. The ground water table is about 3 m (10 ft) bgs (elevation of approximately 18 m or 59 ft) near the TBM retrieval shaft. Piezometer installation at the final retrieval shaft location was limited to one vibrating wire piezometer installed outside of the CSM excavation support wall and two additional standpipe piezometers up to a few hundred feet away from the excavation. The potential for dewatering settlement was expected to be much lower at the retrieval shaft because of an absence of compressible layers at the site and the fact that the base of the excavation encountered Franciscan Formation sandstone. As excavation dewatering progressed, the adjacent external piezometer indicated more drawdown outside the wall than expected; mimicking the changes in water level inside the excavation, as pumping fluctuated during different stages of the project (Fig. 12). The two open standpipe piezometers located near the excavation exhibited a similar trend in their water levels, although the magnitude of the responses was greatly reduced compared to adjacent to the excavation. The rapid response of this instrument is thought to be related to hydraulic communication through the fractured sandstone rock mass. Dewatering-related settlement was not an issue at the retrieval shaft, as was documented by the AMTS-BSP system and LLS systems included in the instrumentation program.

Lesson 6: Who controls the data? The question of control and accountability for the data generated from a complex system of many instruments in a complicated project is not a trivial matter. There are excellent reasons for the project owner to retain the ultimate control over the data set. There are other situations where the owner sees advantage to having the contractor retain ultimate control, or alternatively a neutral third party can be retained for the sole purpose of operating and maintaining the instrumentation system for the benefit of the project. For the Central Subway project, the instrumentation subcontractor was retained by the tunnel contractor to support construction activities.

It was recommend that the ultimate control of the instrumentation system be retained by the owner, either directly or with an independent third-party arrangement. Just as with any inspection or testing services, an impartial independent perspective should be maintained. A conflict of interest can easily arise when data show adverse trends and approach or exceed project limits. Strict guidelines should also be developed and maintained for situations when modifications to historic data are warranted. When an error in the instrumentation or data processing occurs, it is essential that all anomalies, changes, or modifications be documented to maintain data integrity. Since real-time direct access to the reduced data is now typically available via a web-based system, it presents challenges to adjust or modify algorithms or edit erroneous or unrepresentative data without verifiable documentation. It is critical to thoroughly label and document any changes or modifications to the data. With the ultimate management and maintenance of the instrumentation system in the owner's control, the process of collecting, reviewing, processing, and reporting can clearly be maintained with an eye on overall project success.

Recommendations and conclusions

- The instrumentation installed for the Central Subway project turned out to be somewhat different than the original design. Changes to elements of the project and enhancements suggested by the contractor were combined with negotiated changes in the overall system components. This is not unusual for a project of this magnitude and complexity.
- Overall, the instrumentation system allowed the major objectives of the project to be met, although attention to details and some creative approaches to using different data sets were needed to develop comprehensive interpretations.
- A comprehensive approach and methodology should be applied to designing, installing, operating and managing an instrumentation system from design through construction.
- An understanding of the site geology and the anticipated ground movements is essential in interpretation of the instrumentation data.
- High quality instrumentation data are difficult to achieve on a low bid budget! A qualifications based selection process with the owner contracting directly with the instrumentation specialty firm is recommended.
- Don't compromise on the specifications. The bid process is based on the specifications included in the bid package and should be accounted for. Shortcuts or modifications to procedures and requirements typically come with unforeseen costs or implications.
- Owner-retained instrumentation contractors will typically provide independent data monitoring and interpretation free of potential conflicts, with the contractor's goal being to reduce cost and complete the job.
- Good quality instrumentation data provide an important basis from which to better understand and further develop tunnel design and construction technology for future projects and advance the profession. ■

Acknowledgments

The authors acknowledge the support of and discussions with other staff members of Parsons Brinckerhoff and McMillen Jacobs Associates, which helped improve much of the material presented herein. We also acknowledge the joint efforts and contributions of the construction team including BIH JV and Wang Technology to collect and manage much of the data presented in this paper. The permission to publish the paper by SFMTA is greatly appreciated. The points of view expressed in the paper are solely those of the authors.

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FEATURE ARTICLE

Cutting Edge heads to Denver for fourth installment

by William Gleason, Senior Editor

In 2008, the world quietly hit a milestone that did not receive much fanfare or publicity, but it hit one that marked a turning point in the history of mankind and the way the planet is and will be inhabited in the future. It was in 2008 that, for the first time, more than half of the world's population, an estimated 3.3 billion people, resided in urban areas. The world's population had moved from being a majority of agricultural and rural society to an urban society. Andrew Whalley, deputy chairman for Grimshaw Architects, said this change in where and how people live will continue to increase urban populations and, by 2050, it is estimated that more than 6.4 billion people will live in urban areas. To meet these needs, Whalley, speaking during the keynote session of the 2105 Cutting Edge conference in Denver, CO, said future cities will have to be reimagined and redesigned to be more efficient. A large part of that design will be in the infrastructure of those cities.

At the Fourth Annual Cutting Edge Conference, Sept. 21-23, much of the discussion was around how the tunneling and underground construction industries improve cities in a number of ways, including societal, environmental and in overall efficiency. There was talk, not just about the improvements that society enjoys at the completion of such projects, but also about the challenges faced by the owner and contractor in the construction of such projects.

The conference, titled Urban Tunneling, brought together some of the top minds in the industry to not only discuss the issues faced today, but also those that will shape the industry in the future.

For his part, Whalley spoke about a number of projects around the world and how they have impacted society in ways beyond simply providing a better means for transportation of people or water. Notably, he spoke about the Crossrails project in London.

London is a city of 8.6 million people and a history that dates back nearly 2,000 years. It is a great example of the challenges the industry faces in bringing modern efficiencies to an established city.

Running more than 100 km (62 miles) with more than 42 km (26 miles) of tunnels passing through 40 stations, including 10 new stations, the project is the largest in Europe and will transform the way people move about the city.

To build the project, eight tunnel boring machines (TBM) were used for five, twin-borehole tunnel drives to increase London's rail capacity by 10 percent, creating a better means of transportation.

The 2015 Cutting Edge Conference attracted more than 100 attendees to Denver, CO.

Likewise, New York City presents its own challenges. The city's underground transportation systems has long been its lifeblood, but there are improvements that can be made. One of those is the new Fulton Center.

Fulton Center is a new subway station in lower Manhattan that features open direct paths, widened corridors and new mezzanines to separate entering, exiting and transferring customers.

This better distributes passengers, decreases overcrowding and vastly reduces train loading and unloading delays, improving the overall customer experience. It is a station that helped transformed the subway from dark and scary to light and airy.

Another New York City project was covered by Andy Thompson, vice president, Hatch Mott MacDonald, who discussed the $10.4-billion East Side Access Project. The project included the construction of an underground terminal beneath Grand Central Station. Thompson spoke about the restraints imposed by the congested urban setting and how those restraints impacted everything from scheduling to construction.

It is these kinds of projects that help drive the industry forward, and, while the industry still faces an array of public relations challenges, well-thought-out projects can help stem the tide of negative publicity.

Seattle is a city that knows all too well what kind of publicity can come to rest on the doorstep of a project manager when things don't go as planned. The SR 99 project has been on the front page of the local and national media far too often for the likes of Dave Sowers, deputy program administrator – engineering and program management director, Washington State Department of Transportation. He spoke about regenerating Seattle's central waterfront. And, while he did not go into detail about the TBM that became stuck while boring the tunnel for the SR99 project, he did speak about the need to have a tunnel in Seattle to replace the old Alaskan Way Viaduct. Specifically, he spoke about the challenges faced by a project that involves many governmental and nongovernmental entities that are each trying to serve a different group of constituents

The two-day conference featured a robust technical program with seven sessions in addition to the keynote. A few of the presentations are highlighted in the following section.

Mexico City's wastewater crisis. Mexico City has a population of 19 million people and is one of the largest cities in the world, but its infrastructure is struggling to keep up with demand. Between 1970 and 2000, the population doubled, and today it produces 40 m^3/sec of wastewater. However, capacity is only 10 m^3/sec.

Roberto Gonzales, general manager, Robbins Mexico, spoke about the issues the city is facing and the urban tunneling project that should solve many of the problems.

The National Water Commission, CONAGUA, has developed a critically designated plan to assuage health concerns and the potential for catastrophic flooding if a wastewater line should fail.

The first of these is the country's largest project, the 62-km (38-mile) long Túnel Emisor Oriente (TEO).

Recently, CONAGUA launched a plan to bolster another aging sewer line, the Túnel Emisor Poniente (TEP). The TEP II project involves 5.5 km (3.7 miles) of excavation through volcanic rock, sand, and clay, using a unique hybrid type, "Crossover" TBM that was launched in summer 2015.

Gonzales spoke about the challenges of Mexico City's wastewater network and its urban tunneling projects, with an eye toward TBM excavation at both TEO and TEP II projects and lessons learned.

Remote Cutterhead Maintenance in Pressurized Face TBMs. Difficult variable ground, high face pressure and large diameters have become common challenges for many tunneling projects, Werner Berger, chief engineer, Herrneknecht AG, spoke about these issues in the Innovations in Urban Tunneling session.

According to Berger, whereas previously, technical specifications for seal systems or structures set the limitations, the necessity for options for cutter tool maintenance or chamber interventions are now becoming one of the key determining factors on today's modern TBMs. This presentation highlighted the latest developments and related efforts to reduce intervention frequencies and durations by the use of "non exposure maintenance" technology.

Copenhagen's Cityringen Project. In the TBM Operation and Logistics in Urban Settings session, Valerio Violo, managing director, Seli Tunneling, Denmark, discussed Copenhagen's Cityringen Project. The four TBMs mining the Cityringen project in Copenhagen, faced challenges when driving in a contaminated area of the town. Both drives, the north and the south, required the TBMs to be equipped to cope with the contaminated water table and soil.

Tours. Cutting Edge 2015 also featured a tour to the Eisenhower and Twin Tunnels. The Eisenhower-Johnson Memorial Tunnels are dual-bore, four-lane vehicular tunnels approximately 50 miles (80 km) west of Denver.

Early registration for the 2016 Cutting Edge: Advances in Tunneling Technology conference at the Hyatt LAX - Los Angeles, CA, Nov. 6-9 is now open. To register, go to

Edgerton elected to National Academy of Construction

The National Academy of Construction (NAC) has elected William W. Edgerton, a principal with McMillen Jacobs Associates, as a member of its 2015 class. He was inducted Oct. 23 at the NAC Annual Meeting in Charleston, SC. The 2015 class includes 26 inductees. More than 250 industry leaders were considered for the NAC's rigorous nomination and election process.

Edgerton holds a bachelor's degree in civil engineering from Tufts University and an MBA from George Washington University. He also is a registered professional engineer. From 1999-2011, he served as president of Jacobs Associates, where he directed strategic planning, business development, and administration, and served in a technical capacity on various underground projects. McMillen Jacobs Associates is headquartered in San Francisco, CA.

He currently serves as the manager of tunneling for the DC Water $2.6 billion Clean Rivers Project in Washington, D.C. He is the immediate past chair of the executive committee for the Underground Construction Association of SME and currently serves on the SME Board of Directors. He was recognized as the Outstanding Individual in the Underground Industry at the 2002 North American Tunneling Conference, and, in 2012, received the Golden Beaver Award for Engineering from the prestigious industry group The Beavers. He also has received several distinguished service awards from Tufts University and serves as a program evaluator for civil and construction engineering programs on behalf of ABET. He resides in St. Inigoes, MD. ■

FEATURE ARTICLE

Confessions of a millennial on the job site

Millennials. Doesn't the word just make your blood boil? You've probably encountered one of those kids who think they know best despite a lack of any real experience.

Hi, my name is Erica, and I am a Millennial.

We often get a bad rap, sometimes for good reason. But we do have qualities that are often overlooked. For example, I am happy to share with my generation a real desire to make a difference in the world and a commitment to innovation. Does this mean I think we always have good ideas? No – especially not right away. After all, few of us came anywhere near a piece of construction equipment until arriving for our first job, as was the case for me. We may have fancy degrees, but not many of us learned to run a jackleg drill in school.

Two weeks after graduating college in 2011, I packed up my bags and moved to New York City to work as a field engineer for Traylor Bros. Inc. on the Queens Bored Tunnels project (Granite/Traylor /Frontier Kemper, JV), part of NYC MTA's multi-billion dollar Long Island Railroad East Side Access project. It was here I became acquainted with the notorious New York City union workers. Perhaps the greatest challenge of my career thus far was earning the respect of the field supervision and craft workers on this first project.

The first time I asked a maintenance mechanic to clean a piece of equipment in accordance with our maintenance protocol I got a flat-out "No." It was the most powerless I had ever felt. But why should these experienced workers trust a 21-year-old girl with her civil engineering degree and no prior experience? I realized no employee on the job had any reason to listen to me — not until I proved my worth. Fortunately, I arrived on the job site just as we were commissioning the slurry plant for the first tunnel drive. I dove into learning as much about the slurry tunneling process as possible and was able to quickly pick up the ins and outs of running the slurry separation plant. As none of the other engineers or management had first-hand experience on a slurry tunneling job, I soon became the go-to engineer in the slurry plant. No one questioned me if I asked to have something done around the plant after that, or if they did, they quickly learned that I had a convincing answer as to the need for the task. I was even able to play a large role in shaping our slurry monitoring and control methodology.

by Erica Frederickson

Erica Frederickson, member UCA of SME, is is a field engineer with Traylor Bros., Inc. email efrederickson@traylor.com.

The author faced challenges, and learned lessons at New York's East Side Access project.

After almost a year in the slurry plant, I asked to be reassigned to the tunnel and had my first opportunity to work on a tunnel boring machine. That first experience was not your typical one. About a month in, we clogged our rock crusher and spent four weeks mucking out the cutterhead in compressed air. This was an unplanned stop in sandy ground conditions. It is only now, years later, that I understand the full magnitude of the risks we were forced to undertake to save the job. Once, I even entered the bubble chamber under compressed air myself with a miner to reset a switch after all the other miners on site had already completed their one allowed daily intervention. The Queens Bored Tunnels project ended up being a great success thanks to the hard work and determination of the whole team on the job. And although it was not an easy start for me, I was able to make a significant contribution to the success of the project. The circumstance that no one on the job had extensive slurry tunneling experience turned out to be fortunate, leveling the playing field for an inexperienced engineer and allowing me to establish myself as a valued member of the team.

I'm glad I did not lose heart at the first sign that I was out of my element. I can't wait to one day ride the Long Island Railroad through the tunnels I helped build. I look forward to completing more, yet-to-be-identified projects that will make a lasting difference for the next generation to follow us millennials. Lastly, I want to say: Thanks, construction industry, for giving me a chance. But thanks for not making it too easy. ■

COMPILED BY JONATHAN KLUG, DAVID R. KLUG & ASSOCIATES

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Gateway Tunnel	Amtrak	Newark	NJ	Subway	14,600	24.5	2016	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	Kiewit - Shea JV awarded
Water Tunnel #3 Stage 3 Kensico	NYC-DEP	New York	NY	Water	84,000	20	2017	Under study
Cross Harbor Freight Tunnel	NYC Reg. Develop. Authority	New York	NY	Highway	25,000	30	2016	Under study
South Conveyance Tunnel	City of Hartford	Hartford	CT	CSO	16,000	26	2016	Bid date 02/09/16
Red Line Tunnel - Cooks Lane Tunnel	MD Transit Administration	Baltimore	MD	Subway	14,000	22	2016	Project delayed
Red Line Tunnel - Downtown Tunnel	MD Transit Administration	Baltimore	MD	Subway	36,000	22	2015	Project delayed
Purple Line - Plymouth Tunnel	MD Transit Administration	Baltimore	MD	Subway	1,000	30x40	2016	Proposals due 1Q 2016
Thimble Shoal Parelel Tunnel	Chesapeake Bay Bridge & Tunnel Dist.	Chesapeake	VA	Highway	5,700	45	2016	Proposal stage
Northeast Boundary Tunnel	DC Water and Sewer Authority	Washington	DC	CSO	17,500	23	2018	Under design
U.S. Highway 17 drainage tunnel	City of Charleston	Charleston	SC	CSO	8,420	12	2016	Bid date 1Q 2016
Bellwood Tunnel Phase 1	City of Atlanta	Atlanta	GA	Water	6,000	12	2016	Bid date 11/17/15
Phase 2					21,000	12	2016	Under design
Olentangy Relief Sewer Tunnel	City of Columbus	Columbus	OH	Sewer	58,000	14	2016	Under design
Blacklick Creek San. Interceptor Tunnel	City of Columbus	Columbus	OH	Sewer	24,000	10	2015	Bid date 11/18/15
Alum Creek Relief Tunnel Phase 1	City of Columbus	Columbus	OH	Sewer	30,000	18	2016	Under design
Phase 2					21,000	14	2017	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
Ohio Canal Interceptor Tunnel	City of Akron	Akron	OH	CSO	6,170	27	2015	Kenny/Obayashi awarded
Continental Rail Gateway	CRG Consortium	Detroit	MI	Rail	10,000	28	2015	Under design
ALCOSAN CSO Program	Allegheny Co. Sanitary Authority	Pittsburgh	PA	CSO	35,000	20	2016	Under design
Lower Pogues Run	Indianapolis DPW	Indianapolis	IN	CSO	9,000	18	2016	Under design

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
White River Tunnel	Indianapolis DPW	Indianapolis	IN	CSO	28,000	18	2016	Under design
Three Rivers Protection/Overflow	City of Fort Wayne	Fort Wayne	IN	CSO	26,400	12	2017	Under design
Albany Park Stormwater Diversion	Metro.Water Reclamation Dist.	Chicago	IL	CSO	5,700	18	2015	Kenny Const. low bidder
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	Bid date 12/18/15
Downtown Bellevue Tunnel - E330	Sound Transit	Seattle	WA	Transit	2,000	40x30	2015	Atkinson low bidder
Ballard to Washington Tunnel	Seattle Public Utilities	Seattle	WA	CSO	14,250	14	2018	Under design
L.A. Metro Regional Connector	Los Angeles MTA	Los Angeles	CA	Subway	20,000	20	2014	Skanska-Traylor JV Awarded
L.A. 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 2016 2017	Skanska/Traylor, Shea awarded Under design Under design
Speulvada Pass Corridor	Los Angeles MTA	Los Angeles	CA	High/Trans.	55,500	60	2017	Under study
Northeast Interceptor Sewer 2A	LA Dept. of Water and Power	Los Angeles	CA	Sewer	18,500	18	2015	RFQ under way
River Supply Conduit - Unit 7	LA Dept. of Water and Power	Los Angeles	CA	Water	13,500	12	2015	Under design
JWPCP Effluent Outfall Tunnel project	Sanitation Districts of LA	Los Angeles	CA	Sewer	37,000	18	2015	Bid date late 2016
Freeway 710 Tunnel	CALTRANS	Long Beach	CA	Highway	26,400	38	2016	Under design
BDCP Tunnel #1 BDCP Tunnel # 2	Bay Delta Conservation Plan	Sacramento	CA	Water	26,000 369,600	29 35	2018 2019	Under design Under design
SVRT BART	Santa Clara Valley Trans Authority	San Jose	CA	Subway	22,700	20	2016	Under design/ Delayed
Coxwell Bypass Tunnel program	City of Toronto	Toronto	ON	CSO	35,000	12	2015	Under design
Yonge St. Extension	Toronto Transit Commission	Toronto	ON	Subway	15,000	18	2016	Under study
Scarborough Rapid Transit Extension	Toronto Transit Commission	Toronto	ON	Subway	25,000	18	2017	Under design
CSS - East-West	City of Ottawa	Ottawa	ON	CSO	14,400	10	2015	Under design
CSS - North-South	City of Ottawa	Ottawa	ON	CSO	5,300	10	2015	Under design
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

NEW PRODUCTS

Atlas Copco's Meyco Versa shotcrete rig offers accurate spraying

Wet mix shotcrete in midsized tunnels can now be applied accurately by a single operator with the self-contained mobile Atlas Copco Meyco Versa concrete spraying system. The stable spraying platform cuts project time while increasing operator comfort and safety.

The new rig comes with a sturdy mezza telescoping boom that provides stability during spraying operations. The theoretical pump capacity of the Versa system is 19.9 m^3/hr (26 cu yd/hr) at 4,999 kPa (725 psi). Its concrete hopper holds 250 L(66 gal).

Low pulsation and high dosing accuracy from the unit's highly accurate

The Meyco Versa is 2.6 m (8.5 ft) tall, 7.8 m (25.6 ft) long and has a turning radius of 6.7 m (22 ft) outer and 3.5 m (11.5 ft) inner.

Dosa system and data-logging feature means lower costs from material wasted in over-application. Dosa also adjusts liquid accelerator volume and flow instantly during operation and has an auto-stop function to prevent under-spraying. The Versa 4-by-4 carrier with crab steering is powered by a 56-kW (75-hp) Deutz EPA Tier 4 Final, four-cylinder engine. Its entire design shares components in common with other Meyco machinery, ensuring ready availability of parts. Components are arranged to minimize setup and cleaning time. All key functions are carried out through radio remote control.

www.atlascopco.us

Akkerman P100E offers alternative to Tier 4 diesel standards

The P100E Power Pack from Akkerman was developed to provide contractors with an alternative to address regional requirements of the EPA's mandate for Tier 4 diesel emission standards. The P100E is powered by a 75-kW (100-hp) motor to match the hydraulic requirements of Akkerman's guided boring machine jacking frames. The electrical motor allows contractors to capitalize on the unit's useable horsepower, nearly 30 percent more than the diesel version, due to a higher

The P100E is comparable to the diesel version in the Power Pack family.

input horsepower to the pump. The soft-start feature makes it possible to couple the unit with an array of generator sizes, down to the recommended operating minimum requirement of 125 kW/150 kVa.

To contend with the demanding environments where pipe jacking systems are used, the unit features a totally enclosed fan-cooled electric motor. The fan-cooled motor is a robust and more reliable power source and has also been integrated into the tunnel boring system's 5200 pump unit.

The control panel is located on the container's door for accessible operation. Power pack startup can be initiated from the control panel or with the in-shaft pendant. The unit's three-phase indicator provides a visual indication of correct connections to the generator. The power supply cable is secured to the control panel and conveniently stored on the container door. ■

www.akkerman.com

PERSONAL NEWS

ERIC EISOLD, PG, has been named vice president of Bradshaw Construction Corp. He has more than 20 years of experience in heavy civil construction. Previously, he held the position of area manager, responsible for the day-to-day management of estimating and project management departments. In his new position, Eisold will be responsible for expanding the pipeline of new business and building the company's market position as well as continuing his management role in estimating and operations. ■

EISOLD

ADVERTISER INDEX • DECEMBER 2015

ABC Industries 52
Advanced Concrete Technologies 55
Alpine Equipment 33
Antraquip Corporation 40
Atlantic Industries Ltd 6
Atlas Copco Construction & Mining USA LLC 46
Avanti International . . . . . Inside Front Cover, 16
Bradshaw Construction Corp. 51
Brokk Inc 42
Brookville Equipment Corp 48
CDM Smith 32
CTS Cement Manufacturing Corp 43
Daigh Co Inc 57
David R. Klug & Associates Inc 53
Dr. Mole Inc 56
DSI Underground Systems 20, 21
FKC-Lake Shore 24, 25
Gall Zeidler Consultants 50
Geokon 36
Grindex Pumps 44
Hatch Mott MacDonald 35
Hayward Baker Inc. . . . . . Outside Back Cover, 30
Heintzmann Corporation 54
HIC Fibers 54
HNTB Corportation 38
ILF Consultants 55
Jennmar Corporation 12, 13
Kiewit Infrastructure Co 28, 29
Lachel & Associates 46, 47
Malcolm Drilling Co Inc 3, 17
McMillen Jacobs Associates 56
Mining Equipment Ltd 41
Moretrench 22, 23
Mueser Rutledge Consulting Engineers 57
Naylor Pipe Company 31
Northwest Laborers-Employers Training Trust Fund 49
Parsons 34
Putzmeister Shotcrete Technology 26, 27
Sandvik Mining & Construction LLC 18, 19
Schauenburg Flexadux Corp 39
Surecrete Inc 45
Tensar International Corp. 37
The Robbins Company 14, 15

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TUNNELING & UNDERGROUND CONSTRUCTION INDEX TO VOLUME 9
January-December 2015
Feature Articles, Industry Newswatch, Technology News

A

Australia
Plans are in for new tunnel in Mebourne, Sept 20

B

Baltimore
Engineering of Cooks Lane Tunnel: An overview of challenges, Jun 118

Baltimore Red Line project
Engineering of Cooks Lane Tunnel: An overview of challenges, Jun 118

Bent, William
Cleaning Hartford waterways through underground storage, Mar 149

Black River Tunnel
Black River Tunnel project phase 1: Innovative quality control approach for installation and testing of rock bolts in shafts, Jun 113

Bono, Roberto
Lake Mead intake No. 3: TBM tunneling at high pressure, Sep 135

Brierley Associates
Merges with Mike McTeer, Jun 3

C

California
California Governor defends plans for $15 billion twin tunnel water diversion, June 3

Cimiotti, Claudio
Lake Mead intake No. 3: TBM tunneling at high pressure, Sep 135

Chairman's Column
Exciting times, March 2

Mega projects present more than just technical challenges, June 2

WTC 2016 is around the corner, Sept 2

China
China considers tunnel under Mount Everst, June 8

Combined sewer overflow
Cleaning Hartford waterways through underground storage, Mar 149

Coming Events/Short Courses
Mar 61, Jun 30, Sep 61, Dec 6, 9

Congress
San Francisco to host ITA World Tunnel Congress 2016, Sep 121

Connecticut
Cleaning Hartford waterways through underground storage, Mar 149

Cooks Lane Tunnel
Engineering of Cooks Lane Tunnel: An overview of challenges, Jun 118

Crossrail Project
Tunneling effors on Crossrail Project complete, Sept 18

D

DC Water
DC Water's first TBM completes 4.5 mile tunnel for cleaner Anacostia River, Sept 7

Deep Rock Tunnel Connector
TBM mining for the Deep Rock Tunnel Connector project, Sep 128

E

Edberg, J.
Black River Tunnel project phase 1: Innovative quality control approach for installation and testing of rock bolts in shafts, Jun 113

Edgerton, William
Exciting times, March 2

Mega projects present more than just technical challenges, June 2

Elioff, Amanda
San Francisco to host ITA World Tunnel Congress 2016, Sep 121

G

Gateway Project
US transportation secretary opens discussion about Gateway Project, Sept. 4

Guay, Mark
TBM mining for the Deep Rock Tunnel Connector project, Sep 128

H

Haacke, Eric
TBM mining for the Deep Rock Tunnel Connector project, Sep 128

Hogan, William
Cleaning Hartford waterways through underground storage, Mar 149

I

India
TBM mining for the Deep Rock Tunnel Connector project, Sep 128

Indiana
TBM mining for the Deep Rock Tunnel Connector project, Sep 128

Indianapolis
TBM mining for the Deep Rock Tunnel Connector project, Sep 128

Robbins begins work on Eagle Creek Tunnel, June 10

Infrastructure
Obama administration calls for improvements to nation's infrastructure, March 4

ITA
San Francisco to host ITA World Tunnel Congress 2016, Sep 121

J

JF Shea Construction
TBM mining for the Deep Rock Tunnel Connector project, Sep 128

Joint ventures
What's in a name? A look at the who, what and why of forming a joint venture partnership, Mar 156

Jones, Zachary D.
The allocation of differing site condition risk, Mar 159

K

Kaneohe-Kailua Project
Construction begins on Hawaii's longest tunnel, Sept 16

Kiewit
TBM mining for the Deep Rock Tunnel Connector project, Sep 128

Kral, Steve
RETC headed to New Orleans for 2015 conference, Jun 124

Kirby, T,
Engineering of Cooks Lane Tunnel: An overview of challenges, Jun 118

L

Lake Mead
Lake Mead intake No. 3: TBM tunneling at high pressure, Sep 135

Las Vegas
Lake Mead intake No. 3: TBM tunneling at high pressure, Sep 135

Light Rail
Engineering of Cooks Lane Tunnel: An overview of challenges, Jun 118

M

Moonin, Erika
Lake Mead intake No. 3: TBM tunneling at high pressure, Sep 135

N

Nasri, Verya
Cleaning Hartford waterways through underground storage, Mar 149

Engineering of Cooks Lane Tunnel: An overview of challenges, Jun 118

New Jersey
US transportation secretary opens discussion about Gateway Project, Sept. 4

New Orleans
RETC headed to New Orleans for 2015 conference, Jun 124

RETC hosts more than 1,250 and 157 exhibitors in New Olreans, LA, Sept 21

New Media
Jet Grouting: Technology Design and Control, Sep 61

Rapid Excavation and Tunneling Conference Proceedings, Jun 30

New Products
Atlas Copco Meyco Versa shotcrete rig, Dec 76

Akkerman P100E PowerPack, Dec 76

North Link Project
Robbins TBM begins work on North Link Project, June 10

New York
New York Harbor tunnel proposal discussed, March 7

Tunnel option one of four for I-81 replacement, June 4

US transportation secretary opens discussion about Gateway Project, Sept. 4

Nickerson, Jim
Lake Mead intake No. 3: TBM tunneling at high pressure, Sep 135

O

Obituaries
Burke, Jack, Sep 59

Cruz, Edward, Sep 60

McKelvey, James, Sep 60

Ohio
Black River Tunnel project phase 1: Innovative quality control approach for installation and testing of rock bolts in shafts, Jun 113

P

Parker, Harvey
San Francisco to host ITA World Tunnel Congress 2016, Sep 121

Personal News
Mar 61, Jun 30, Sep 56, Dec 76

R

Rashidi, S.
Engineering of Cooks Lane Tunnel: An overview of challenges, Jun 118

RETC
RETC headed to New Orleans for 2015 conference, Jun 124

RETC hosts more than 1,250 and 157 exhibitors in New Olreans, LA, Sept 21

Scholarships presented, Sep 58

Riyadh Metro Project
Bechtel-led team begins work on $10 billion Riyadh Metro Project, Sept 12

Risk management
The allocation of differing site condition risk, Mar 159

Roach, Michael
What's in a name? A look at the who, what and why of forming a joint venture partnership, Mar 156

Robbins
Robbins TBM begins work on North Link Project, March 6

Construction begins on Hawaii's longest tunnel, Sept 16

Rock bolts

Black River Tunnel project phase 1: Innovative quality control approach for installation and testing of rock bolts in shafts, Jun 113

S

San Francisco

San Francisco to host ITA World Tunnel Congress in 2016, Sept 29

Seattle

Access pit for Bertha repairs completed in Seattle, Mach 5

Seattle Tunnel Partners announce new schedule for Bertha, Sept. 6

Silber, Artie

WTC 2016 is around the corner, Sept 2

South Hartford Conveyance and Storage Tunnel

Cleaning Hartford waterways through underground storage, Mar 149

Stolkin, Michael

TBM mining for the Deep Rock Tunnel Connector project, Sep 128

SR-99 Project

Access pit for Bertha repairs completed in Seattle, Mach 5

Seattle Tunnel Partners announce new schedule for Bertha, Sept. 6

T

TBM

Lake Mead intake No. 3: TBM tunneling at high pressure, Sep 135

Robbins TBM begins work on North Link Project, March 6

Seattle Tunnel Partners announce new schedule for Bertha, Sept. 6

DC Water's first TBM completes 4.5 mile tunnel for cleaner Anacostia River, Sept 7

Construction begins on Hawaii's longest tunnel, Sept 16

Tunneling

What's in a name? A look at the who, what and why of forming a joint venture partnership, Mar 156

U

UCA of SME

Highlights of the UCA Executive Committee Meeting, Sep 55

Robinson and O'Donnell join UCA Executive Committee, Sep 55

UCA seeks nominations for the Executive Committee, Sep 55

UCA scholarships are presented at RETC, Sep 57

W

Washington

King County sues insurers over Brightwater Project, June 6

Water

Cleaning Hartford waterways through underground storage, Mar 149

Lake Mead intake No. 3: TBM tunneling at high pressure, Sep 135

World Tunnel Congress

San Francisco to host ITA World Tunnel Congress 2016, Sep 121

WTC 2016 is around the corner, Sept 2