T&UC®

TUNNELING & UNDERGROUND CONSTRUCTION

THE OFFICIAL PUBLICATION OF UCA OF SME   WWW.TUCMAGAZINE.COM   VOLUME 8 NO 4 DECEMBER 2014

San Francisco Bay Tunnel

Risk management in tunneling

Special Editorial Section from the publisher of *Mining Engineering*

T&UC®
TUNNELING & UNDERGROUND CONSTRUCTION
AN OFFICIAL PUBLICATION OF UCA OF SME WWW.UCA.SMENET.ORG VOLUME 8 NO 4 DECEMBER 2014

COVER STORY

In this issue — The San Francisco Bay Tunnel was part of a $4.6-billion water system improvement program to repair, replace and seismically upgrade the 1920s era infrastructure. Included was an 8-km (5-mile) tunnel, page 59. Also, the importance of risk management in tunneling projects is discussed on page 65. Cover photo courtesy of San Francisco Public Utilities.

TUNNELING & UNDERGROUND CONSTRUCTION (ISSN 0026–5187) is published quarterly by the Society for Mining, Metallurgy, and Exploration, Inc., at 12999 E. Adam Aircraft Circle, Englewood, CO 80112-4167. Phone 1–800–763–3132 or 303–973–9550. Fax: 303–973 –3845 or e-mail: sme @smenet.org. Website: www.smenet.org. **POSTMASTER:** Send changes of address to TUNNELING & UNDERGROUND CONSTRUCTION, 12999 E. Adam Aircraft Circle, Englewood, CO 80112-4167. Article copies and back issues available on microfilm or microfiche from Linda Hall Library in Kansas City, Mo. Printed by Cummings Printing Co.

CONTENTS

FEATURE ARTICLES

T&UC®

CHAIRMAN'S COLUMN

Information exchange improves the entire industry

I attended the Cutting Edge Conference in New York City, Nov. 3-4.

For those of you who missed it, the focus was "Groundwater Control for Tunneling." Despite the somewhat limited attendance, the conference program was one of the best that the UCA of SME has put on in recent years. Why is that? Because, for the most part, the case studies included projects that were forced to overcome adversity: they didn't all go right all the time. It was not the normal assortment of "Here's a project that my company did really well and it all came out great. You should hire us the next time."

The case studies included projects with serious problems: lots of water that forced changes in mining methods, contaminated water that forced changes in alignment, hot and cold water that challenged both personnel and equipment, and a host of other difficulties. Adding to those case studies, the speakers presented new engineering approaches, materials and equipment that have a good chance of improving the success of future projects in especially difficult environments. It is axiomatic that lessons we learn from projects that don't go as well as planned are far more useful in advancing the state of the practice than those from projects that come out just the way the planners and designers intended.

Facilitating an exchange of information like this is one of the things that the UCA does very well. It's an important means by which we achieve our mission: "To promote the responsible development and use of underground space and facilities." Recognizing this, UCA Strategic Committee Number 3 is tasked with identifying action plans for how we can "Improve the effectiveness and efficiency of the underground construction industry."

Conferences like Cutting Edge are but one way to do this. Keep an eye out for future initiatives by the UCA in such areas as codes and regulations that impact underground construction; new technical publications to facilitate the exchange of similar information; and identifying guidelines for education and training of planners, engineers and construction supervisors.

The UCA is doing its best to identify ways in which our industry can be improved, and make the development of underground space more competitive with other uses of the country's financial resources. Please review the charge and leadership of all three of our strategic committees (page 10). And please give us feedback. This will help make our industry a more profitable and effective place to make a career. ■

William W. Edgerton,
UCA of SME Chairman

Hartford Metro District Commission initiates first of two CSO tunnels

The Metropolitan District Commission (MDC) of Hartford, CT, is initiating the first of two large combined sewer overflow (CSO) tunnel projects with the prequalification of tunnel contractors for the South Hartford tunnel. A prequalification RFQ is expected to be released prior to the end of 2014 with construction bidding scheduled for September 2015. Interested contractors may register with the MDC's ebid system at www.ebidexchange.com/mdc to receive notifications and access RFQ documents.

A nonmandatory presubmittal meeting will be held with interested contractors shortly after the release of the RFQ. The second tunnel, known as the North Tunnel Extension, is being initiated with a basis of design report in early 2015 with construction bidding planned for 2018.

Work included in the South Hartford tunnel contract will include construction of a 5.4-m (18-ft) finished (lined) diameter tunnel 6,650 m (21,800 ft) in length in deep rock, launch shaft, retrieval shaft, pump station excavation shaft, eight drop shafts, adits, six deaeration chambers and odor control at potential release points. The launch shaft is to be excavated at 11.5-m (38-ft) diameter, the retrieval shaft at 10-m (33-ft) diameter, and the pump station shaft at 22-m (74-ft) diameter. The drop shaft diameters vary from 106 cm to 182 cm (42 in. to 72 in.). The estimated construction duration is 54 months.

At this time, the liner will be at the option of the contractor and may be either a cast-in-place liner or a precast liner. This is subject to change as the design is finalized. The contract documents will include a geotechnical data report, a geotechnical baseline report and dispute resolution board participation. Escrowed bid documents will also be required.

The completion of the overall South Hartford project will also include three additional construction contracts for the fit out of the tunnel pump station along with two consolidation conduit contracts to convey flows from current overflow locations to the drop shafts. The consolidation contracts will be bid in 2016 and the tunnel pump station fit out in 2017.

Both the South Hartford tunnel and the North Tunnel Extension are required components of a federal consent decree and a state consent order. The tunnels are major components of the MDC's Clean Water Project and will complement the Hartford water pollution control plant's expansion to treat wet weather flows up to 200 million gal/day.

Local voters have already authorized funding for the Hartford plant expansion, the design and construction of the South Hartford Tunnel and the basis of design report on the North Tunnel Extension. Supplemental funding is anticipated from the CT DEEP for all of these projects. With the funding comes the requirement of 6 percent minority business enterprise and 5 percent women business enterprise participation.

The North Tunnel Extension will be similar in size and length as the South Tunnel. Final diameter, length and route will be determined in the basis of design report to be concluded in early 2016. ■

Spadina extension could be delayed again

Toronto's $2.5-billion, six-stop Spadina subway extension from Downsview Station to Vaughan Metropolitan Centre was originally supposed to open in 2015. But in late 2012, the Toronto Transit Commission (TTC) said it wouldn't happen until the fall of 2016. It now appears that date could be "at significant risk," said TTC CEO Andy Byford, who admitted that another delay would almost certainly have budget implications, Toronto's *Metro News* reported.

The subway extension into York Region has suffered setbacks almost since work began in 2010. The subway construction started 16 months late due to funding issues and the schedule was never adjusted to account for that, said Byford. Other difficulties ranged from an unusually harsh winter last year to tunneling issues under York University.

In 2011, 24-year-old construction worker, Kyle Knox, was killed at the York University site, and the Ontario Ministry of Labour investigation suspended some work there into 2012.

Three stations — Pioneer Village, York and Vaughan Metropolitan Centre — have been particularly problematic, according to *Metro News*.

Last year, TTC officials admitted there were issues with Walsh Construction, which has the $170-million contract to build the Pioneer Village Station.

(Continued on page 6)

Ancient tunnel yields 2,000-year old relics

It's not very often that a news item in *T&UC* focuses on a tunnel that has been closed, but then again, it's not very often that ancient artifacts are discovered in a tunnel that was sealed nearly 2,000 years ago.

The Associated Press reported on a years long exploration of a tunnel in the ancient city of Teotihuacan, Mexico. Archaeologists working at the site have discovered thousands of relics in three chambers that could hold more important finds.

Project leader Sergio Gomez said researchers recently reached the end of the 103-m (340-ft) tunnel after meticulously working their way down its length, collecting relics from seeds to pottery to animal bones.

A large offering found near the entrance to the chambers, some 18 m (59 ft) below the Temple of the Plumed Serpent, suggests they could be the tombs of the city's elite.

"Because this is one of the most sacred places in all Teotihuacan, we believe that it could have been used for the rulers to ... acquire divine endowment, allowing them to rule on the surface," Gomez said.

Unlike at other pre-Columbian ruins in Mexico, archaeologists have never found any remains believed to belong to Teotihuacan's rulers. Such a discovery could help shine light on the leadership structure of the city, including whether rule was hereditary.

"We have not lost hope of finding that, and if they are there, they must be from someone very, very important," Gomez said.

So far Gomez's team has excavated only about 60 m (200 ft) into the chambers. A full exploration will take at least another year.

Initial studies by the National Institute of Anthropology and History show the tunnel functioned until around 250 A.D. when it was closed off, *The Associated Press* reported.

Teotihuacan long dominated central Mexico and had its apex between 100 B.C. and 750 A.D. It is believed to have been home to more than 100,000 people, but was abandoned before the rise of the Aztecs in the 14th century.

Today, it is an important archaeological site on the outskirts of Mexico City and a major tourist draw known for its broad avenues and massive pyramids. ■

Spadina: Subway extension faces another delay

(Continued from page 4)

Byford said the TTC has since been working with Walsh and its other contractors to recover the lost time. But the contractors are having difficulty with subcontractors, who want a premium to expedite the necessary work.

The subway tunneling is complete, most of the concrete has been poured and the base structures are in place. There is still plenty of work to be done installing track, signaling, power and automatic train control, and testing the trains.

"Although late fall 2016 seems a long way away, it isn't," said Byford.

Pioneer Village is particularly critical in completing the project, or at least opening some stations. But temporary piles that support the structure being built around them are standing in the middle of the track area. There's no way to run trains up the line as long as they are there.

Whether those can be removed earlier is one idea Byford hopes to explore with a team of international experts he is recruiting to study how the schedule could be expedited. That panel was expected to be on site in November.

"Are there things we can safely and legitimately claw back to make up lost time? No option is being left off the table," he said.

Byford would not speculate on the length of another potential delay. He said he hopes to know more once the expert panel has looked at the schedule and remaining work.

"If the schedule has to change, what we cannot do is keep announcing dates and keep missing them," he said.

Byford has already informed the TTC board and mayor-elect John Tory that the subway opening could be delayed. He said Tory appreciated the warning, and the TTC has promised the incoming mayor will be the first to know of any revisions to the opening schedule.

The new subway stops are expected to generate an additional 30 million TTC trips annually by 2021, with the York University stop expected to be the main destination.

The project is being funded by Ottawa, the province, Toronto and York Region. ■

Correction

In the September issue of *T&UC* the location of the McOrmond Drive sanitary and storm sewer trunk project was incorrect. The $32 million project is being built in the city of Saskatoon, Canada. Work is being completed by Michels Canada Co. ■

Tunnel boring machines used to drive tunnels at Australian coal mine

In August 2014, major progress was made at the Grosvenor decline tunnel project coal mine in Queensland, Australia, when a Robbins dual mode earth pressure balance (EPB) rock tunnel boring machine (TBM) was successfully rolled out from the first of two access tunnels. The specialized machine is the first TBM to be used at a coal mine in Queensland, and there are many aspects of both the TBM and project that make it unique.

The 8-m (26.2-ft) Robbins machine and continuous conveyor system were chosen by Anglo American for the project, where it began excavation in December 2013 for two tunnels consisting of sedimentary hard rock up to 120 MPa UCS, mixed ground of mainly sand and clay, and coal seams.

The TBM was chosen over the traditional roadheader method for several reasons including speed of excavation — the swift machine has proven to be about 10 times faster than a roadheader. Another reason was maintenance. "The final tunnels need to remain intact for the life of the Grosvenor Mine, which is expected to be about 40 years, and be maintenance-free with cement linings," said Adam Foulstone, underground construction manager at Anglo American. "This was the biggest factor when determining our tunneling method."


The Grosvenor decline tunnel project in Queensland, Australia, was built with a dual mode Robbins tunnel boring machine.

The machine is optimized toward hard rock (single shield) excavation, as only the first 300 m (984 ft) of each tunnel are in mixed ground. A two-stage, center-mounted screw conveyor works in hard and mixed ground conditions, and the cutterhead can be outfitted with backloading cutters in hard rock mode, as well as knife bits and scrapers in EPB mode.

Additionally, the machine uses its EPB technology to deal with methane gas, a standard in coal mines. To ensure worker safety and avoid explosions, gas levels must be kept under 2 percent at all times. If any methane leakage is detected, a snuffing box evacuation system will draw the methane out of the screw conveyor and directly into the ventilation system. In the first tunnel, methane was detected within the first 300 m (984 ft). "The snuffing box was very useful," said Foulstone. "It allowed us to monitor the tunnel face, plus a boundary sensor ensured we didn't go above 0.5 percent methane content."

The first tunnel is at a grade of 1:6 for men and materials; the other at 1:8 for conveyors. The approximate lengths of the tunnels are 1,100 m (3,600 ft) and 950 m (3,100 ft), respectively. Lengths of the tunnels are approximate and based on the location of the coal seam. "As soon as we see coal coming out of the conveyor, we conduct face inspection to verify. Once we have a coal seam taking up approximately 50 percent of the tunnel diameter, we know we've gone far enough," said Foulstone.

Australian tunnels require constant ground support, and the TBM was customized with a Robbins-designed Quick Removal System, which allowed the machine to be removed from the initial tunnel and retracted from its outer shield bodies, leaving them behind to support the ground. At the second tunnel, a new set of shields will be assembled onto the machine. Upon completion of the second tunnel, these shields will also be left in place. In order to transport the machine to the next tunnel 2 km (1.2 miles) away, it had to be split into two sections and required a large 600-t (661- st) lift. The machine was expected to begin boring the second tunnel in November 2014 following reassembly, and reach its final breakthrough in March 2015.

"This is the better methodology," said Foulstone, when asked if he thought more TBMs would be used on mines in the future. "[Use of TBMs] opens up a new chapter, not just with Anglo American, but with the whole coal industry in Australia. Now we can draw up a new coal mine in less than a year, compared with two to three years if we use roadheaders." Foulstone also noted that there are few limitations for TBMs in mines. "Anywhere we need to get men and materials into an underground environment is an opportunity to use a TBM," he said. ■

Excavation of TBM resumes in Seattle after brief delay

Excavation near the trapped tunnel boring machine (TBM) at Seattle, WA's SR-99 project was halted when a collection of shells were found on Oct. 23 near the TBM named Bertha.

Fearing the shells could be part of an important historical discovery work was halted while archaeologists examined the site.

On Nov. 3 state archaeologists gave Seattle Tunnel Partners clearance to resume access pit excavation.

Archaeologists believe the shell deposits are the product of commercial shellfish activities carried out by early Seattleites around the turn of the 20th century, but more information will be obtained after a full laboratory analysis is completed. Still, after exercising due diligence, and following state and federal laws through coordination with the Department of Archaeology and Historic Preservation, tribes and King County, excavation was allowed to proceed.

The find caused 10 days' delay to STP's repair operation, which entails detaching Bertha's cutting head, damaged seals and main bearing, so the drive parts can be repaired or replaced at street level. STP has set a goal of restarting the tunnel bore to South Lake Union in March, as described here by STP director Chris Dixon. The contractors haven't issued any further notice of delays. "As far as we know, they're still planning to lift the machine out of the ground in December," said Laura Newborn, a DOT spokeswoman.

The giant tunneling machine remains buried 18 m (60 ft) below street level, following a stall in early December.

When the deep vault is finished, Bertha will drill through the concrete about 13 m (43 ft), into open air below a crane. The $2-billion project is at least a year behind schedule, and officials now hope to open the four-lane highway tube to traffic in late 2016.

Prior to the delay, Hitachi built and shipped a new seal ring in Japan for the stranded machine.

The new bearing block is to be installed this winter inside Bertha.

Previously, Seattle Tunnel Partners (STP) said it kept a spare bearing, a requirement of its $1.44-billion contract to build the four-lane Highway 99 tunnel from Sodo to South Lake Union. In early December 2013, the rotary cutting drive overheated, and grit penetrated the rubber seals that protect the German-made bearing. The new Hitachi seal ring contains stiffer material, and the front end generally will be strengthened by steel rods and plates. ■

UCA of SME approves new five-year strategic plan

In April of this year, the Executive Committee of the Underground Construction Association of SME (UCA) approved the division's strategic plan, which the committee formulated in November of last year. The plan outlines the major goals and objectives for the next three to five years.

One of the first steps in building the strategic plan was to identify a mission statement for the UCA. The mission of the UCA is to promote the responsible development and use of underground space and facilities.

In addition to creating a mission statement, three strategic goals were developed.

Strategic Goal 1: Become the primary resource for underground construction issues and information requests.

Strategic Goal 2: Improve the image of underground construction in the minds of the public, government, owners and all key constituencies.

Strategic Goal 3: Improve the effectiveness and efficiency of the underground construction industry.

The next step was to develop an action plan for how the UCA can achieve each of these goals in the near term. It is the division's intent to create a strategic committee for each of these goals to develop the necessary action plans. These strategic committees will consist of a chair, four to six members, a UCA staff member and an Executive Committee member liaison.

UCA Strategic Goal One: Become the Primary Resource for Underground Construction Issues and Information Requests.

- Develop a UCA media package.
- Identify a UCA spokesperson; develop protocols for media engagement.
- Establish an "expert list" for subject matter areas.
- Identify areas of expertise for all 1,100 UCA members.
- Maintain and update knowledge base including case histories and historic achievements in underground construction.
- Sponsor UCA sessions at other industry events.
- Gain political/owner support and acceptance for underground solutions through outreach, media and targeted publications.
- Conduct market research relevant to underground construction.

Members of this goal development team include: David Klug, Paul Headland, Ray Brainard, Nik Sokol, David Field, Steve Hunt, Derek Zoldy, Bob Goodfellow and Nasri Munfah.

UCA Strategic Goal Two: Improve the Image of Underground Construction in the Minds of the Public, Government, Owners and all Key Constituencies.

- Identify and publish underground construction successes.
- Address the "why" of underground construction failures.
- Distribute relevant information to mainstream media, government agencies, environmental communities and regulatory groups.
- Become proactive with facility planners.
- Attend other professional association conferences.
- Identify and publicize innovations in underground construction.

Members of this goal development team include: Paul Gribbon, Stephen Liu, Artie Silber, Jon Klug, Mike Vitale, Mark Johnson, Heather Ivory, Kellie Rotunno, Krishniah Murthy and Brian Zelenko.

UCA Strategic Goal Three: Improve the Effectiveness and Efficiency of the Underground Construction Industry.

- Complete a broad-based industry survey to identify issues and champions.
- Research, review and comment on codes and regulations that impact underground construction.
- Identify two to three subject areas relevant to underground construction to address in new technical publications. Possible subjects include design, construction, procurement, regulatory areas, e.g., hyperbaric regulations, PPP procurement guidelines, etc.
- Provide guidelines for education and training of engineers and craft labor.

Members of this committee include: Gregg Davidson, Darrell Wilder, Zachary Jones, Jon Hurt, Dave Young, Steven Fradkin and Dan Ifrim. ■

UCA of SME prepares for George A. Fox Conference

The UCA of SME will present the George A. Fox Conference on Jan. 27 at City University of New York under the theme of "Tunneling: Past – Present – Future."

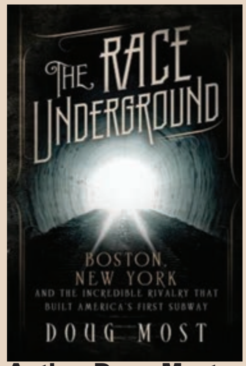
The one-day conference that sold out last year will include a keynote session featuring *Boston Globe* deputy managing editor Doug Most, author of *The Race Underground*, one of Amazon's Top 10 books of 2014.

The book chronicles the race between Boston and New York to build the first subway system in an American city.

The competition between Boston and New York was played out in an era of economic upheaval, job losses, bitter political tensions and the question of America's place in the world.

Amazon writes, "*The Race Underground* is peopled with the famous, like Boss Tweed and Thomas Edison, and the not-so-famous, like the countless "sandhogs" who dug and blasted into the earth's crust, sometimes losing their lives in the process of building the subway's tunnels. Doug Most chronicles the science of the subway, looks at fears people had about travelling underground and tells a story as exciting as any ever ripped from the pages of U.S. history. *The Race Underground* is a great American saga of two rival American cities, the powerful interests within and an invention that changed the lives of millions."

The remainder of the conference will be broken into three segments. The first will focus on the history of tunneling in the United States. The next session will focus on the present state of tunneling in the United States and beyond and the conference will conclude with a session focusing on the future of tunneling.



Author Doug Most is the scheduled George A. Fox Conference keynote speaker.

Because of the popularity of the George A. Fox Conference, there will be no onsite registration. To reserve your spot for the conference, please register online at www.georgeafoxconference.com. ■

T&UC

BUSINESS PROFILES

A special advertiser sponsored advertorial section

DECEMBER 2014

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

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

Makers of Underground History

Local Presence. Global Competence.

DSI Underground Systems 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:

- Aliva/Sika – Shotcrete Products
- ALWAG – Support Systems
- Biomarine – Tunnel Rescue Equipment
- Boart – Probe and Roof Bolting Equipment
- CBE – Segment Moulds – Precast Segment Moulds, Related Equipment & Plants
- ChemGrout – Grouting Equipment
- Condat – Ground Conditioning Chemicals and Lubricants
- Cooper & Turner – Bolts and Sockets for Precast Segments
- Montabert – Excavator Drilling Attachments & Replacement Drifters
- Dywidag – Bolts and Accessories including DSI Threadbar, Friction Bolts and Omega Bolts

DYWIDAG-SYSTEMS INTERNATIONAL

DSI

DSI Underground Systems, Inc.

Telephone: +1-276-466-2743
dsiunderground.com

- ES – Rubber Segment Gaskets
- Geodata – Monitoring Equipment
- Häny – Grouting Systems
- Promat International – Fire Protection Products
- Tunnel Tec – TBM Cutting Tools
- Vik Orsta – CT-Bolts – Double Corrosion Protection
- Weldgrip – Fiberglass Bolts and Dowels
- WIRTH – TBM, Pile Top Rigs
- ACI – Steel Ribs, Liner Plates, Lattice Girders, Lagging and Miscellaneous Support Items
- ACI – Tunnel Fabrications and Accessories

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.

Lower North Outfall Sewer

Los Angeles, CA
Metro Gold Line C800

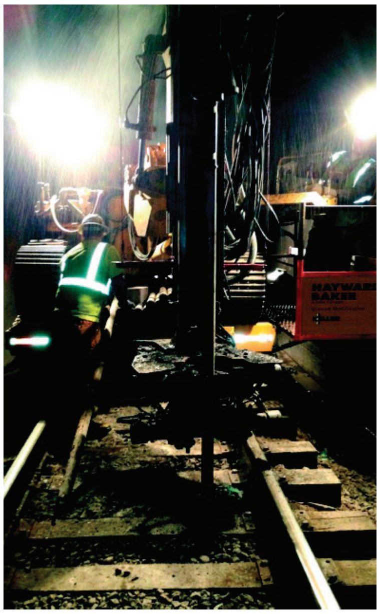
Construction of twin subway tunnels for the LA Metro's Gold Line would cause ground loss, endangering overlying structures unless the soils surrounding the tunneling zone were treated prior to excavation. Using conventional horizontal drilling to install steel and PVC sleeve port grout pipes, Hayward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

St. Louis, MO
Baumgartner Tunnel Alignment

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

Big Bend Tunnel Improvement
Big Bend, WV

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



Big Bend Tunnel Improvement

Hayward Baker
Geotechnical Construction
7550 Teague Road, Suite 300
Hanover, MD 21076 USA
Toll Free: +1-800-456-6548
Telephone: +1-410-551-8200
Fax: +1-410-799-3786
www.HaywardBaker.com

CDM Smith

CDM Smith provides lasting and integrated solutions in water, environment, transportation, energy and facilities to public and private clients worldwide. As a full-service 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

CDM Smith
www.cdmsmith.com

CDM Smith
cdmsmith.com

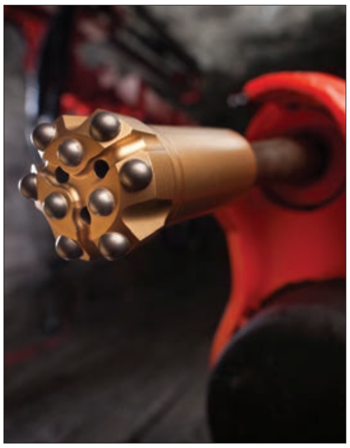
Sandvik in Tunneling

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
300 Technology Court
Smyrna, GA, 30082
Phone: +1-404-589-3800
Email: info.smc-us@sandvik.com
www.construction.sandvik.com

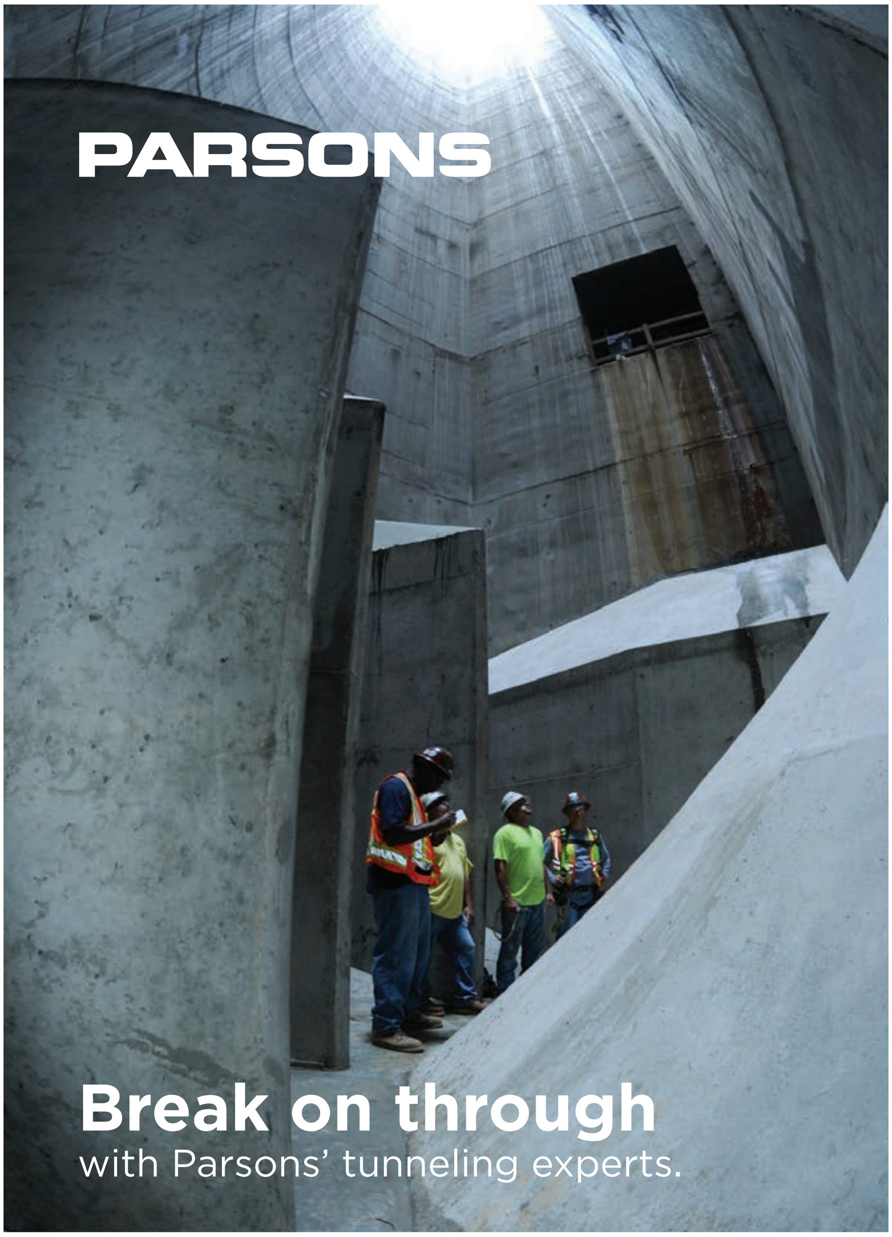
Parsons: Connecting infrastructure across the globe

Celebrating 70 years of growth, Parsons is the premier source for end-to-end design-build transportation engineering capabilities, including expert multidisciplinary planning, all phases of construction and implementation, and maintenance and improvements. The firm employs more than 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 Division has contributed to hundreds of international tunnel projects, including the Caldecott Tunnel improvement project, which involves the construction of a fourth bore through the Berkeley Hills, near Oakland, California, and the Washington, D.C., Metro twin-tunnel program, cited by the American Underground Association as one of the most significant tunneling projects in the last 10 years.

Serving the underground engineering and program management needs of a diverse clientele, Parsons lends its expertise to projects such as underground utilities, water storage and transportation tunnels, and underground buildings. The firm has provided advisory services, performed subway construction, and delivered major highway tunnel projects, including the New York Gowanus Expressway and the English Channel Tunnel.

Parsons offers a host of innovative tunneling techniques, like the New Austrian Tunneling Method, top-down tunneling, advanced hard-rock and soft-ground tunnel-boring machine technology, single-pass tunnel construction, and advanced tunnel waterproofing systems, to minimize the risks associated with underground structures. Throughout the firm's history, Parsons has worked to provide safer, better, more sustainable ways to travel the world — one project at a time. Learn more at www.parsons.com.



www.parsons.com

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

Tensar International Corporation

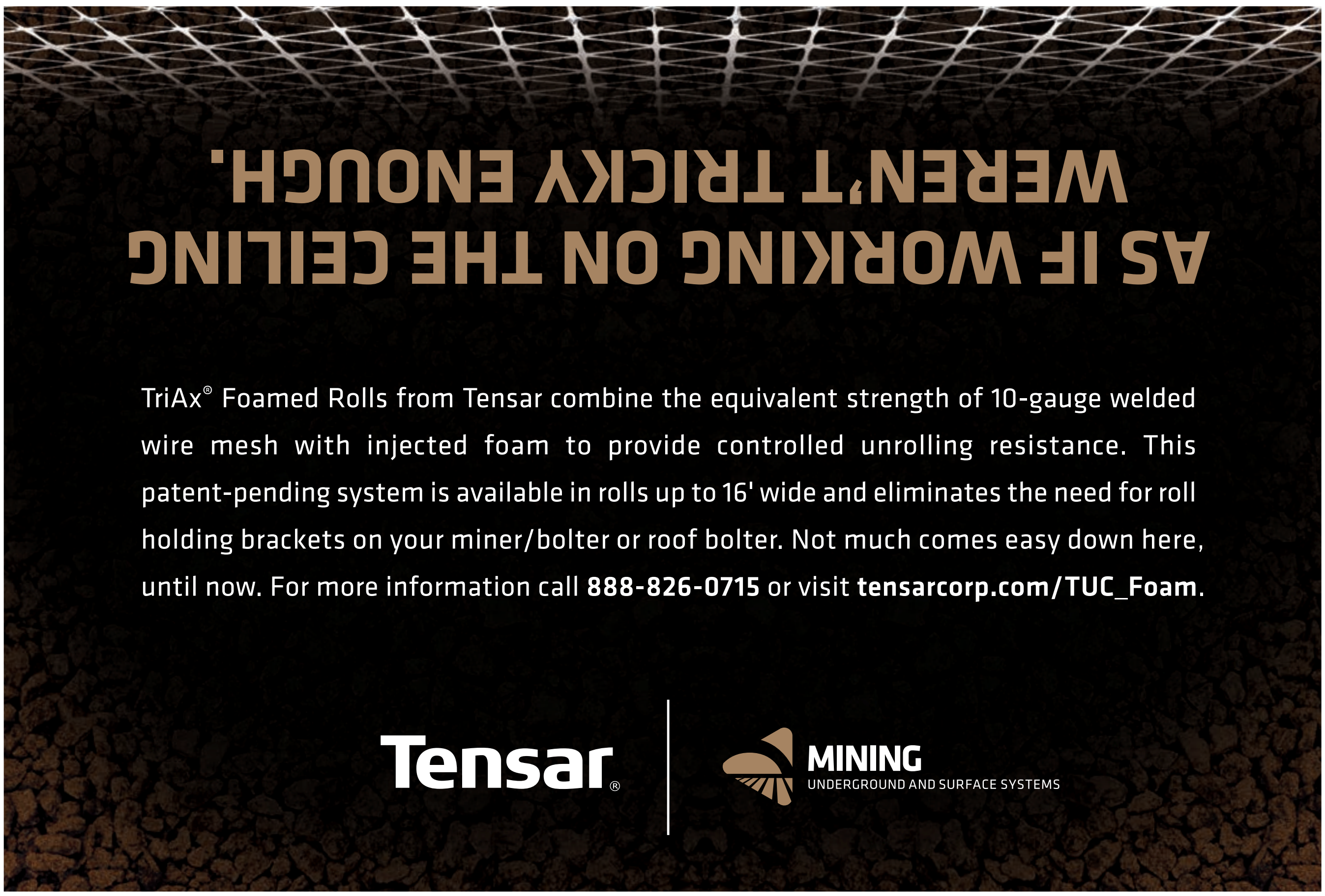
Tensar International Corporation (Tensar) offers a number of solutions to support the unique requirements of mining and tunneling construction. Tensar® Mining Systems include a family of polymeric grid products.

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

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

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

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



Industry Experts Committed to Innovation, Quality and Support

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 2014, and will continue this progress in 2015. Innovative concepts keep expanding the company's scope, from efficient TBM assembly methods to high-performance machine designs resulting in landmark performances through both soft ground and hard rock.

Total Supply Company

Robbins is a total supply company, offering everything from cutters and stacker conveyors to knowledgeable field personnel and technical support. Robbins' time-saving Onsite First Time Assembly (OFTA) method was first used at Canada's Niagara Tunnel Project in 2006 and continues to be successfully carried out on multiple projects and with all types of TBMs. The method results in significant time savings and cost reductions for the contractor, all by initially assembling the TBM at the jobsite rather than in a manufacturing facility. At the Black River Tunnel in Lorain, Ohio, a massive 7.0 m (23 ft) Robbins Double Shield TBM and continuous conveyer system were assembled in just three months using OFTA. The TBM made a swift breakthrough in April 2014.

Robbins' field service personnel bring years of engineering experience to each project. In 2014, personnel assisted in successful urban tunneling just 3.4 m (11 ft) below active rail lines in downtown San Francisco. The team stayed on through the breakthrough of the two 6.3 m (20.7 ft) diameter Robbins EPBs at the Central Subway project in June 2014. On the other side of the globe at Australia's Grosvenor Decline Tunnel, Robbins field service directed a successful excavation using a unique 8.0 m (26.2 ft) Single Shield/EPB TBM for a coal mining tunnel. The Dual Mode machine completed its first mine access tunnel in May 2014 at rates 10 times higher than the conventionally used roadheader excavation method.

Continued Success in Soft Ground

Robbins EPBs continue to show their reliability and robustness, even in some of the world's most difficult ground conditions. Three 8.93 m (29.3 ft) Robbins EPBs are navigating very difficult ground for Mexico City's Emisor Oriente Wastewater Tunnel. Robbins Field Service and Engineering have worked closely with the contractor to maneuver the challenging geology, and strong machine performance is expected in 2014.

Robbins refurbishes many machines, and recently completed refurbishment and OFTA on a 6.65 m (21.8 ft) EPB for Seattle's North Link Light Rail Extension. The mixed ground machine, previously used on tunnels in Singapore, was assembled in a tight and narrow jobsite alongside Washington State's busiest roadway, Interstate 5. The machine recently launched in the last quarter of 2014.

Robbins innovations will continue to advance into 2015, with major hard rock and mixed ground projects underway across North America, and spanning the globe. For further information on tunneling projects and groundbreaking R&D, visit www.TheRobbinsCompany.com or call +1 (440) 248-3303.

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

Moretrench

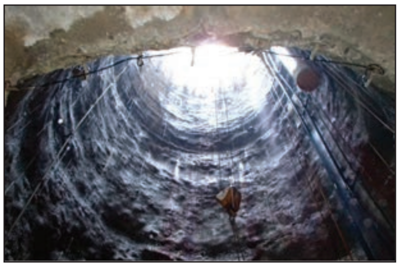
Specialty geotechnical contractor Moretrench, headquartered in Rockaway, New Jersey, offers a range of services for tunneling and underground construction, including ground freezing, dewatering and groundwater control, and various grouting techniques. The company's capability and versatility were recently demonstrated in two very different projects.

Port of Miami, Miami, Florida *(pictured upper left)*

At the Port of Miami in Florida, ground freezing was recently used for the first time in North America for construction for two of the five cross passages. The cross passages lay approximately 100 ft below groundwater level and mostly within the highly pervious Key Largo formation that had been determined to become potentially unstable during tunneling. Pre-freezing analyses were conducted to determine a ground freezing design that would achieve the required thickness of frozen ground within the relatively short timeframe. This resulted in a system consisting of two concentric rings of freeze pipes, horizontally drilled and installed from within the Eastbound tunnel. Freezing was initiated following a grouting program to reduce permeability of the formation and the velocity of groundwater flow that could inhibit freeze closure. Drilling and freezing operations were extensively instrumented and monitored throughout the program to ensure closure had been successfully achieved.

OSIS Augmentation and Relief Sewer, Columbus, Ohio *(pictured lower left and right)*

For Phase 2 of a 23,000 foot-long storm and sanitary overflow and relief sewer in Columbus, OH, three deep shafts were to be installed through highly variable karstic rock under hydrostatic head of up to 150 feet. Solution features ranged from small fissures to large voids. It was estimated that inflows of thousands of gallons per minute could be anticipated during shaft excavation.



Pre-grouting of the rock was therefore required by the bid documents. The shafts extended through shale underlain by three distinct strata of limestone. A specially designed suite of four balanced-stable grouts was developed by Moretrench to cater to the highly variable conditions present throughout. Grouting was performed through a double row of holes outside the shaft perimeters, with grouting parameters monitored by an automated data system. The grouting program as designed successfully addressed the challenging conditions, allowing the general contractor to excavate to design depth with minimal water inflow.

Moretrench
Tel: 1-800-394-MORE
www.moretrench.com


CHOOSE US EARLY UP THERE.
BEFORE THINGS GET TOUGH DOWN HERE.
When it comes to the complexities
of underground construction,
no one has seen more than Moretrench.
If your project is going underground, choose the right partner and choose them early.
©2014 Moretrench
MORETRENCH
No one has seen more.™
Groundwater Control
Earth Retention
Deep Foundations
Grouting
Ground Freezing
moretrench.com

Putzmeister Shotcrete Technology, Your Worldwide Partner for Quality and Innovation

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

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

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

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

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

Mixkret 4 - Low Profile Concrete Mixer

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

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

Throughout the years, numerous milestones have been achieved:

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

SPM 307 Nozzle Carrier

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

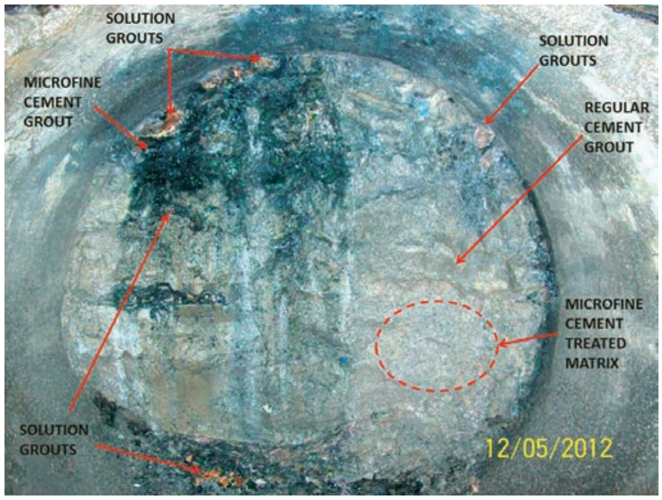
With Putzmeister's reputation for excellence and expertise built on our commitment to application-oriented engineering and customer service – put the strength of Putzmeister to work for you. Contact us at (800) 553-3414 or visit PutzmeisterShotcrete.com.

Putzmeister
SHOTCRETE TECHNOLOGY

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

TBM Under Ocean Waters – AvantiGrout to the Rescue

Build it and they will come! That was the government's mantra to attract larger ships into the Port of Miami. However, the existing channel between Fisher Island and Miami Beach was too shallow. In order to deepen the channel, an aging sanitary sewer main belonging to the Miami-Dade County Water and Sewer Department had to be lowered.

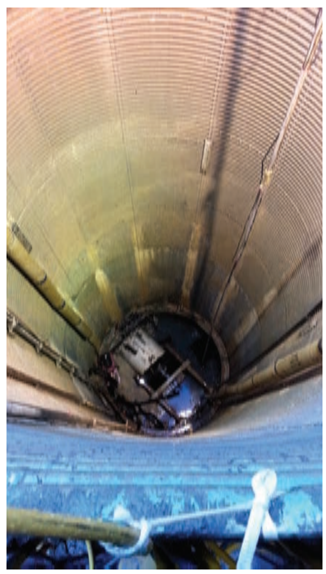


The new sanitary sewer main consists of a 54 inch HDP pipe located approximately 100 foot below the ground surface for approximately 850 linear feet. This successful design-build shaft and tunnel project was led by Ric-Man Construction (Ric-Man). An experienced contractor like Ric-Man recognized immediately that groundwater would cause problems for underground construction in and under the ocean waters of the Atlantic. Ric-man hired ECO Grouting Specialists (ECO) to design and direct a pre-excavation grouting program to facilitate the construction of three shafts planned to access the new sanitary sewer alignment tunnel. The shafts, constructed using 100 foot plus deep secant piles, were situated both on land and in the channel. The planned tunnel would be six feet in diameter.

The geology of the area consisted of highly variable porous soft limestone, coral and silty sand. ECO developed a specially formulated grout to treat these highly variable soils and rock strata prior to the secant pile installation to provide groundwater control. This pre-excavation grouting was very successful. Upon completion, the TBM was assembled in the shaft and prepared to launch through the shaft wall. During the break-in, the geology was not as competent as expected and groundwater inflows of 500+ gallons immediately flooded the TBM and shaft halting tunnel construction. ECO was again called upon by the Contractor to reduce the water inflow around the TBM to a manageable inflow that would allow for the break-in to occur and the tunnel liner to provide a water seal. This was a formidable grouting challenge because the TBM could not be locked in place with the grout.

The solution? A solution grout, AV-160 Acrylate by Avanti International. From previous grouting experience, it was known that the existing geologic formation was amenable to cementitious grouts, however this type of grout would provide a greater risk to grouting the TBM in place. The strength characteristics of the AV-160 were perfectly suited to encapsulate the TBM, providing a protective shell from the cementitious grout. To seal the water beyond the AV-160, Ultrafine Cement from Avanti was used to grout the erratic geology effectively sealing the water off. To accomplish this grouting procedure, various sleeve pipes were installed and packers were used to deliver the grout to isolated stages of the geology.

The grouting operation was continuously monitored with CAGES (Computer Aided Grouting Evaluation System), a real-time monitoring system, and the permeability of the subsurface was reduced to target values which reduced the inflow to less than 5gpm. The careful selection and use of the Avanti grouts allowed for the tunneling operation to resume and successfully complete the tunnel.



Avanti International
822 Bay Star Blvd.
Webster, TX 77598 USA
Telephone: +1-800-877-2570
www.avantigrout.com


TUNNEL
Grout Solutions
AvantiGrout—multiple grout solutions for more effective tunneling and transit operations—before, during, and after construction.
Pre-Excavation | Dewatering | Soil Stabilization | Pre-Lining | Tunnel Boring Machines
Solving geotechnical problems and improving tunneling operations, Avanti answers the call with multiple grouting solutions:
• CHEMICALLY-ACTIVATED
• MOISTURE-ACTIVATED
• HYDROPHOBIC
• HYDROPHILIC
• ULTRAFINE CEMENT
• MICROFINE CEMENT
For expert advice on the optimum grout for your tunneling application, consult with our geotechnical team by phone or visit the industry's most resourceful website today:
www.AvantiGrout.com
822 Bay Star Blvd • Webster, Texas 77598
800.877.2570 • 281.486.5600
AVANTI
Stop leaks. Stabilize soil.
Control groundwater. Permanently.

JENNMAR

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

A Single Source Provider

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

JENNMAR Affiliates

JENNMAR Civil

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

J-LOK

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

JENNCHEM

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

KMS (Keystone Mining Services)

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

JENNMAR Specialty Products

JENNMAR Specialty Products is a full-scale steel fabricator specializing in roll-forming coil, sheet and structural beams to provide quality arch and corrugated products. In conjunction with KMS, we can also custom design and fabricate products for a variety of applications.

JM Steel

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

JENNMAR McSweeney

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

CSA (Compliance Staffing Agency)

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

MARJENN Trucking

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

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

JENNMAR
258 Kappa Drive
Pittsburgh, PA 15238 USA
Phone: +1-412-963-9071
Fax: +1-412-963-9767
Email: info@jennmar.com
Web: www.jennmar.com

Messinger Bearings - A Kingsbury Brand

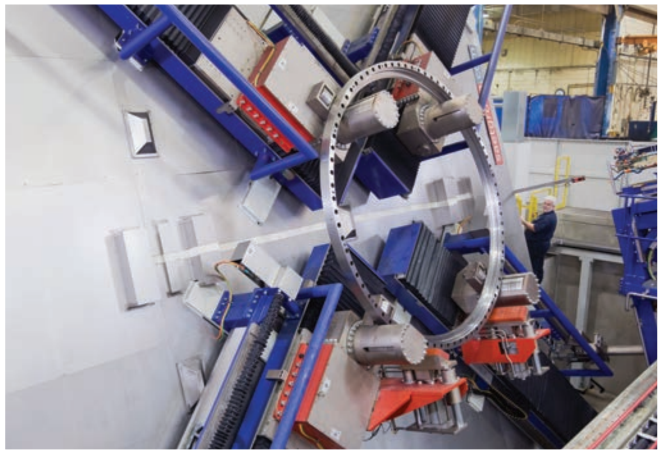
Messinger Bearings is one of an elite few companies in the world capable of producing large, custom-designed bearings for tunnel boring machines (TBMs). Messinger is addressing the challenge from end users who require new or repaired bearings of this size delivered in a reasonable timeframe.

TBM Bearing Customers Have an Option

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

New or Rebuild? Your Choice

Deliveries for 3-row TBM main bearings have been a recurring challenge for TBM customers. Messinger is committed to supporting its customers in its core business, that is, large heavy-duty custom bearings for specialty applications in limited quantities. In addition, Messinger maintains a repair and service department that



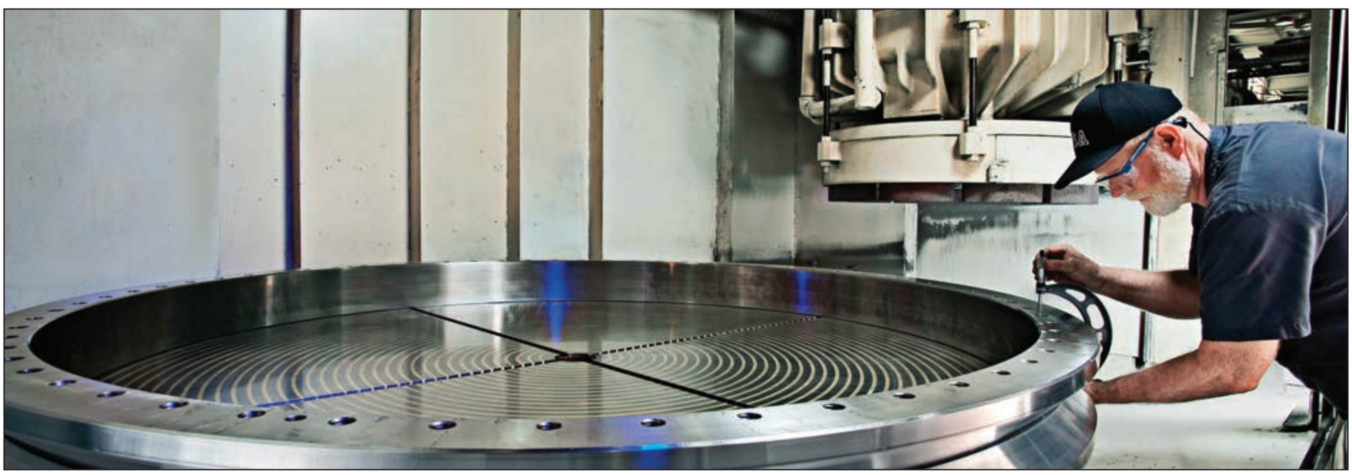
is capable of rebuilding old bearings at a fraction of the cost of new.

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

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

MessingerBearings
A KINGSBURY BRAND

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



Antraquip Corporation

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

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

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

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

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.

ILF Consultants, Inc.
400 112th Avenue NE, Suite 205
Ph: (425) 505-2907
www.ilf-usa.com
Email: info@ilf-usa.com

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.

Telephone: +1-814-466-7134
Email: info@alpinecutters.com
www.alpinecutters.com

Rapid Set® Cement Products for Tunneling and Mining

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

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

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

CTS Cement Manufacturing Corp.
Telephone: +1-800-929-3030
www.ctscement.com

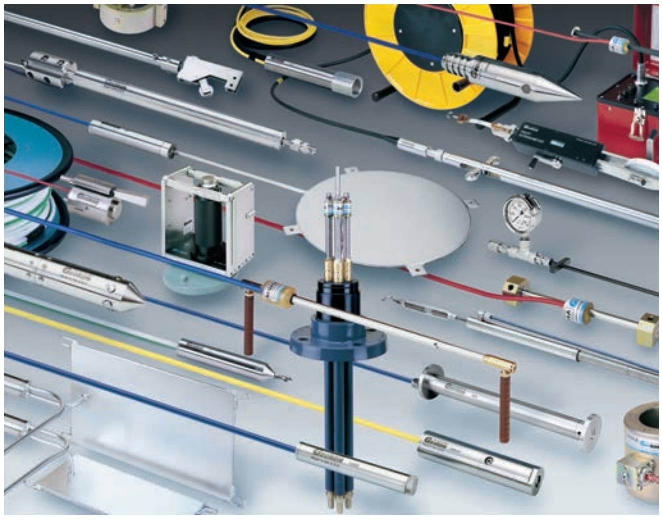
Rapid Set®
Construction Cement Products

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.

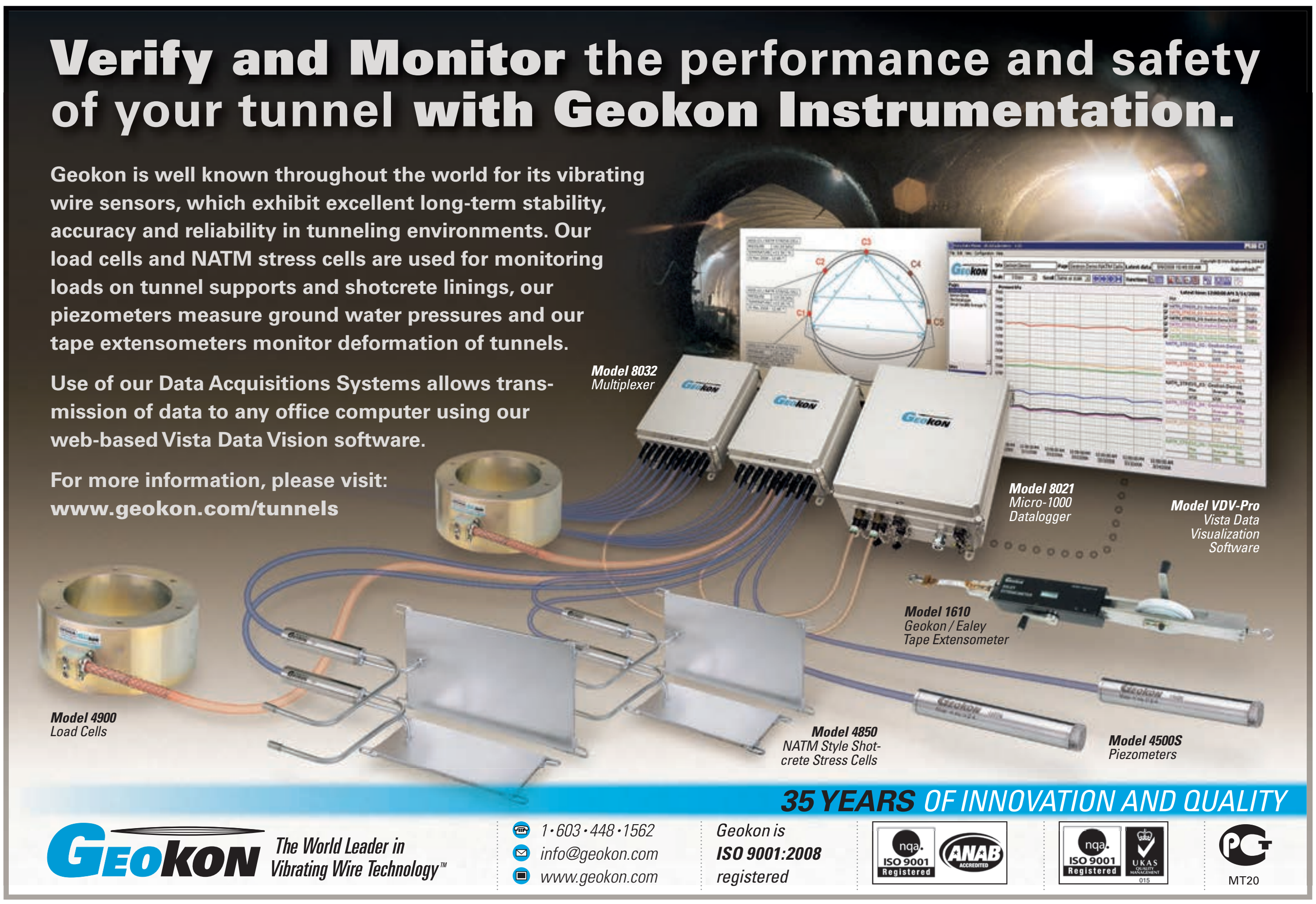
In addition to almost all major cities in the USA, our instruments have been used in tunnels and subway systems around the world, including those found in Seoul, Taipei, Guangzhou, Istanbul, Hong Kong, Singapore, London and the Channel Tunnel.

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.

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



Premier Pipe Systems Manufacturer for over 85 Years

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

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

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

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

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

Every length of Naylor Pipe is inspected and where required hydrostatically tested to applicable ASTM specifications. The pipe is available in lighter weights than other pipe making it possible to save money, not only on initial cost, but also in

transportation, handling and installation. By sizing the diameter of the pipe to the exact requirements, with exact lengths and factory-sized ends, the greatest economies can be realized.

Quotations are immediately available on inquiry.

Naylor Pipe Company
1270 East 92nd Street
Chicago, IL 60619 USA
Telephone: 1-773-721-9400
Fax: 1-773-721-9494
Email: sales@naylorpipe.com
www.naylorpipe.com

Gall Zeidler Consultants

Gall Zeidler Consultants (GZ) is a worldwide leader in tunnel design and engineering, tunnel construction management, tunnel rehabilitation and upgrade programs with special expertise in transportation and infrastructure projects. The company specializes in mastering difficult ground conditions by using state-of the art ground improvement methods. GZ offers exceptional expertise in urban tunneling by innovatively applying state-of-the-art tunneling and waterproofing techniques.

GZ employs 50+ staff worldwide, and can look at a history of over 170 miles of successfully completed international tunneling projects. The company's expertise has consistently been sought after by major project owners to assist with the mitigation of risks associated with tunneling, streamlining the design process and thus making it more time and cost efficient.

GZ provides specialized staff to conduct quality assurance and control, safety and tunnel inspection services in support of assessing structural conditions for upgrade and rehabilitation needs, and construction management for a number of complex, large-scale infrastructure projects.

Recently completed projects include the Dulles Metrorail Extension (Silver Line) in Washington, DC, the Caldecott Fourth Bore project in Oakland, CA, and the Dulles Automated People Mover System at the International Airport in Washington, DC.

Gall Zeidler Consultants

GEOTECHNICS | TUNNEL DESIGN | ENGINEERING

GZ is currently involved in rehabilitation and upgrade work for the Washington Metropolitan Area Transit Authority (WMATA), Metro Transit St. Louis, and the Pennsylvania Turnpike Commission. Construction is currently ongoing for the Vauxhall Station Upgrade Project in London, UK, East Side Access Project in New York, NY, and the Anacostia River Tunnel in Washington, DC.

Gall Zeidler Consultants
+1 (703) 726-2700
gzconsultants.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.

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.

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.

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.

Hatch Mott MacDonald

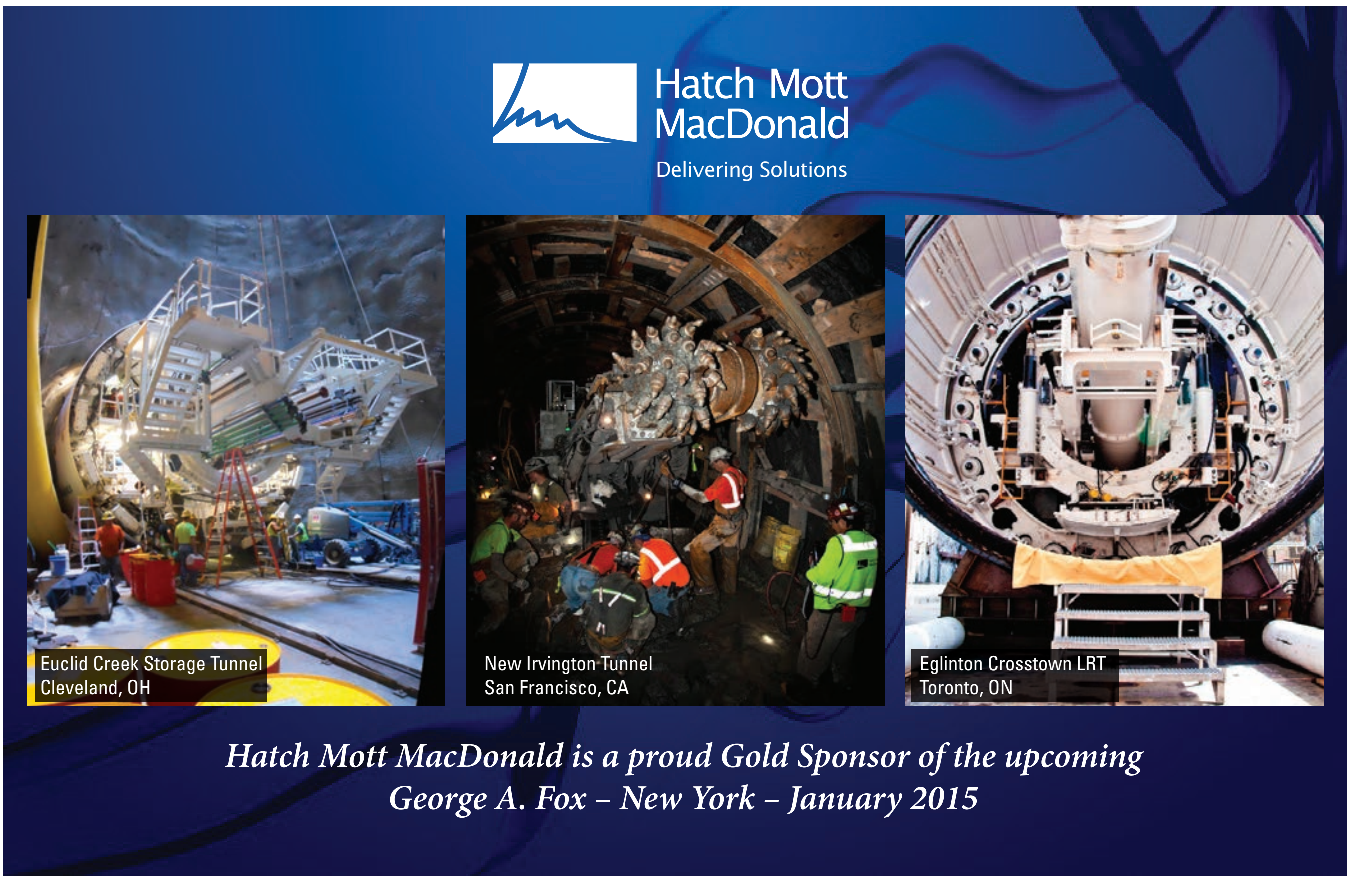
Tunnel engineering is one of Hatch Mott MacDonald's core services. For a wide-range of public and private clients, we have engineered transportation tunnel solutions for roadway, passenger rail, freight rail, subway, pedestrian, cable and communications projects. Our expertise spans a broad-range of 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.

Hatch Mott MacDonald
www.hatchmott.com



Mining Equipment Ltd.

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

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

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

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

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

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

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

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.

Surecrete Inc.
155 NE 100th Street, Suite 300
Seattle, WA 98125
Telephone 206.523.1233
FAX 206.524.6972
Jeff@surecrete.com
www.surecrete.com

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
FAX: +1-724-942-4671
Email: dklug@drklug.com

McDowell Brothers Industries, Inc.

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

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

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

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

McDowell Brothers Industries, Inc.
Telephone: +1-705-566-8190
Email: sales@bmcdowell.com
www.bmcdowell.com

McDowell

RENTALS, PARTS & SERVICE SINCE 1968

+1-705-566-8190

www.bmcdowell.com

sales@bmcdowell.com

T&UC - Tunneling & Underground Construction - covers all things underground. From extreme excavating challenges to large civil projects worldwide, T&UC has the solutions 15,000 industry readers rely on.

T&UC®

www.tucmagazine.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

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.

ABC Industries, Inc.
P.O. Box 77
Warsaw, IN 46581 USA
Telephone: +1-574-267-5166
Toll Free: +1-800-426-0921
Email: sales@abc-industries.net
www.abc-industries.net

Grindex next generation drainage and sludge pumps

Delivering greater performance and reduced total cost of ownership

Grindex is a world leader in electrical submersible pump technology for demanding applications such as construction, mining, marine and heavy industry--offering a complete line of highly efficient and reliable submersible pumps for drainage, sludge & slurry applications in the marine industry. From 0.6 to 140 HP. Solids handling capability of up to 3.2”, capacities of up to 750 feet and 5100 GPM. Stainless steel options available. Unique features: air valve and SMART™ electronics. These features prevent overheating, incorrect motor rotation, and single phasing.

Grindex
www.grindex.com
Email: info.us@grindex.com

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.

Bradshaw Construction Corporation
175 West Liberty Road
Eldersburg, MD 21784 USA
Telephone: +1-410-970-8300
Fax: +1-410-970-8340
www.bradshawcc.com

BROOKVILLE Exhibiting Latest Advancements in Mining and Tunneling Vehicles in Denver

Brookville Equipment Corporation (BROOKVILLE) will exhibit its latest innovations in rail-mounted mining and tunneling haulage and transport equipment from booth 1908 at the SME Annual Conference and Expo to be held at the Colorado Convention Center in Denver from February 15-18, 2015.

Founded in 1918 and based in Western Pennsylvania, BROOKVILLE is an American manufacturer of customized rail-mounted battery and diesel powered locomotives, personnel carriers, and combination vehicles for the mining and tunneling industries.

BROOKVILLE units have played a key operational role in many recent notable projects, including the Traylor Brothers East Side Access Project in New York City and the Stillwater Mine in Montana. In 2015, three 27-ton MSHA permissible diesel locomotives will be on the job for the Walsh-Shea Corridor Constructors' Crenshaw/LAX Transit Corridor Tunnel Project.

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

Atlas Copco Innovation

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. Over the years, the Atlas Copco legacy continued to grow.

Today, the Atlas Copco mining product range includes:

- Blast hole drilling rigs
- Exploration drilling equipment
- Ground engineering equipment
- Rock reinforcement equipment
- Large rotary and DTH blast hole rigs
- Raiseboring equipment
- Face drilling rigs and scalers
- ANFO charging trucks and underground utility vehicles
- Underground loading and hauling vehicles
- Rock drilling tools, hammers, bits

Atlas Copco has a heritage of innovation and service that stretches over more than 140 years. But rather than rest on their reputation and strong standing, they continue to develop new ways for their mining customers to work more safely and more productively.

Atlas Copco
www.atlascopco.us

40 Years of High-Performance Waterproofing Solutions

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

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

Stirling Lloyd Products, Inc.
152 Rockwell Road, Building A
Newington, CT 06111 USA
Telephone: +1-860-666-5008
Fax: +1-860-666-5016
Email: northamerica@stirlinglloyd.com
www.stirlinglloyd.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.

Contact HIC Fibers direct at (323)-935-4500 or visit us on the web at HIC Fibers.com

HIC Fibers, Inc.
4801 Wilshire Blvd., Ste. 305
Los Angeles, CA 90010 USA
Telephone: +1-323-935-4500
Email: sergi.kim@hicfibers.com
Contact: Sergi Kim
www.HICFibers.com

Brierley Associates

Twin Vehicular Box Tunnels, Liberty University. Designed by Brierley Associates. Photo courtesy Liberty University.

Celebrating 15 Years Brierley Associates is a privately-held tunnel, trenchless, geotechnical, and geo-structural design firm with offices strategically located in nine states. With over 60 underground engineers and geologists, Brierley Associates has a long history of delivering recognizable value to our clients by providing cost effective and constructible solutions for underground projects.

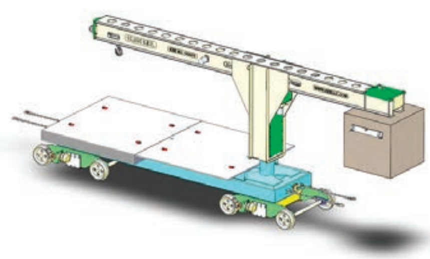
The nationwide and international underground project knowledgebase of Brierley Associates is key to anticipating ground behavior and helping our clients with design and construction of successful projects which is a cornerstone of Brierley's business vision to *"Create Space Underground- Coast to Coast"*

Brierley News: Named tunnel consultant for City of Mishawaka, IN CSO program; Geotechnical and tunnel engineer for BCRUA Deep Water Intake Project, Lake Travis, Austin, TX

Kelley Engineered Equipment

Custom Equipment Design Specialists

Kelley Engineered Equipment, LLC was founded in 2007 by Brian and Cindy Kelley. The firm is located in Gretna, Nebraska and has a growing staff of mechanical engineers, control system engineers, designers and drafters with extensive experience in tunneling and mining equipment design. Brian has 25 years of tunneling equipment design experience at Robbins, Kiewit and Kelley Engineered Equipment. Mechanical Engineering PE licenses are held in Nebraska, New York, California, Texas, Virginia, and Washington State.



The company specializes in custom tunneling equipment design, including lifting systems, mucking systems, gantries, pipe carriers, trailing gear, custom attachments, conveyors, lift cars, equipment modifications, ventilation personnel access systems and more.

Kelley Engineered Equipment has a growing line of standard products including mobile reelers for wire rope and conveyor belt, hydraulic drive pulleys and material handling/ storage bins and more.

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.

Doctor Mole Incorporated
990 S. Broadway, Suite 222
Denver, CO 80209 USA
Telephone: +1-303-797-1728
www.drmoleinc.com

DOCTOR MOLE INCORPORATED

Underground Consultation

- Tunnels
- Shafts
- Caverns
- Conventional Tunneling
- TBM's
- Pre-bids
- Design/Build
- Dispute Resolution
- Claims
- Forensic Investigations
- Geotechnical Report Preparation

For more information contact:

Gary Brierley

gbrierley@drmoleinc.com or 303.797.1728

Advanced Concrete Technologies, Inc. - We Add Profitability to the Mix

Advanced Concrete Technologies, Inc. (ACT) is a single source supplier of turnkey concrete batching and mixing plant solutions that draws on over 45 years of experience and more than 4,000 concrete plant installations worldwide. ACT provides the industries most flexible and proven solution for producing highest-quality, central mixed concrete and backfill grout for on-site construction, tunneling and mining projects. ACT's MobilMat batch plants, come in ten different sizes, ranging from 30 up to 240 cubic yards per hour concrete output. We offer high intensity HPGM counter-current mixers and DWM twin-shaft mixers, advanced PCS control automation, commissioning services as well as an industry leading training & support program.

ACT's plant solutions deliver superior quality concrete with the ideal combination of proven components engineered by the world's most respected names in the business - Wiggert & Co. and Würschum GmbH.

Advanced Concrete Technologies, Inc.
300 Portsmouth Avenue
Greenland, NH 03840 USA
Telephone: +1-603-431-5661
www.concretebiz.com

You're only as strong as your Weakest Link

Contact us to find out how successful concrete producers maximize the strength of every link in their production process with ACT's progressive mixing and batching plants, all backed by our industry leading after-sales support.

ADVANCED CONCRETE TECHNOLOGIES®
WE ADD PROFITABILITY TO THE MIX
American division of Wiggert+Co. and Würschum

603.431.5661 · www.concretebiz.com

Rock Splitting Mortar

Dā-mite Fractures Rock and Concrete in No Blast Conditions
Dā-mite aids and accelerates mechanical rock excavation
No fly rock, no vibration, no noise,
Applications: Boulders, mass rock, tunneling, concrete removal

DAIGH COMPANY, INC.
2393 Canton Hwy, Ste 400, Cumming, GA 30040
Office: 770-886-4711, Fax: 770-887-3783
www.daighcompany.com sales@daighcompany.com

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.

Daigh Company, Inc.
2393 Canton Hwy., Ste. 400
Cumming, GA 30040
Telephone: +1-770-886-4711
Fax: +1-770-887-3783
Email: sales@daighcompany.com
www.daighcompany.com

Rock Splitting Mortar

Design Solutions for Tunnels and Shafts

Soft Ground & Rock Tunnels & Shafts • Ground Freezing
Underpinning • Excavation Support • Tunnel Rehabilitation
Microtunneling & HDD • Instrumentation & Monitoring
Construction Evaluation • Utilidors • Tunnel & Shaft Design

Norfolk Approach - VDOT Downtown Tunnel / Midtown Tunnel
Norfolk to Portsmouth, VA

Mueser Rutledge Consulting Engineers
14 Penn Plaza • 225 W. 34th • New York, NY 10122
T: (917) 339-9300 • F: (917) 339-9400 • www.mrce.com
Foundation Engineering Since 1910

Mueser Rutledge Consulting Engineers

Providing Design Solutions for Tunnels and Shafts

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.

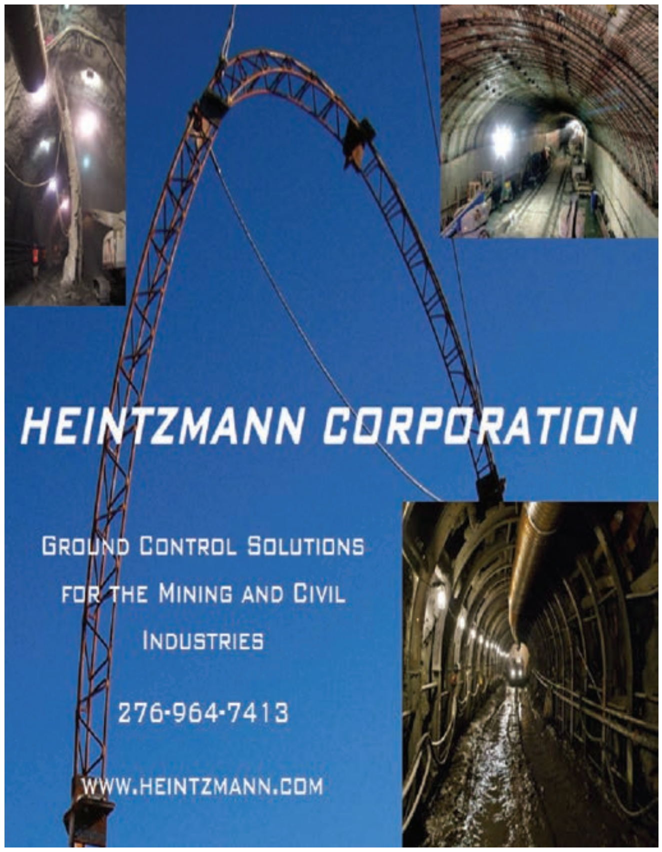
Mueser Rutledge Consulting Engineers
14 Penn Plaza, 225 W. 34th Street • New York, NY 10122 USA
Telephone: 917-339-9300 • Fax: 917-339-9400
Email: farland@mrce.com • www.mrce.com

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
Telephone: +1-276-964-7413
www.heintzmann.com



Jacobs Associates

Changing with the Times

For nearly 30 years, Jacobs Associates has provided preliminary and final design services to owners in the underground industry. Throughout this period, procurement of these services has been based on qualifications. Collaborating with teaming partners that share our culture and focus has helped us remain an industry leader. However, our industry is undergoing dramatic change. Best Value Selection is replacing Quality Based Selection. Teaming partners with cultures similar to ours are moving away from employee development and client service to focus on profit centers and daily stock performance. Jacobs Associates thrives on multidisciplined projects and repeat clients. This becomes harder when disciplines are mired in internal processes and our client relationships are controlled by someone else's contract. We look to our past to help us adapt to our future. Throughout our history, we have evolved to meet the needs of our workforce and clients. In 2015 you will see this evolution continue.

Daniel N. Adams
President

Jacobs Associates
800.842.3794
www.jacobssf.com


Rue Conti
Conti
Rue Bourbon
Bourbon

FEATURE ARTICLE

Construction of the San Francisco Bay Tunnel

The San Francisco Public Utilities Commission (SFPUC) manages a large water supply system of reservoirs, tunnels, pipelines and treatment systems that stretches about 320 km (200 miles) from the Hetch Hetchy Reservoir in Yosemite National Park to the San Francisco Bay Area (Fig 1).

The SFPUC serves 2.4 million residential, commercial and industrial customers. In November 2002, the SFPUC launched a $4.6-billion water system improvement program (WSIP) to repair, replace and seismically upgrade the aging 1920s era infrastructure.

During the WSIP engineering design studies, the SFPUC found two major water supply pipeline arteries in the system to be particularly vulnerable to seismic events. These pipelines travel from Newark, above ground on wooden trestles, under the San Francisco Bay, on a 1920s era bridge, and then across marshy wetlands on a pile-supported trestle into Menlo Park. The replacement of these pipelines, Bay Division Pipelines 1 and 2 (BDPL 1 & 2), with a more seismically robust tunnel (Bay Tunnel) was identified as a key element of the WSIP program.

The Bay Tunnel alignment is located between two shafts. The presence of environmentally sensitive habitats on the Bay margins precluded using cut-and-cover pipelines, which resulted in the need for an 8-km (5-mile) long tunnel with launching and receiving shafts only and no intermediate construction shafts. These two shafts are located on properties owned by SFPUC in Newark (Newark site) and Menlo Park (Ravenswood site). Figure 2 provides an aerial view of the Bay Tunnel alignment.

The project bids were opened on Nov. 11, 2009. The lowest bid was submitted by a joint venture of the Michels Corporation of Brownsville, WI; Jay Dee Contractors of Livonia, MI and Frank Coluccio Construction Co. of Seattle, WA (MJC). MJC's bid for the project construction was $215.3 million which was only $97,000 below the second bidder and $35 million under the engineer's estimate of $250 million for the project.

The construction notice-to-proceed was issued in April 2010 with a specified final completion date in May 2015.

R. John Caulfield, Ed Whitman, Jim Stevens, Kit Fleming and Johanna I. Wong

R. John Caulfield, member UCA of SME, is principal, Jacobs Engineering, **Ed Whitman** and **Jim Stevens**, members UCA of SME, and **Kit Fleming** are project engineer, project director, assistant project engineer, respectively, Michels/Jay Dee/Coluccio joint venture and **Johanna I Wong** is regional project manager, San Francico Public Utilities, email john.caulfield.com.

FIG. 1

Schematic diagram of the SFPUC's water distribution system.

Ravenswood site layout and launch shaft

The main construction staging area and location of the tunneling support facilities was the Ravenswood site located in Menlo Park on SFPUC property. It encompasses about 56,250 m^2 (13.9 acres) of level land and was readily accessible to main arterial highways which were more than sufficient to support the construction operations. The Ravenswood site layout and construction staging are depicted in Fig. 3.

The launch shaft for the tunnel boring machine (TBM) was constructed at the Ravenswood site in the vicinity of the existing BDPL pipelines. Due to constraints on the release of ground water into the adjacent wetlands and concerns over settlement, the shaft was required to be essentially watertight. A diaphragm slurry wall shaft was selected as the preferred method of construction. The shaft is 37.8 m (124 ft) deep to the invert, with 43-m (141-ft) deep slurry walls panels that extend below the shaft bottom. It has an outer diameter of 19.5 m (64 ft) with 0.9 m (3-ft) thick walls, resulting in an internal diameter of 17.7 m (58 ft). The shaft was excavated in the wet, which required the placement of a 3.7-m (12-ft) thick reinforced concrete tremie slab that was keyed and dowelled in to the shaft walls at the bottom (Wong et al., 2011).

FIG. 2

Aerial view of the Bay Tunnel alignment.

The geology in the shaft location generally consisted of 3.7 m (12 ft) of fill and alluvium of soft silty clays and loose silty sand, overlying 5.2 m (17 ft) of very soft to very stiff Bay Mud, 30.5 m (100 ft) of San Antonio Formation sandy and silty clays with some loose sand layers, and then stiff to very stiff, high plasticity Old Bay Clay to a depth of 54.9 m (180 ft). The geotechnical investigation included the installation of multilevel, vibrating-wire piezometers to monitor ground water pressures near the two shaft sites. Piezometer readings indicated that the ground water pressures were generally consistent at 1 to 3.4 m (3 to 11 ft) below the ground surface and were influenced by tidal variations. Readings between piezometer levels indicated that there was some hydraulic conductivity between the individual geologic units. The interconnection of aquifers below the site led the designer to specify that the shaft be designed to accommodate hydrostatic loading.

The shaft panels were excavated using a clam-shell bucket with heavy chisel teeth suspended from a 91 t (100 st) crawler crane. The six primary panels were 2.7-m (9-ft) long by 0.9-m (3-ft) wide. Each primary panel was reinforced with two W33×130 Grade 50 H-pile soldier beams as end stops, with the interior of the panel provided with a steel reinforcing cage. The six secondary panels were 8.2-m (27-ft) long (three 2.7 m (9 ft) bites) by 0.9-m (3-ft) wide.

The secondary panel reinforcing consisted of steel cages that were placed in two top and two bottom sections that were clamped together during installation. Fiberglass reinforcement was used with one of the secondary panels in the area of the soft eye for the TBM breakout. A 1.5-m (5-ft) by 0.3-m (1-ft) deep shear key was blocked out along the slab/shaft interface and was used in conjunction with form savers to allow for connection of the slab reinforcement. The shear keys were outfitted with jackpacks and plywood filler to facilitate clearing them prior to concrete placement.

The top portion of the shaft was excavated in the dry to the greatest extent possible and then subsequently in the wet down to the total shaft depth. The shaft was excavated using a Manitowoc 3900 crane outfitted with a 2.3-m^3 (3-cu yd) clamshell bucket. Geotechnical instrumentation to detect any excessive shaft movements and/or deflections was monitored daily during the excavation.

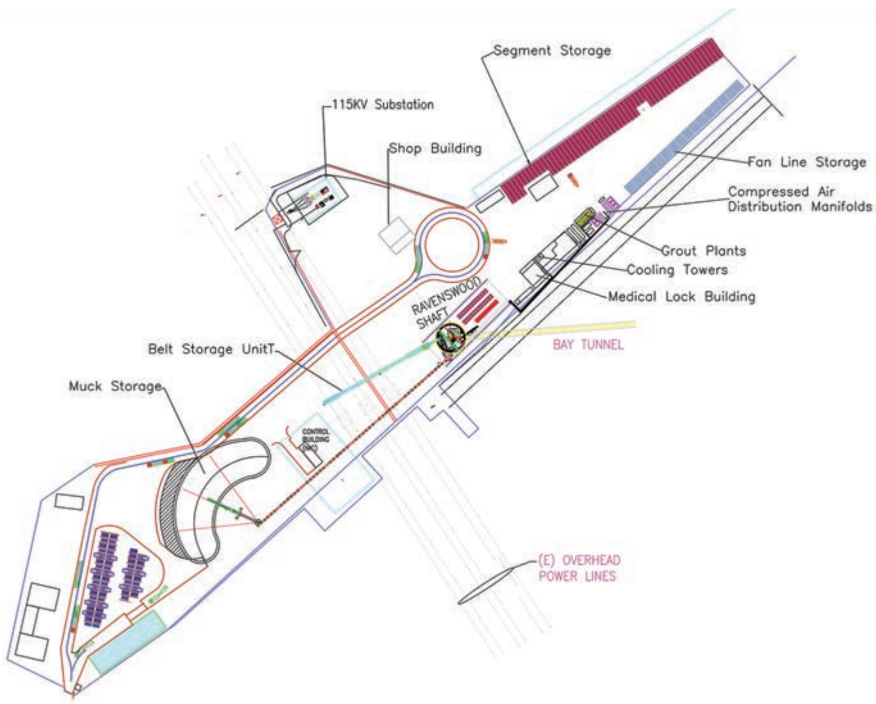
Following the shaft excavation, the shear keys were cleared by inflating the jackpacks and divers were used to make the dowel connections to the formsavers and the tremie slab reinforcement. The reinforcing of the tremie slab consisted of two mats with a total weight of approximately 45 t (50 st). The mats were lowered with their support structure using a 240-t (265-st) Liebherr hydraulic crane through the water in the shaft and tied-in to the dowels. Approximately 918 m^3 (1,200 cu yd) of 41Mpa (6,000 psi) concrete was then placed in a mass pour using two 76 m^3/h (100 cu yd/hr) concrete pumps fed by 42 transit mixers delivering concrete from three separate batch plants.

Once the tremie slab had cured, the water within the shaft was pumped out. Water disposal was an important aspect of the construction. At the Ravenswood site, the only economical discharge point for collected ground water and construction water was the surrounding environmentally sensitive marsh and tidal flats that ultimately discharged into San Francisco Bay. Because of this, stringent water disposal standards were enforced on the project. The project contract documents required a water treatment facility that could sufficiently treat up to 125 L/sec (2,000 gpm) in order to accommodate any uncontrolled large inflows into the launch shaft, particularly during the TBM breakout period.

Ground improvement by jet grouting had been specified for a minimum of 12.2 m (40 ft) outside of the shaft and in the direction of the tunnel, within two tunnel diameters from the centerline of the tunnel, to create a seal outside the shaft to mitigate the inflow of water and soil upon breakout of the TBM through the soft eye. The area was of particular concern because of the close proximity to the existing in-service BDPL's. Through field observation of the ground conditions during the shaft excavation as well as additional subsurface exploration, MJC determined that the ground improvement zone could be exchanged for an alternate construction method. MJC proposed to substitute the jet grout block with a custom-built compound mechanical breakout seal, designed and manufactured by the Mutsubishi Rubber Co. in Japan (Fig. 4). This seal was installed over the fiberglass rebar tunnel eye, at the bottom of the shaft. This seal was further supplemented by additional geotechnical monitoring together with a contingency compensation grouting plan to mitigate any settlement risk under the critical pipelines at a crucial stage of the project where volume loss often occurs.

FIG. 3

Ravenswood site layout and construction staging.



Tunnel boring machine and tunneling conditions

The TBM for the Bay Tunnel project was manufactured by Hitachi-Zosen of Japan. The TBM was an earth pressure balance machine (EPBM) with an excavated diameter of 4.56 m (15 ft) that incorporated features to facilitate excavation through the anticipated ground conditions along the alignment (Fig. 5).

The EPBM was capable of delivering 1,225 kN/m^2 of propulsion force and an advance rate of 25.4 cm/m (10 in./min). The muck extraction was handled by a set of 624 mm (24 in.) ribbon type screws with a capacity of 370 m^3/hr (484 cu yd/hr). The cutterhead could deliver a torque of 2,387 kN·m at 4 RPMs and was able to be dressed either with disc cutters or scrapers. However, through the entire drive the EPBM utilized only scrapers bits and managed to complete the drive without changing any of the cutterhead tools. Advance rates were exceptional for the drive with more than 61m/d (200 ftpd) achieved on numerous occasions. The EPBM was outfitted with independent soil conditioning ports both on the cutterhead and in the mixing chamber, which enabled MJC to implement different soil conditioning techniques simultaneously and maintain better control over the EPBM throughout the drive. The electrical cabinets were outfitted with a purge and pressurized system and all the electrical controls and sensors were permissible in anticipation of a potential Cal/OSHA reclassification of the tunnel from "potentially gassy with special conditions" to "gassy."

The EPBM was outfitted with 12 hydraulic thrust cylinders for propulsion and steering of the machine. The EPBM main and tail shields also incorporated articulation to help facilitate line and grade adjustments, as well as negotiating curves.

The launch of the EPBM started in August 2011. The EPBM shields and 25 ancillary gantries of the 230-m (754-ft) long machine were launched from the shaft and, after four setup changes, completely assembled by the end of December 2011, two months ahead of schedule.

The geotechnical evaluations during the design phase resulted in the tunnel being situated primarily in the San Antonio Formation to optimize tunneling conditions, depth, and seismic performance. Figure 6 provides a generalized geologic profile along the tunnel alignment.

The San Antonio Formation consists of interbedded medium stiff to hard clays, silts and sands, with random perched brackish water pockets in confined lenses of silts, sands and some gravel. In addition to the San Antonio Formation materials, at the end of the drive, it was necessary to tunnel through a 226-m (740-ft) long section of Franciscan Formation bedrock that consisted mainly of highly fractured basalt and serpentine rock. The entire tunnel alignment was under the water table and subject to approximately 3.2 bars (46 psi) of hydrostatic pressure.

The stiffness of the clays encountered was higher than anticipated and the soil conditioners originally intended for the drive were unable to penetrate the ground and proved, initially, to be ineffective at conditioning the muck. The "extruded bands" of clay discharged by the screw conveyor were so compact and dense they posed significant risks to the tunnel conveyor system, precluded the spoils from being extracted out of the shaft using the EPBM vertical hold conveyor, and also compromised the control of the EPBM while it was in close proximity to existing critical SFPUC infrastructure at the surface. Additionally, the risk of either plugging the machine's mixing chamber or spoils bridging over the screw intake was significant.

Using laboratory analysis of the clays, MJC first select-

FIG. 4

Compound mechanical seal at the EPBM breakout.

ed viable additives and associated proportioning capable of breaking down those clays. But the composition and proportions of the soil conditioners, however instrumental, were only part of the solution to the muck conditioning issues. To overcome the imperviousness of the stiff clays, MJC resorted to carefully adjusting the injection of raw soil conditioners (no air) at the face of the excavation, while foamed conditioners were simultaneously being injected into the mixing chamber through separate ports. As tunneling progressed, the proportions of additives were further adapted to optimize the muck conditioning and extraction in varying geologies and better control the EPBM.

While lenses of coarse grained materials within the clays were predicted, the EPBM encountered numerous, unexpected, and rapidly changing face conditions of a much greater magnitude than previously considered by MJC. In many instances the EPBM encountered up to a full face of sand. Those extreme variations in ground conditions required modifications to MJC's original ground conditioning plan to accommodate such broad disparities. Furthermore, the early signs of those changing ground conditions and the great differences in the length of those lenses made it very difficult to repeatedly and diligently alternate the ground conditioning parameters and, by extension, control the EPBM effectively in those isolated zones at first. The lag between the face changing quasi-instantaneously from a full face of clay to a full face of sand and the blowing out of loose sand and water through the screw conveyor once the last "plug" of clay had exited, momentarily compromised the EPBM control until soil conditioning changes could be implemented. The lack of cohesiveness of those sands and the large amounts of ground water that they contained required the use of much dryer foams, with minimal amounts of added water; a drastic contrast to what had just been injected for most of that shove. Additionally, having no ability to quantify or relieve the mixing chamber's "air bubble," most of the wet material that had not fallen off the tunnel conveyor advancing tail piece, would uncontrollably blow out of the screw as compressed air bubbles trapped in the muck would violently exit the screw conveyors. In such conditions, soil conditioners, air ratios, screws and screw gates had to constantly be adjusted to respond to those unsteady ground conditions. Despite these conditions, for most of the drive, the geotechnical instrumentation indicated volume losses less than 1 percent with most readings within the 0.2 percent to 0.6 percent range.

During the design phase, soil abrasion tests (SAT) were conducted on the range of soil types expected to be encountered during tunnel excavation to provide a general indication of abrasion of the excavation tools. The SAT is a relatively new test procedure and is modeled on the abrasion value (AVS) test originally developed for rock (Nilsen et al., 2006). The SAT results are compared to the standard AVS test results to determine the relative abrasivity of soils. The SAT mean values from 10 samples selected from the tunnel envelope ranged from 3 to 23, which indicated "very low" to "medium" abrasivity. The actual ground conditions encountered during construction together with appropriate ground conditioning provided for excellent results in terms of abrasive wear. In fact, only marginal primary wear was observed on the excavation tools and the original dressing of the cutterhead was never changed over the entire 7-km (5-mile) tunnel drive.

Considering the exceptional longevity of the cutting tools selected and the condition of the cutterhead following an inspection stop, as well as the performance of the EPBM through the 72MPa concrete of the launch shaft, MJC decided, after tunneling 7.5 km (4.7 miles) of the soft ground reach, to attempt to complete the Franciscan Formation bedrock reach with the original cutterhead dressing. One of the main difficulties to surmount through this rock reach was preventing the angular rock cuttings from locking in the screw conveyors. MJC was not able to batch sufficiently dense bentonite slurry to "carry" the cuttings through the screw conveyors. Ultimately, the bentonite was supplemented with stabilized tunnel backfill grout that proved very effective in increasing the density of the slurry and facilitating the extraction of the rock spoils.

The EPBM performed extremely well and the estimated production rates were exceeded by 50 percent within two months of the machine being completely assembled. It also provided excellent availability that allowed those production rates to be sustained throughout the drive with an average advance rate of 38 m/d (125 ft/day) (using two 10-hour shifts), a peak of 68.6 m/d (225 ft/day) and a record distance of 850 m (2,788 ft) advanced. After a 17-month drive the machine finally holed through into the Newark receiving shaft in January 2013.

Due to the nature of the ground along the tunnel drive and an anticipated hydrostatic head of up to 3.2 bar (46 psi), MJC also prepared for hyperbaric interventions by screening and training personnel and assembling on site a complete hyperbaric emergency facility, capable of extracting, transporting, and dispensing emergency medical treatment to personnel under hyperbaric conditions. However, the tunnel work plan indicated that compressed air interventions would only be used when the ground conditions warranted them. Through careful selection of the EPBM inspection points, MJC was able to perform all of its nine scheduled cutterhead inspections under atmospheric conditions without incidents.

During construction planning, MJC had evaluated several innovative muck removal systems including high capacity concrete pumps, a 45-m (147.6-ft) continuous vertical ribbon screw and a dedicated incline tunnel. The JV eventually chose to use a variable frequency drive (VFD) operated, composite conveyor system consisting of a 7-km (4.3-mile) continuous tunnel conveyor, tripping at the shaft into a vertical hold conveyor. This vertical conveyor system was manufactured by Hirosawa Corp. in Japan, and included a set of overland and stacker conveyors on the surface. Despite requiring frequent adjustments, this system ultimately proved to be very effective and a much safer alternative to the traditional muck box approach.

FIG. 5

Assembly of the earth pressure balance machine.

The stockpiled tunnel muck was screened for hazardous materials to identify the appropriate disposal location and it was loaded into trucks with a Fuchs material handler equipped with a clam bucket. This allowed more than 160 trucks to be loaded in a 10-hour shift.

The majority of the tunnel muck was ultimately dispositioned for beneficial reuse in nearby quarry reclamation and levee restoration projects. Some elevated levels of chrysotile asbestos and naturally occurring heavy metals were found within the muck that was generated within the Franciscan Complex bedrock materials near the end of the tunnel drive. This required disposal as a classified hazardous waste. This also required enhanced personal protective equipment for underground personnel during excavation, as well as increased air quality monitoring.

The tunnel was constructed as a two-pass system. The first pass of initial ground support consisted of a bolted and gasketed, precast concrete segmental lining erected immediately behind the EPBM. The contract plans and specifications included a preliminary segmental lining design detailed enough for bidding. However, the final segmental lining design was modified by MJC for their means and methods of tunnel excavation. The arrangement of the segments is shown in Fig. 7. Each 3.9-m (12-ft-10 in.) I.D segmental ring consisted of six trapezoidal pieces. The segments were 254 mm (10 in.) thick and 1.5 m (5 ft) in length with a taper of 19 mm (0.75 in.), which could facilitate a minimum curve radius of 177 m (580 ft). The segment materials were comprised of 41 Mpa (6,000 psi) concrete and reinforced with a dosage of 35.5 kg/m^3 (60 lbs/cu yd) of Maccoferri Wirand FF3 steel fiber. The segment joints were fitted with EDPM gaskets to minimize water inflows to the contract specified toler-

FIG. 6

Generalized geologic profile along the tunnel alignment.

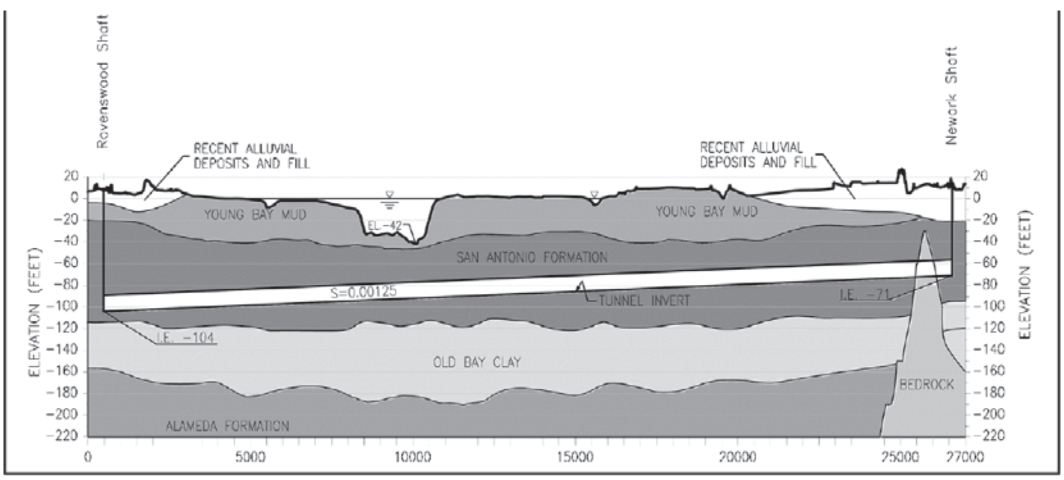
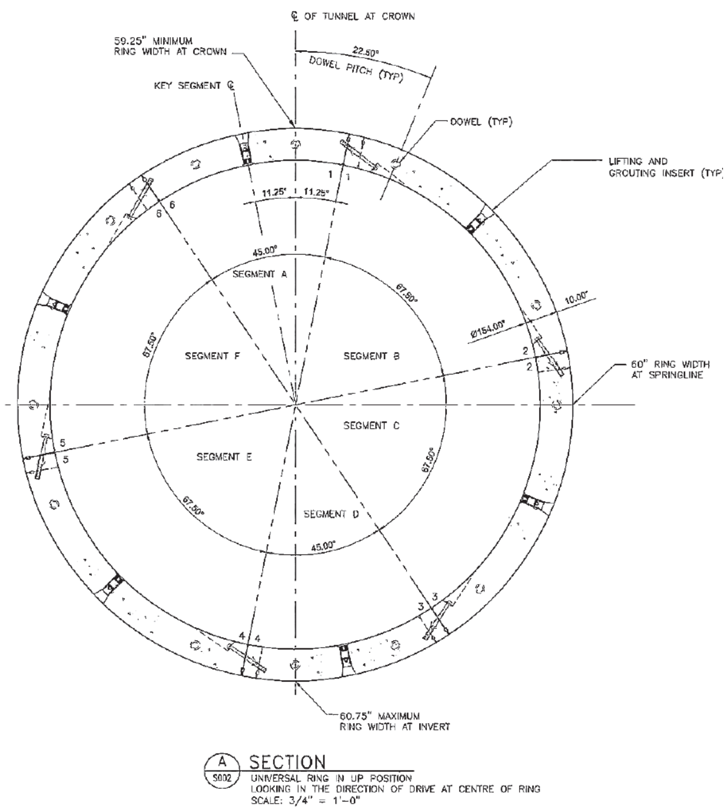


FIG. 7

Precast concrete segment arrangement.



ances. The segment radial joints were provided with bolt connections, while the circumferential joints were provided with Sofrasar self-locking dowels. Production builds of the rings in the tunnel had an average cycle time of about 10 to 11 minutes.

Following segment ring installation backfill grouting of the void between the segments and the surrounding ground was performed. MJC selected a Sagami-Servo RS-20LS-2 automatic mixing plant as the surface backfill grout plant for mixing the A component of the two part backfill grouting to fill the annular space outside of the installed segmental lining transported via truck to the site. The backfill grouting was performed through grout ports in the segments.

The segments were manufactured at the Traylor Shea plant located approximately 135 km (84 miles) away from the site near Stockton, CA. Segments were transported to the Ravenswood site two rings at a time via truck.

Receiving shaft and disposition of the EPBM

The receiving shaft at the Newark site also provided its specific challenges. The design originally called for an 8.5 m (27.9 ft) ID by 30-m (98.5-ft) deep slurry wall or caisson shaft installed in the wet, located at the end of a narrow site, with environmentally protected wetlands, endangered species, and with the existing BDPL pipelines less than a meter from the shaft. The Newark shaft site was also located within plumes of contaminated ground water with elevated levels of chlorinated volatile organic compounds so it was important to avoid cross contamination of the site aquifers. The ground water required pretreatment to meet the discharge standards specified by the local sanitary sewer agency.

MJC proposed altering the specified excavation method as well as the size and location of the shaft. The shaft internal diameter was reduced to 6.4 m (21 ft), and moved 6.7 m (22 ft) away from the BDPLs. To prevent accidental spills of drilling fluids, reduce the footprint and ground loads, avoid employee exposure to the hazardous contaminants, prevent the spreading or cross-contamination of the aquifers and spoils, limit vibrations close to the BDPLs, and provide better control over the quality of the work, MJC opted for excavating the shaft in the dry using ground freezing techniques with zone freezing and bore-through freeze pipes as the initial shaft support method.

An originally specified jet grout ground improvement zone outside the shaft was also eliminated and replaced by a mechanical exit seal in tandem with a top hat. The hole-through procedure was similarly modified to abandon the EPBM by converting the shields into an extension of the mechanical seal system, acting as a 44-mm (1.75-in.) thick steel collar, extending through the tunnel eye, 12 m (39.4 ft) into the ground.

Final lining

The final tunnel lining will consist of welded steel pipe 2.74 m (108 in.) in finished diameter including a 16 mm (5⁄8 in.) thick mortar lining. The annular space between the outside of the pipe and the initial support was backfilled with cellular concrete.

Steel riser pipe were installed in within the shafts and the annular space backfilled with a combination of concrete and controlled low strength material.

Summary

The SFPUC's 8-km (5-mile) long Bay Tunnel is a critical lifeline water supply facility for the greater San Francisco Bay Area communities. Replacement of the existing antiquated 1920s era pipeline system with the seismically robust Bay Tunnel was necessary to adequately address all of the project service requirements.

The ground conditions within the underlying San Antonio Formation were very well suited for Earth pressure balance tunneling technology and excellent advance rates of 38.1m/day (125 ft/day) average and 68.6 m/d (225 ft/day) peak were achieved during construction. The tunnel excavation commenced in August 2011 and the hole-through occurred 17 months later at the receiving shaft in January 2013, approximately eight months ahead of schedule. (References available from the authors.) ■

T&UC

FEATURE ARTICLE

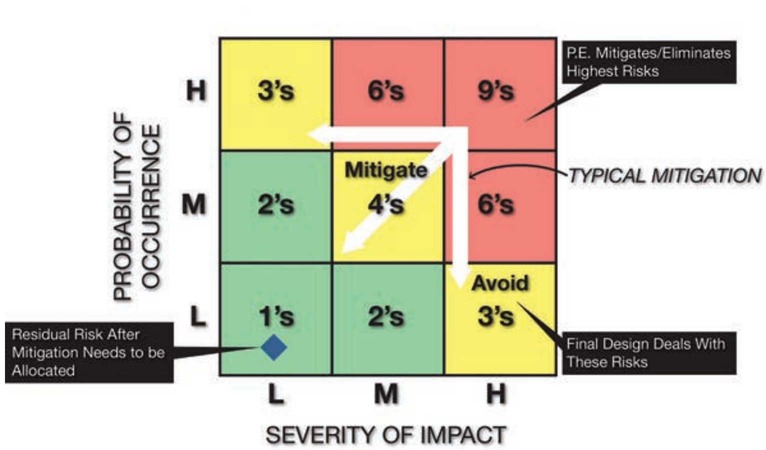
The importance of risk management on tunneling and underground construction projects

Several major impediments threaten the successful delivery of tunnel and underground construction projects. In addition to technical design and construction risks associated with tunnel projects, many of which are well understood, budgetary pressures, funding constraints and the complexity of procuring, administering and executing multiple concurrent projects in a large program could also have a catastrophic impact on the program's objectives. Contributing factors often include poorly managed design, procurement, construction, managerial, organizational, market and stakeholder risks, as well as nonconforming inputs or outputs to the costs and schedule, or any other potential inabilities to deliver the required or desired results.

A strategy to prevent 'failure' of a project requires a proactive and holistic approach to risk management. Through planning, identification, analysis, management, monitoring and control of the project's risks (both threats and opportunities), attention to management of risk will increase the probability and impact of positive events and decrease the probability and impact of events adverse to a project's objectives.

FIG. 1

Management philosophy.



Start by planning for success

Managing risks, and their potential impacts, is critical to achieving a project's overall cost, schedule, safety and performance objectives. As a process and management approach, risk management is an integral part of a successful project delivery. By promoting proactive risk management strategies that eliminate, or lessen the severity of, as much risk as possible from the earliest project planning and design stages, tunneling and underground construction projects can be successfully delivered, with a higher degree of certainty in terms of cost and time, despite many political, financial or regulatory obstacles and market conditions.

A successful project is one that will have met all of the following, as a minimum:

- Be deemed to have realized the opportunities (goals and objectives) identified for the project.
- Completed within cost and schedule goals.
- Achieved the quality and performance expected by owner and stakeholders.
- Engendered no adverse political or stakeholder reaction throughout its design, construction and commissioning.

Risk management is an explicit, structured process and a tool to help manage uncertain events, so as to maximize the chances of achieving a successful project. As such, it will help all stakeholders, owner, designer, contractor and other third parties understand and manage the relationships between their business environment, their strategic objectives, the risk to achieving these objectives and their actual performance.

Often, by the time a project is under way, managers are forced into a reactive stance, responding to each threat as it emerges. This reactive stance results in perpetual firefighting with lit-

Joe O'Carroll

Joe O'Carroll, member UCA of SME, is national practice leader, geotechnical & tunneling TEC, Parsons Brinkerhoff, email Ocarroll@pbworld.com.

FIG. 2

Project risk register.

PROJECT RISK REGISTER *(Extract)*
Project X, Toronto Canada
REV : 0
DATE PREPARED: July 28, 2010

Category	Risk Ref. I.D.	Risk Description
6.0 PLANNING		
	6.0.1	Delivery of design and construction does not align with the requirements of the EA documents that leads to undertakings not as described (scope changes), concepts oversimplified, design poorly translated & construction poorly implemented.
	6.0.2	Challenges to the EA documents with potential for court protests result in costly legal processes and delays
	6.0.3	Public feel they have not be given adequate "voice" at the public meeting and open houses leads potential for increased protests.
	6.0.4	Concept plans are hurried and budgets inadequately reflect the true costs for delivery the program.
	6.0.5	Ridership forecasts overestimates/underestimates ridership impacting vehicle requirements impacting costs and operational capacity.

tle chance of regaining control. To be effective, project managers and project engineers must identify, evaluate, communicate and prioritize risks on the basis of likelihood and severity of effect on the project from the earliest planning stage.

The projects that planners, engineers and constructors undertake in today's business environment continue to push the envelope in terms of technical difficulty, size, overall complexity, financing challenges and project delivery. Risk management is not a new concept to the world of tunneling and underground construction. Professionals in the industry are acutely aware of what could go wrong on a project and do their best to plan accordingly.

In recent years, tools, such as the geotechnical baseline report, have been put in place that communicate risk and a changed condition clause in the contract that allow a mechanism for risk allocation and sharing. While there is no arguing that these two critical components of managing risk on an underground project have contributed to increase the opportunity for projects to be more successful, there are so many more 'softer' factors that force a project, from inception through to completion, that can go 'wrong.' There are many simple steps that can be taken to provide a higher level of confidence that a project can go 'right.'

Managing risk has always been at the heart of the underground construction industry. However, in recent years the benefits of having a formal, systematic and comprehensive risk management program in place that can be carried through all phases of a project is being realized by all stakeholders in a project, be they owners, designers or contractors, financers or insurers. A risk-based approach relies on teams understanding their missions and a relentless focus on early identification and prevention of problems thereby increasing the confidence in a within time and on budget delivery.

Understanding "soft" risks and how to manage them

Some examples of 'softer' risks that are equally important in managing and delivering a tunnel and underground construction project and suggested steps to mitigate and manage them include:

Not properly identifying (and articulating) the risks beforehand, or not allocating these risks in a clear (unambiguous) and balanced manner.

This is best managed by a clear articulation and understanding by all stakeholders on the project of strategic, technical, environmental, financial, economic, political, operational, schedule and resource risks. In addition to the common documents an owner procures during the early phases of a project such as conceptual engineering report (CER); basis of design report (BOD); construction phasing and contract strategy report it is recommended that the owner also develop a risk register, a risk and contingency management plan (RCMP) and a risk allocation report (RAR).

Also important is letting a party bear the risk that it can control (i.e., the owner should take on the risk of geological conditions, environmental and other types of permits necessary to implement the project, authorizations, land use, advance long lead utility relocations). The contractor should take on the risk of means and methods, productivity, suppliers, subcontractors, workforce, materials, equipment and others. The design consultant should bear the risk of design performance.

Tunneling projects face a multitude of risks to health, safety, third-party property, the environment and community infrastructure.

Risk-based approaches designed to manage known environmental risks, anticipate unforeseen risks and pro-actively intervene to streamline project delivery are highly recommended. Early project definition that communicates environmental, utility and right of way impacts to all stakeholders and the community in which the project is being constructed will pay dividends in the long run. When it comes to interacting with the public, communication is king. A well-developed risk management plan should address and help manage risk to:

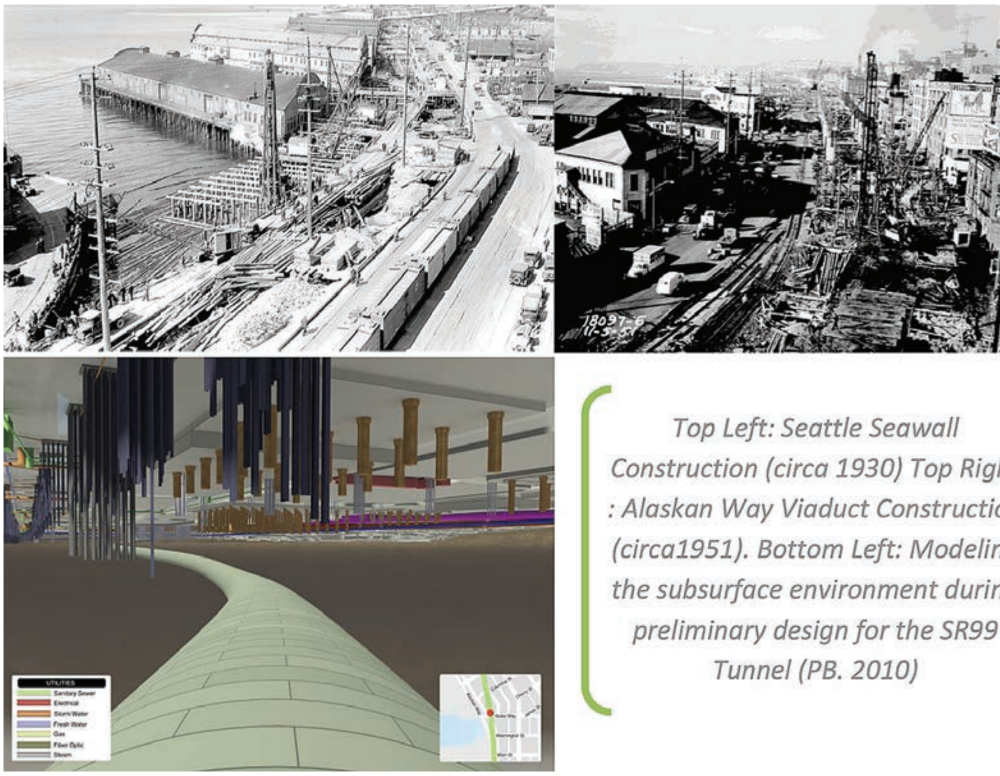
- Health and safety of third parties.
- Third party property, including utilities, existing buildings and structures, cultural heritage

buildings and above and below ground infrastructure.

- The environment including possible land, water, air and noise pollution.
- Community infrastructure, i.e., extent of traffic lane and sidewalk closures, barricades, in excess of what the community expects.
- Local businesses and residents from more noise, dust, dirt and vibration than the city regulations permit or the community expects.
- Health and safety of workers, many of whom will be hoping for employment or other business opportunities as a result of the project being in their neighborhood.

FIG. 3

Historical look at Seattle tunneling.



Top Left: Seattle Seawall Construction (circa 1930) Top Right : Alaskan Way Viaduct Construction (circa1951). Bottom Left: Modeling the subsurface environment during preliminary design for the SR99 Tunnel (PB. 2010)

Preventing procurement risk

A major risk on tunneling projects is that the owner enters a contract based on expectations of cooperation, not conflict, and assumes that most of the objectives of the owner and the contractor are the same. Several risks result from this risk, not least of which is:

- Lack of clarity and direction when disputes arise.
- Not finishing the project on time.
- Not finishing within budget and at the agreed-upon level of quality.
- Misunderstanding by contractors of the objectives of the owner.

A well-developed, comprehensive risk management plan will provide:

- A clear definition of the scope of works and risk allocation.
- Well prepared bid documents that give an unambiguous set of conditions as well as clear requirements on risk allocation.
- Well-defined rules for acceptance and take-over by the owner .
- A balanced sharing of risk and conflict resolution schemes that secure a quick resolution of conflicts.

Avoiding cost overruns and schedule delays from the start

Major tunneling projects are at high risk of cost overruns and construction delays because of the linear nature of construction. It is unlikely that a project will not be completed due to technical reasons however cost overruns and construction delays are probable and an important source of risk. The first step in preventing cost overruns and schedule delays is through development of robust cost estimates and construction schedules by estimators experienced in preparing bid-like cost estimates and schedules for contractors on major tunnel projects followed by the identification and management of risks, and their potential impacts, that could adversely impact the completion cost of the project.

Risk identification can be conducted through a series of risk interviews and workshops engaging all key project participants and stakeholders. The objective is to examine baseline assumptions and assess the impact of risk to completion within the desired cost and schedule objective. The process is supported by a Monte Carlo analysis on both cost and schedule, taking into account all identified and quantified risks producing a probability distribution of the project's possible complete dates and costs. This level of risk analysis provides a quantitative basis for levels of confidence; serves to prioritize attention on risk most likely to have a significant impact and establishes required cost and schedule contingency levels.

Major tunnel and underground construction projects run the risk of cost overruns due to:

- Underestimation of construction costs often as a result of needing to stay within a politically acceptable cost estimate.
- Underestimation of risk and its financial consequences.
- Inadequate contingencies to cover risk.
- Lack of understanding as to the purpose and management of contingencies.
- Poor cost control.
- Additional financing expenses.
- Underestimated or increased administrative costs.
- Design and performance requirements changes.
- Ambiguity in the contract documents leading to low bids followed by claims and contractual disputes.

Several risks that contribute to delays on major tunneling and underground projects include:

- Underestimation of construction schedule often as a result of needing to stay within a politically acceptable timeframe for completion.
- Problems with a project's organizational structure resulting in lack of decision making.
- Environmental mandates not being met or being challenged.
- Procurement delays due to stakeholders in a project having different interests.
- Unclear contractual responsibilities.
- Unforeseen geological difficulties.
- Mechanical problems with selected excavation equipment.
- Lower than expected tunneling progress.
- Late changes in the design including technology changes.

Steps that can be taken to more effectively manage these risks and keep your project on the right track include:

- Establishment of agreements with the regulatory agencies to guide the review of the project; by defining clear roles and responsibilities, review and approve timeframes, agreed upon methodologies, funding of dedicated agency staff, and an issue resolution process.
- Establishment of program level agreements for threatened and endangered species, stream and wetland mitigation, or other environmental impacts that may affect procurement schedules.
- Designing to budget.
- Creating geotechnical baselines as a basis for the contract.
- Risk analysis to determine construction contingency in cost estimating.
- Communicate the concept of risks early in the process to help all stakeholders understand tradeoffs.
- Provide transparency in financial reporting system.

Designing to budget

Scope and budget creep during the design phase of a program places major pressures on those responsible for delivery within strict financial and funding constraints. In the planning phase, developing project level budget ranges in association with a risk-based contingency will provide decision makers and their partners with a more accurate assessment of ultimate project and program costs and a realistic confidence level in achieving their target.

Once a robust and realistic budget is established, it is not unreasonable to then expect designers to 'design to budget' in order to more effectively reduce the potential for scope and budget creep prior to award of contracts. Early definition and mitigation of risks associated with environmental constraints, right-of-way acquisition requirements, utility relocations, construction costs and schedule expectations are key to successful delivery of procurement documents that will result in construction bids being received well within established budgets.

Market forces negatively impact project costs. One of the most influential impacts to cost certainty is the prevailing local, national and world economic climate. As was seen in 2004 through 2007, significant overheating prevailed driving up actual bid construction costs well above reported building cost inflation indices. Over the past few years, the depressed economic conditions have, and continue to have, an overriding influence on actual bid costs. It is uncertain how the economic climate over the next few years will influence the bidding market, although one could speculate it could continue to be significant. Traditional trends show sharp depression followed by sharp return to overheating in the construction industry and, the deeper the recession, or in this case the depression, the potentially greater the upswing driven by diminished capacity in material, plant and labor supply chains unable to ramp up to meet the sudden upturn in demand.

A strategy to manage market force surprises could include an analysis of the following market-related scenarios: recession ending with slow recovery, recession ending with fast recovery, prolonged recession with a slow recovery and prolonged recession with fast recovery. Controlling market forces on a project is virtually impossible but understanding their impact and preparing accordingly is critical to achieving cost certainty. Depending upon the prevailing market conditions, progressing quickly with a project may capture the benefit of continuing depressed bids to the advantage of the project.

Preventing geotechnical risk becoming too onerous

Underground projects present unique challenges that increase risk more than any other type of new infrastructure. Risk is increased significantly when the ground conditions are poorly understood and misrepresented in the contract. Irrespective of location and type, the ground conditions will always present an element of risk in the excavation of a tunnel or underground structure.

This is usually caused by:

- Inappropriate site investigation techniques, drilling, sampling and lab testing resulting in poor geotechnical interpretations and baselines.
- Unknown buried obstructions (piling, logs, concrete, sheeting, harbor remnants, boulders) along alignment.
- Insufficient geotechnical data provided to the contractor at time of bid.

And results in:

- Unforeseen and adverse ground conditions, resulting in a delay or stoppage to tunneling.
- Settlement damage or distortion to utilities or other structures due to ground loss going undetected until it effects roadways, utilities, nearby buildings resulting in loss of services, cracked sidewalks, windows and doors of surrounding buildings being out of plumb.
- Excessive settlement of existing structures leads to unacceptable structural damage of masonry buildings.
- Uncontrolled loss of pressure at the tunnel face during excavation causes settlement, sinkholes or, in extreme cases, complete collapse of the ground above the tunnel.

This risk need not become unnecessarily onerous if managed properly from the early phases of a project. Steps in which this risk can be minimized include:

- Carry out a comprehensive desk top study on the historical usage of the project area to get a greater understanding of what might be below the surface in terms of buried structures, industrial debris, disused basements, pipelines, building foundations etc.
- Plan a comprehensive, phased geotechnical program that includes both physical and geophysical investigations where appropriate.
- Identify and prioritize "hot spots" which would be significant in determining both the feasibility and methodology needed for tunnel construction.
- Depending on results of pre-design investigations, define scope for geotechnical investigations for final design including investigating the presence of methane gas, contaminants, fault zones, mixed face conditions as these are likely to significantly increase tunneling and shaft construction costs.

Conclusions

Risk is inherent in most human endeavors. Controlling that risk is often the difference between success and failure. To be successful on today's tunnel and underground construction projects, risk management must be viewed as an explicit, structured process and an integral part of project development — a way of thinking as well as a tool to help manage uncertain events.

To achieve success, one must start by planning for success. Risk management strategies that eliminate, or lessen the severity of as much risk as possible from the earliest project planning and design stages is an important step in achieving this goal. A risk-based approach relies on all participating parties in a project understanding their missions and a relentless focus on early identification and prevention of problems, thereby increasing the confidence in a within time and on budget delivery. A well-developed, comprehensive risk management plan will provide a clear definition of the scope of works and risk allocation, well-prepared bid documents that give an unambiguous set of conditions as well as clear requirements on risk allocation, well-defined rules for acceptance and takeover by the owner and a balanced sharing of risk and conflict resolution schemes that secure a quick resolution of conflicts.

Key to avoiding cost overruns and schedule delays are designing to budget; creating geotechnical baselines as a basis for the contract, and adopting risk analysis techniques to ensure reasonable contingencies are established in the cost estimate and schedule, supported by a contingency management plan that preserves appropriate contingencies through all phases of a project from concept to commissioning.

When owners, designers, constructors and other stakeholders commit to jointly identifying and mitigating risks through the comprehensive assessment of risk value, use of risk workshops, development of an "actionable" risk registers, risk analysis and the development of risk and contingency management plans the industry will benefit from having more projects with fewer delays, less cost increases, reduced environmental or other third party impacts, and ultimately decreased risk to operational safety and reliability of our tunnel or underground construction projects. ■

FEATURE ARTICLE

Controlling ground water in tunneling is subject of third Cutting Edge conference

The third edition of the Underground Construction Association of SME's (UCA) Cutting Edge series of conferences focused on a challenge every underground construction and tunneling project faces: controlling ground water.

The conference, held in New York City in November, is a partnership between the UCA and The North American Tunneling Journal. It featured more than 20 technical presentations by professionals from around the world. Each described specific challenges unique to their projects and the solutions employed. More than 175 professionals attended the two-day conference that included an exhibition featuring 17 companies. In addition to the technical program, the Cutting Edge conference featured a site visit to the $10.4 billion East Side Access Project. Sponsors of the meeting included Soil Freeze, Traylor Bros., Kiewit, Skanska, Moretrench, Aecom and The Robbins Co.

The Cutting Edge conference included a field trip to the East Side Access project in New York City. Photo courtesy of the Metropolitian Transportation Authority.

Technical program

The Harbor Area Treatment Scheme is an attempt to improve the water quality in Hong Kong Harbor. The scheme is being implemented in a number of phases. Stage 1, formerly known as the SSDS, was completed between 1995 and 2001, according to Andy Thompson of Hatch Mott MacDonald, and now stops some 600 t (660 st) of sludge that was being added to the harbor daily. This, he said, has led to a marked improvement in water quality. Stage 1 consisted of six separate tunnels totaling 23.6 km (14.6 miles), excavated at depths of up to 130 m (425 ft), beneath open water, new reclamations, and densely inhabited urban areas. Five of the six tunnels were driven using hard rock tunnel boring machines (TBM). Thompson reviewed the measures needed to control ground water during the tunnel operations and some of the lessons learned.

The final breakthrough at Sweden's Hallandsas project in August 2013 marked the successful completion of two railway tunnels through the ridge of Hallandsas. The combination of highly water-bearing rock and a strict environmental water permit governed the tunneling, according to Skanska's Oskar Aurell. One of the project team's main tasks was to develop methods for limiting ground water ingress and/or handling the water ingress effectively. This was managed by developing several pre-excavation grouting methods, in both open and pressurized mode, and by controlling outwash of backfill material using a combination of pea-gravel and mortar, he said. In addition, ground freezing of the highly weathered rock mass in the Molleback zone was carried out from the tunnel.

Steve Kral, Editor

Two tunneling projects in Iceland have experienced high water inflows during construction, according to Ermin Stehlik, of Gall Zeidler. The key components of the 14-km- (8.7-mile-) long highway project were two road tunnels, Siglu (3.6 km or 2.2 miles) and Olafs (6.9 km or 4.3 miles). During construction of the Olafs Tunnel, there were extremely high inflows of cold water that necessitated a chemical grouting regime, he said. The second project discussed, the Vadlaheidi road tunnel is a 7.2-km- (4.5-mile) long tunnel that is currently under construction. About 40 percent of its length has been excavated. Stehlik said that during excavation, hot water inflows created such difficult conditions that the contractor had to temporarily abandon the heading and start tunneling from another portal.

The Arrowhead Tunnels Project in California was the final portion of a 70-km- (44-mile) long water conveyance facility is to convey up to 28 m3/sec (1,000 cu ft/sec) of water into southern California. The 13-km (8-mile) tunneling portion of the project consisted of two 5.8-m- (19-ft-) diameter TBM bores through extremely variable geological conditions. Brian Fulcher, of Kenny Construction, addressed some of the problems and solutions implemented to advance two hybrid TBMs under conditions that ranged from hard rock with no water inflows to full-face granular material under 10-bar pressure and in excess of 32 L/sec (500 gpm) inflows.

Mark Havekost, of Jacobs Associates, discussed adverse ground water conditions encountered while building a new water-conveyance tunnel and pipeline for the Central Utah Water Conservancy District. The Upper Diamond Fork project consisted of two separately bid and awarded phases, he said. Phase 1 was fully designed but only partially built. Phase 2 was fully built, with design elements modified from Phase 1, as well as new design elements. Phase 1 consisted of 6,950 m (22,800 ft) of 3,200-mm (126 in.) finished diameter tunnel lined with cast-in-place concrete. The tunnel was excavated with a hard rock main-beam TBM. Difficult subsurface conditions included high ground water inflows and hazardous concentrations of hydrogen sulfide that were encountered 80 percent into the drive. These conditions stopped the project, Havekost said, and alternative alignments and methods were evaluated. Subsequently, the project was rebid under a new contract (Phase 2) to bypass the upstream end of the tunnel, including nearly 3.2 km (2-miles) of newly excavated tunnel.

The Sistema de Potabilizacion Area Norte project in Argentina will transport and purify water from the Parana River to provide potable water for the northern Buenos Aires province. The project consists of a 15-km- (9.3-mile-) long, 3.65-m- (2-ft-) diameter bored raw water tunnel, a treatment plant and underground distribution piping to nearby communities, according to Joe Sopko, of Moretrench. The designed excavation support system for Access Shaft #3 was a diaphragm wall with a jet-grouted bottom plug. When the shaft was excavated, leaks were encountered between the wall panels leading to ingresses of water and soil. Remedial efforts were unsuccessful, he said. Eventually, the shaft was filled with lean concrete above the tunnel crown to allow passage of the TBM below. Moretrench was contracted to design, furnish and install a ground freezing system to cut off water entry into the shaft and allow the general contractor to proceed with installation of the final cast-in-place concrete liner.

The South Bay Ocean Outfall Tunnel is part of a system designed to treat and dispose of raw sewage entering the Tijuana River Valley from Mexico. The project is located at the United States/Mexico border. Brett Robinson, of Traylor Bros., provided an overview of the project's construction, with special emphasis on how lessons learned have been applied to other tunnel projects. The 3.5-m- (11-ft-) finished diameter tunnel extends 5.8 km (19,000 ft) west from the bottom of a 60-m- (200-ft-) deep, 11-m- (36-ft-) diameter drop shaft, he said. At the western terminus of the tunnel, a riser shaft connects the tunnel to conveyance and diffuser pipes on the seabed. The tunnel runs through the San Diego Formation, consisting of clay, silt, sand, gravel, cobbles and boulders.

Dealing with water inflows is not new to TBM tunneling. There are, however, an increasing number of methods and best practices to deal with potentially high water inflows efficiently and safely. Brad Grothen, of The Robbins Co., explained some of them. High volumes of water can be safely contained or managed in hard rock TBM tunneling, he said, but this requires the proper foreknowledge and planning. Grothen outlined, from the TBM manufacturer's perspective, how machines can be designed for anticipated high water and how risk can be mitigated during tunneling. A few case studies of hard rock tunneling with heavy water inflows were discussed with an eye toward TBM design and water control programs and how those might be changed to make the outcome more successful. ■

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	Prequals underway
Water Tunnel #3 Stage 3 Kensico	NYC-DEP	New York	NY	Water	84,000	20	2017	Under design
Cross Harbor Freight Tunnel	NYC Reg. Develop. Authority	New York	NY	Highway	25,000	30	2016	Under study
South Conveyance Tunnel	City of Hartford	Hartford	CT	CSO	16,000	26	2015	RFQ underway
Red Line Tunnel - Cooks Lane Tunnel	MD Transit Administration	Baltimore	MD	Subway	14,000	22	2015	Under design
Red Line Tunnel - Downtown Tunnel	MD Transit Administration	Baltimore	MD	Subway	36,000	22	2015	Under design
Purple Line - Plymouth Tunnel	MD Transit Administration	Baltimore	MD	Subway	1,000	30x40	2015	Bid date First Q 2015
Northeast Branch Tunnel Northeast Boundary Tunnel	DC Water and Sewer Authority	Washington	DC	CSO CSO	11,300 17,500	15 23	2018 2021	Under design Under design
Olentangy Relief Sewer Tunnel	City of Columbus	Columbus	OH	Sewer	58,000	14	2016	Under design
Blacklick Creek San. Interceptor Tunnel	City of Columbus	Columbus	OH	Sewer	24,000	10	2015	Under design
Alum Creek Relief Tunnel Phase 1 Phase 2	City of Columbus	Columbus	OH	Sewer	30,000 21,000	18 14	2016 2017	Under design Under design
Dugway Storage Tunnel	NEORSD	Cleveland	OH	CSO	16,000	24	2014	Awarded Salini Impregilo
Doan Valley Storage Tunnel	NEORSD	Cleveland	OH	CSO	9,700	17	2017	Under design
Westerly Main Storage Tunnel	NEORSD	Cleveland	OH	CSO	12,300	24	2020	Under design
Shoreline Storage Tunnel	NEORSD	Cleveland	OH	CSO	16,100	21	2021	Under design
Southerly Storage Tunnel	NEORSD	Cleveland	OH	CSO	17,600	23	2024	Under design
Big Creek Storage Tunnel	NEORSD	Cleveland	OH	CSO	19,500	20	2026	Under design
Ohio Canal Interceptor Tunnel	City of Akron	Akron	OH	CSO	6,170	27	2015	Under design
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
Fall Creek	Indianapolis DPW	Indianapolis	IN	CSO	19,600	18	2016	Under design
White River Tunnel	Indianapolis DPW	Indianapolis	IN	CSO	28,000	18	2016	Under design

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Three Rivers Protection/Overflow	City of Fort Wayne	Fort Wayne	IN	CSO	26,400	12	2017	Under design
Des Plains Inflow Tunnel	MWRD of Greater Chicago	Chicago	IL	CSO	5,400	20	2015	Under design
St. Louis CSO Expansion	St. Louis MSD	St. Louis	MO	CSO	47,500	30	2014	Under design
KCMO Overflow Control Program	City of Kansas City, MO	Kansas City	MO	CSO	62,000	14	2014	Under design
Mill Creek Peaks Branch Tunnel	City of Dallas	Dallas	TX	CSO	5,500	26	2014	Under design
East Link Light Rail Extension	Sound Transit	Seattle	WA	Transit	30,000	22	2016	RFQ underway
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 2015 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	2014	RFQ underway
River Supply Conduit - Units 5 and 6	LA Dept. of Water and Power	Los Angeles	CA	Water	8,608	12	2014	W.A. Rasic low bidder
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	Under design
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	2017 2018	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
Combined Sewer Storgage - East-West	City of Ottawa	Ottawa	ON	CSO	14,400	10	2015	Under design
Combined Sewer Storgage - North-South	City of Ottawa	Ottawa	ON	CSO	5,300	10	2015	Under design
Energy East Pipeline	TransCanada	Quebec City	QC	Oil	13,780	16	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

SHORT COURSE

CSM to host microtunneling short course

The Microtunneling short course returns to the Colorado School of Mines campus in Golden, CO, Feb. 10-13, 2015 for its 21st year. The course includes a one-day pilot tube microtunneling seminar on Feb. 9.

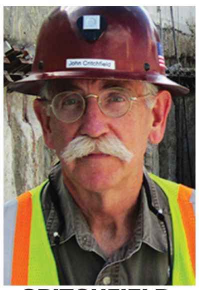
Microtunneling has continued to evolve and expand since its inception in the United States nearly 30 years ago because of its reduced impact on roads, residents and people. The microtunneling short course includes presentations from leading experts discussing all facets of the discipline, from design and planning to shaft construction and slurry management.

Course directors are Timothy Coss, president of Microtunneling Inc. and Levent Ozdemir, president of Ozdemir Engineering.

As part of the program, winners of the microtunneling achievement awards will be recognized at a banquet on Feb. 11, 2015, at the Golden Hotel, in Golden, CO.

For information or to register, please visit http://csmspace.com/events/microtunnel. ■

PERSONAL NEWS


CRITCHFIELD

Jacobs Associates Construction Managers, a division of Jacobs Associates, recently hired two new employees. **JOHN CRITCHFIELD** P.E., a lead associate, serves as resident engineer on the Alaska Way Viaduct Program project in Seattle, WA. He has nearly 40 years of experience in geotechnical and underground engineering in heavy civil projects with particular emphasis on tunneling. **MICHAEL KOBLER** (SME), a senior associate, serves as the resident engineer on the Central Subway Project team in San Francisco, CA. He has more than 30 years of experience in providing services for public agencies and private companies in tunneling and underground construction.


KOBLER

ANDY McKOWN has joined Brierley Associates. His 35-year career has focused on rock engineering, blast consulting, drill and blast design, and blast vibration monitoring of sensitive historic structures and urban infrastructure. He has assisted as a technical expert on numerous blast damage claim investigations and blasting and vibration problems, and as an expert witness on blasting- and vibration-related cases.


McKOWN

GREG YANKEY has established Brierley Associates' newest office in Lexington, KY. Yankey has served as the U.S. geotechnical practice leader and vice president for an international consultancy responsible for geotechnical and civil engineering projects specifically related to dam and levee engineering design, construction, operation and inspection, forensics and failure analysis.

RICK SMITH, P.E., was recently promoted to Senior Associate with Jacobs Associates's Seattle, WA office. Smith has 27 years of geotechnical engineering experience in heavy civil design and construction. He is currently managing geotechnical and trenchless services for the Rainier Valley Wet Weather Storage Project in Seattle and the foundation design for several railroad bridges.


SMITH

Jacobs Associates has promoted three employees to lead associate. **JENNIFER JORDAN**, P.E., is the manager of the Boston, MA office. She has more than 20 years of experience in geotechnical-related field investigation, design and construction. She recently served as lead geotechnical engineer on DC Water's Clean Rivers Project. **ANDREW McGLENN**, P.E., has 17 years of experience in structural engineering for aboveground and underground infrastructure. He is based in the Seattle, WA office, where he serves as the lead structural engineer on underground projects in the Pacific Northwest and overseas. **LAURA MILES,** P.E., is based in the Portland, OR office and has more than 27 years of experience in the civil engineering industry.


JORDAN

ROBERT FILGAS, P.E., has joined Jacobs Associates' Walnut Creek, CA office as a senior associate. He has 34 years of civil, structural and water-resource project experience, including locks, dams, hydroelectric powerhouses, pipelines, canals and tunnels. ■

BUSINESS OFFICE

SME - 12999 E. Adam Aircraft Cir.,
Englewood, CO 80112 USA
+1-800-763-3132 • Advertising: x243
Direct: +1-303-948-4243
Fax: +1-303-973-3845
www.smenet.org

EDITOR
Steve Kral
kral@smenet.org

SENIOR EDITOR
Bill Gleason
gleason@smenet.org

PRESS RELEASES
Steve Kral
kral@smenet.org

ADVERTISING AND PRODUCTION/ MEDIA MANAGER
Ken Goering
goering@smenet.org

PRODUCTION DESIGNER
Jennifer Bauer
bauer@smenet.org

T&UC CLASSIFIEDS

ADVERTISER INDEX • DECEMBER 2014

ADVERTISING SALES OFFICES

HOOPER JONES
CENTRAL, NW U.S.
+1-847-486 -1021
Cell: +1-847-903-1853
Fax: +1-847-486-1025
hooperhja@aol.com

MARSHA TABB
EAST, SOUTH, WEST U.S.
+1-215-794-3442
Fax: +1-215-794-2247
marshatabb@comcast.net

SHERRI ANTONACCI
EAST, SOUTH, WEST U.S.
+1-267-225-0560
Fax: +1-215-822-4057,
smesherri@gmail.com

DARREN DUNAY
CANADA
+1-201-781-6133
Cell: +1-201-873-0891
sme@dunayassociates.com

EBERHARD G. HEUSER
EUROPE
+49 202 2838128
Fax: +49 202 2838126
egh@heusermedia.com

PATRICK CONNOLLY
UNITED KINGDOM
+44 1702-477341
Fax: +44 1702-177559
patco44uk@aol.com

KEN GOERING
INTERNATIONAL SALES
+1-303-948-4243
Fax: +1-303-973-3845
goering@smenet.org

TUNNELING & UNDERGROUND CONSTRUCTION INDEX TO VOLUME 8
January-December 2014
Feature Articles, Industry Newswatch, Technology News