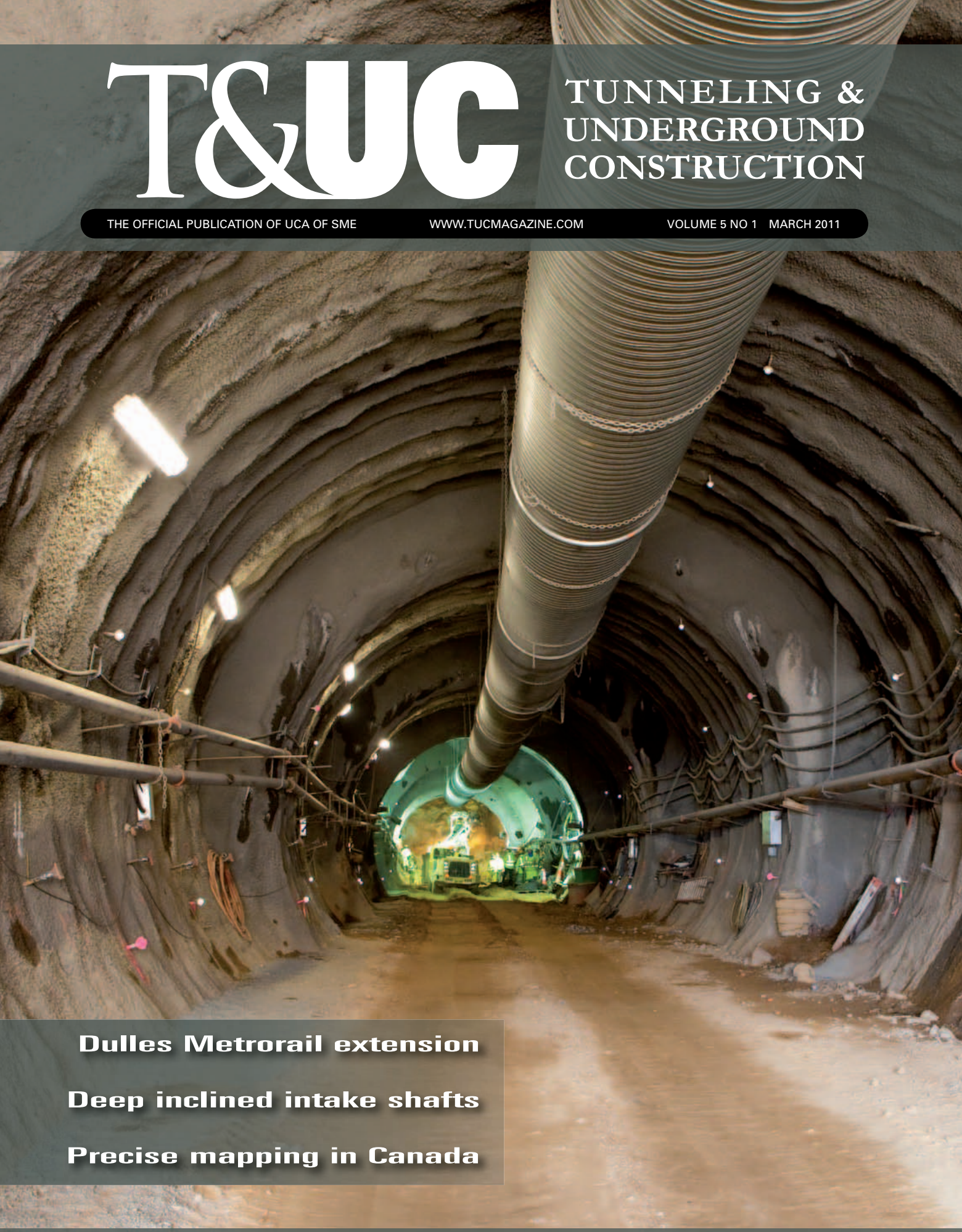

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TUNNELING & UNDERGROUND CONSTRUCTION

THE OFFICIAL PUBLICATION OF UCA OF SME WWW.TUCMAGAZINE.COM VOLUME 5 NO 1 MARCH 2011

Dulles Metrorail extension

Deep inclined intake shafts

Precise mapping in Canada

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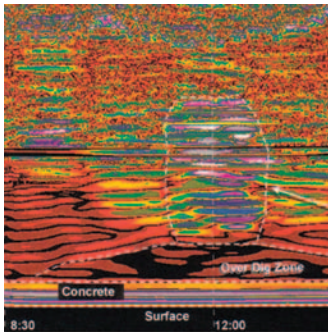
CONTENTS

FEATURE ARTICLES



COVER STORY

COVER — The tunnel section of the first phase of the Dulles Metrorail extension is short, but complex. With just 2 m (7 ft) of ground cover in some places, the tunnel was constructed using the NATM method and need consistent and reliable shotcrete. Liebherr provided the batch plant that mixed the concrete for the tunnel, page 46. Photo courtesy of Liebherr.

DEPARTMENTS

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CHAIRMAN'S COLUMN

Record attendance at George A. Fox Conference reflective of the industry

On behalf of the UCA of SME Executive Committee, I would like to thank all of those who braved the winter weather to attend the 2011 George A. Fox Conference, Jan. 25, 2011 in New York City. We had a record attendance of 351 registrations and many of those were "walk-ups" of project people from the various ongoing tunnel projects currently under planning, design or construction in the greater New York City area. The success of the Fox Conference is a direct result of the hard work and coordination efforts put forth by the UCA George Fox Conference Committee members and its chairman, Hugh Lacy. The program was titled "Drill and blast excavation: Experience and advantages." The speakers were informative and the topic was timely to the current industry requirements. It seems we still have a large number of people in our industry who enjoy drilling holes and blowing things up.

On Jan. 26, we had our semi-annual UCA of SME Executive Committee meeting. I am pleased to announce that the UCA of SME is financially sound and the current membership has grown to almost 900 members as of Dec. 31, 2010. I must request that you be diligent and renew you membership and encourage others within the industry to join if they are not already members. To be blunt, it takes revenue to advance the industry outreach and scholarship programs and the UCA of SME is a way for everyone in the industry to contribute to the betterment of the industry. During the meeting, the committee elected its new executive committee members whose terms will be the committee effective July 1, 2011. Bill Edgerton was elected as the new vicechairman; new executive committee members elected to join the committee on July 1, 2011 are:

- Engineers — Nasri Munfah for a full term, Heather Ivory to complete Edgerton's term.
- Owners — Judy Cochran.
- Contractors — Mike Roach.
- Suppliers — Len Worden.

The executive committee is looking forward to working with the new members and appreciates the service of the members who are rotating off. All new members will be formally introduced at the June 22, 2011 executive committee meeting during the RETC in San Francisco, CA. I want thank those who are rotating off the executive committee for their many years of service to the organization.

The presentation of awards for industry achievement is an important responsibility of the UCA Executive Committee.

We are most deliberative and cognizant of the fact the awards must be presented in a manner that affords the recipients the opportunity to receive adulation from their peers while providing the proper forum for an acceptance speech. Due to time constraints in the RETC 2011 program, the UCA will not be presenting any awards during RETC 2011.

The executive committee discussed the matter and voted to approve the policy of presenting UCA awards on an alternate year basis at the UCA North American Tunneling conference awards dinner. The next UCA awards presentation will occur at the NAT 2012 conference in Indianapolis, IN. We appreciate the time that individuals took to make nominations for 2011. However, the action taken is in the best interest of the RETC and UCA programs and were within the full

(Continued on page 7)

David R. Klug,
UCA of SME Chairman

Tunnel under the Hudson is not dead yet

The first four listings of this issues' Tunnel Demand Forecast (page 44) are part of the Access to the Region's Core (ARC) project. While still officially listed as "canceled," there are question marks attached to the status of each project thanks to an announcement from Amtrak that it intends to spend $50 million to study a new Hudson River tunnel project.

The "Gateway" tunnel proposed by Amtrak would largely follow the same footprint as the canceled 14-km (9-mile) ARC tunnel from Secaucus to New York City. However, the Gateway tunnel will connect to new tracks in an expanded New York Penn Station instead of dead-ending deep under West 34th Street, representatives for U.S. Sens. Frank Lautenberg and Robert Menendez said.

The Gateway project is part of a larger Amtrak plan for high-speed rail along the Northeast corridor. The plan has been in the works for a few years but was fast-tracked after New Jersey Gov. Chris Christie canceled the ARC project. The Obama administration has made high-speed rail a priority, and New Jersey's senators said they would try to snag money left on the table by Midwest governors who rejected projects.

The Gateway project would be less beneficial to commuters than the ARC project because its primary goal is to speed long-distance trains between New York and destinations like Philadelphia and Washington, D.C. The extra capacity for commuter trains is an ancillary benefit. As with ARC, Gateway is expected to create jobs and boost real-estate values.

The Gateway tunnel would allow 13 additional NJ Transit trains per hour — from 20 to 33 — and eight more Amtrak trains. The ARC project would have allowed 25 extra NJ Transit trains per hour.

The project could cost more than $10 billion. *The Wall Street Journal* reported that, while it is unclear where the money would come from, Amtrak has said it is looking for private-sector partners. One of its commissioners said the train company would "put a significant part of its capital resources" into Gateway.

The project also could benefit from the engineering work done previously for ARC.

Amtrak had intended to build another tunnel to improve capacity in the nation's most congested rail corridor, but not until 2040. The killing of the ARC tunnel expedited the Gateway tunnel plans.

Citing projected cost overruns that would leave New Jersey taxpayers on the hook, Christie pulled the plug on the nation's largest public works project on Oct. 27.

Lautenberg immediately began working with Amtrak to revive the trans-Hudson rail tunnel project, which he says will benefit New Jersey's commuters by giving them transfer-free train rides to prosperous jobs in Manhattan, increase property values along the rail line and put contractors to work. ■

New Jersey makes a case to keep ARC funds

Because the Federal Transit Administration (FTA) said the tunnel portion of the Access to the Region's Core project would cost between $9.8 billion and $12.7 billion, well above initial estimates of $8.7 billion, attorneys argued that NJ Transit could not guarantee it would be able to pay its portion and, therefore, will not repay $271 million in federal grants.

Originally, NJ Transit's financial plan had New Jersey paying $2.7 billion of the likely $8.7 billion price tag, but it was also responsible for any extra costs.

Attorneys from the Washington D.C. firm Patton Boggs said in papers filed with the FTA, "NJ Transit's inability to carry out the ARC project was caused by reasons beyond its control. Therefore, NJ Transit has no repayment obligation."

Patton Boggs said NJ Transit only owes $51.5 million in "new starts" money for the tunnel and said the FTA is trying to recoup $219.5 million in funds from two other grant categories the state would have received anyway.

In that analysis, consultants Delon Hampton and Associates said parts of the project were underestimated by as much as 50 percent for construction of the actual tunnel under the Hudson River. Other factors included having to add funds to acquire real estate in Manhattan and New Jersey, the *Asbury Park Press* reported.

That analysis said those added costs had the potential to bring the total project cost from $8.7 billion to a high of $14 billion, which Gov. Chris Christie said the state could not afford.

NJ Transit's attorneys argue the agency is not liable to return the funds because the project was canceled due to circumstances beyond its control, which is permissible under the agreement it signed with the FTA. Attorneys added that the FTA has failed to provide all the tunnel project documents requested since November. NJ Transit officials also said the FTA changed how it analyzed risks in the project between 2009 and 2010. ■

Seattle Tunnel Partners submit winning bid

The Seattle Tunnel Partners offered the winning bid to build the nearly $1.1-billion, 2.7-km- (1.7-mile-) long, deep bore tunnel that will replace the Alaskan Way Viaduct in Seattle, WA.

The Seattle Tunnel Partners, a joint-venture group that includes New York-based Dragados USA, whose parent company is ACS of Spain; and HNTB Corp., which is headquartered in Kansas City; and Tutor-Perini of California outbid the Seattle Tunneling Group with a proposed price of $1.09 billion to build the tunnel.

Washington State Transportation officials said the winning bid was slightly higher than a bid from the competitor, but Seattle Tunnel Partners' proposal was notable for its soil protection plans, as well as its anticipated schedule and design aspects. A wider roadway was also promised by the construction team, *Seattlepi.com* reported.

The value of the contract could be worth as much as $1.42 billion if the construction team can hit certain bonuses for things such as completing the tunnel ahead of schedule and successfully protecting downtown buildings from damage during construction.

The state also offered about $210 million in allowances and incentives from a $415-million reserve fund to keep the project within budget. Half of that money was to cover higher inflation estimates and higher costs for insurance and bonding.

Although the contract was signed, construction cannot begin until approval by the federal government, which is expected later this year.

When construction does begin, a 17-m- (57-ft-) diameter tunnel boring machine will burrow beneath downtown, starting from Alaskan Way in Sodo, and lay the framework for a tunnel that will have two road decks and be the world's largest soft-ground tunnel when it opens in 2015 or 2016.

Seattle Mayor Mike McGinn has been a vocal opponent of the project, citing fears that because of the Seattle's glacial soils and the size of the tunnel, that there will be cost overruns that will be passed on to the city. The budget for the entire tunnel project, including the portals, property acquisition and management, is about $1.96 billion and the cost estimate for the entire viaduct replacement project, which includes work to demolish the southern stretch of the viaduct and the city's plans to build a new waterfront park, is $4.2 billion.

Two citizens' groups are leading efforts to block the project.

The state's contribution to the tunnel project is capped at $2.8 billion, which includes $400 million from tolls that would be collected on the new tunnel. The Port of Seattle would chip in another $300 million. ■

San Vicente Pipeline completed

The San Diego County Water Authority dedicated the 17-km (11-mile) San Vicente Pipeline on Jan. 19.

The 2.6-m- (8.5-ft-) diameter tunnel is part of the agency's $1.5-billion emergency storage project that was built with the goal of storing up to six months of water for use in case of an earthquake or another disaster that interrupts normal supplies. The pipeline can move up to 12,600 L/s (200,000 gpm) and is the largest element of the capital improvement program.

"Completion of the San Vicente Pipeline marks another major step forward for the region's long-term water reliability," water authority chairman Michael Hogan said. "This new pipeline provides greater flexibility for how the water authority can store and move water around the county."

As prime consultant, Jacobs Associates served as tunnel and shaft designer and provided construction engineering support to SDCWA in its efforts to complete the project in a cost-effective manner while balancing community and environmental concerns.

Most of the pipeline was constructed in a tunnel about 17 km (11 miles) long with a finished inside diameter of 2.6 m (102 in.). This high-pressure water conveyance facility will have internal hydrostatic pressures ranging from about 1.38 to 1.72 MPa (200 to 250 psi).

Jacobs Associates said various tunneling methods were used on different reaches of the tunnel, including a 3.5-m (11.5-ft) hardrock tunnel boring machine (TBM) to bore through 1.6 km (5,255 ft) of granitic rocks, and two 3.7 m (12-ft) digger shields to excavate remaining sedimentary formations; drill-and-blast methods are being used in one reach, and the New Austrian Tunnel Method was utilized for a mixed face reach.

Tunnel excavation was staged from three shafts and one portal. Various rock support methods were employed, including rock dowels, steel sets and expanded precast segments. The final lining consists of buttwelded steel pipe.

Construction began in 2005 at four locations along the route. Nearly 1,150 pipe sections were linked and testing was completed in December.

The emergency storage project also includes a pipeline and dam in Olivenhain, and a pipeline from Olivenhain to Lake Hodges. ■

Lake Mead project delayed

On the final work shift of 2010, the starter tunnel at the Lake Mead project in Nevada flooded with water and muck for a third time. Now, the Southern Nevada Water Authority is planning to abandon the tunnel that is 183 m (600 ft) underground and start a new tunnel that will skirt a fault line.

The Las Vegas Review Journal reported that Marc Jensen, director of engineering for the water authority, said the design change could put the project behind schedule by several more months, but he could not be any more specific.

When completed, the $700 million project will provide a third intake into Lake Mead that is deeper than the two existing intakes. The Las Vegas Valley gets nearly 90 percent of its water from Lake Mead. The third intake would pull from deeper in the lake, allowing the flow of water to continue even if the reservoir was to shrink enough to shut down one of the two existing straws.

Officials were pushing for a 2013 completion date to ensure that the system would have sufficient capacity to meet the Las Vegas Valley's peak demand in the summer. A drought has continued since then, but water use has declined and new water banking agreements have been reached. Concerns about capacity have been extended several years, *The Las Vegas Review Journal* said.

The project involves mining a 7-m (23-ft) tunnel through 4.8 km (3 miles) of solid rock beneath the bottom of Lake Mead and connecting it to an intake structure that will stick up from the lakebed at one of the deepest spots in the reservoir's Boulder Basin.

The tunnel under the lake will be excavated using a tunnel boring machine that will be lowered in pieces down the 183-m (600-ft) vertical access shaft and put together underground. But that cannot happen

(Continued on page 6)

Brightwater project closes in on final stage

The Brightwater project is coming closer to completion, but it is also approaching what could be one of the most difficult segments of the entire $1.8-billion project.

The project, which is now well behind the original target date, is expected to be completed by September. When it is completed, it will begin carrying treated wastewater to Puget Sound in July 2012.

Currently, the tunnel boring machine (TBM) is going downhill — not a desirable direction — which means workers must pump water uphill and be alert to any sign of flooding. The TBM is also working through changing geology and is approaching high water and ground pressure as much as 122 m (400 ft) underground.

However, the other machine, a slurry machine, was left beneath Lake Forest Park because of danger from removing it.

A team from Jay Dee and Coluccio was hired by county executive Dow Constantine to finish the tunnel using an earth pressure balance machine.

Using a machine like Jay Dee's is unconventional, said the team's project manager, Greg Hauser, explaining that "slurry" machines such as the one abandoned by Vinci are the standard choice for mining in extremely high-pressure areas — often sandy soil saturated with water.

"We're doing things that haven't been done before. Taking an earth-pressure balance machine to these pressures isn't done," Hauser said.

Slurry and earth pressure-balance machines use different techniques for equalizing pressure on the outside and inside faces of the machine.

Jay Dee worked with the machine manufacturer to retrofit the machine for the high-pressure Lake Forest Park tunnel segment.

Hauser said he will try to avoid stopping for maintenance in high-pressure spots, but is prepared to do so, if necessary.

High-pressure areas present two kinds of challenges. One is to maintain a proper pressure balance and keep the machine in good operating condition.

The other challenge is to maintain or repair the face of a machine under high pressure. Short of a months-long process of sinking wells to freeze or dewater the soil, standard practice is to counter the outside pressure with compressed air.

The Vinci group ran into trouble at pressures under six bars, or six times atmospheric pressure, and the Jay Dee team has been told to prepare for pressures in excess of seven bars.

During boring for the 17-m- (57-ft-) wide tunnel that will replace the Alaskan Way Viaduct, the state Department of Transportation predicts pressures approaching five bars for only a short stretch.

While Jay Dee continues to tunnel, King County and Vinci are in court fighting over who was responsible for the contractor's difficulties and who should pay Jay Dee's bills, part of more than $178 million in disputed costs, *The Seattle Times* reported

The county claimed Vinci defaulted on its contract when it said it could not finish tunneling until the end of 2012, putting the overall project three years behind schedule.

Even though Jay Dee did not guarantee a fixed price — or even that it could complete the job — county officials said it offered a greater likelihood of finishing the tunnel sooner and at lower cost.

Vinci said soil conditions and pressure were different from what the county's bid documents stated. After the two boring machines were damaged, an expert panel set up by the county and the contractor recommended drilling test holes and creating "artificial safe havens" where crews could perform maintenance at or near atmospheric pressure, Vinci's lawyers claimed in pleadings in King County Superior Court.

Neither recommendation was carried out after Vinci asked the county to pay for that work and the county refused, according to pleadings from both sides. ■

Lake Mead: New tunnel to be built

(Continued from page 5)

until the contractor can figure out a way to keep that assembly area and starter tunnel from flooding.

The first flooding incident happened on July 1 when workers excavating a cavern hit a fault zone.

Vegas Tunnel Constructors, the project's general contractor, spent weeks trying to stabilize the fault by drilling down from the surface and injecting grout into the fracture zone. Once that was done, workers went back underground to drain and clean out the cavern.

They had just reached the original spot where the July 1 mishap occurred when more water, rock and clay flowed into the cavern on Oct. 27.

Authority officials are currently in talks with the contractor to determine how much the design change will cost and who should pay for it

Vegas Tunnel Constructors plans to excavate a new starter tunnel from the same vertical access shaft at about a 20° angle from the current tunnel.

The company is a joint venture of S.A. Healy Co. and its Italy-based parent company, the Impregilo group, which is one of the biggest construction firms in the world. Impregilo's projects include flood control gates in Venice, Italy, new locks at the Panama Canal and the world's longest railway tunnel through the Alps of Italy and Switzerland. ■

Chairman's column

(Continued from page 2)

programs and were within the full understanding and approval of both executive committees.

The SME/CMA 2011 Annual Meeting and Exhibit will be held in Denver, CO, Feb. 27 to March 2, 2011. On Tuesday, March 1, the UCA of SME will have a morning and an afternoon session. Jamal Rostami will be the chair of the session and I will be the co-chair. The purpose of the one-day session is to demonstrate how civil construction practices are used in mining for production and mine development applications on a domestic and international basis. If you are involved in this market, I encourage you to attend the session in Denver. You can travel to Denver on Friday, ski on the weekend and attend the UCA session on Tuesday.

In previous columns, I requested that people who are interested in being on the UCA Education Committee to please step forward. I want to thank those that have offered to be a working committee member. I want to give a special note of thanks to David Chapman, president, Lachel and Associates Inc. for volunteering to be the new committee chairman as the current committee chairman, Bill Edgerton, will be moving into the vice-chair of UCA. As stated in previous columns, the goal of the UCA Education Committee will be to assist academia in the development of programs that are needed by the industry by being a sounding board and source for industry specialists to act as guest lecturers. It is not a program to displace academia, as we do not have the resources to perform such an activity.

If you are interested in serving on this committee, please forward an expression of interest complete with your full contact information to: David Klug (e-mail: dklug@drklug.com) and Bill Edgerton (E-mail: edgerton@jacobssf.com). We will approve of the new Education Committee members at the June 2011 meeting.

Brenda Bohlke has the Scholarship Committee functioning in conjunction with the SME rules and regulations for such awards. The UCA of SME will provide two $5,000 scholarships for school year 2011 and plan to do this or better for school year 2012. It may be hard to believe, but it is difficult to obtain good applications for such awards. Applicants should be in their junior or senior year of college with a major in civil engineering. We would like to give the scholarships to students that have a desire to participate in the tunnel business, as nepotism should not be the sole plan for future corporate staffing requirements. As I can attest, family members tend to rebel after low pay, 60-hour work weeks and minimum vacation time.

In summary, the industry remains strong. The contract for the Alaskan Way Highway Tunnel was signed between the Washington Department of Transportation and Dragados/Tutor-Saliba joint venture. Hopefully, construction will begin this summer. Major underground work continues to bid in New York City with the Second Ave. 72nd Street and 86th Street Station projects bidding. The DEP Harbor Siphon Tunnel has been awarded and is moving to construction. The Transbay Station and Central Subway projects are under design in San Francisco. And a major water program was announced in California that may have up to 30 miles of tunnel. Many local water and CSO programs are currently under design. The issue of funding always looms, but if the public demand is there, the projects always seem to find the funding.

Please feel free to contact me with any comments or suggestions regarding our organization.

David R. Klug
Chairman
UCA of SME
e-mail: dklug@drklug.com. ■

Devil's slide excavation completed

Excavation work of the twin bores of the Devil's Slide Tunnel on Highway 1 between Pacifica and Montara, CA has been completed.

The two tunnels beneath San Pedro Mountain are each 9-m- (30-ft-) wide and 1,280-m- (4,200-ft-) long. At the northern end, a 305-m- (1,000-ft) bridge will span the valley at Shamrock Ranch.

The tunnels were constructed as a realignment of Route 1 at the southern end to provide safe transition into and out of the tunnel.

The initial breakthrough of the north and southbound tunnels was in October.

About a year's worth of work remains before the tunnels and connecting bridges open to traffic, but the excavation part of the tunnels is complete after a little more than three years.

Workers still need to finish installing a waterproof lining and electrical equipment, give the tunnel walls a final coating of concrete, and build the road bed and traffic lanes.

Tunneling crews using special digging equipment removed about 240,000 m^3 (314,000 cu yd) of soil, clay and rock from the mountain. It was placed in dump trucks that hauled it to nearby hills, where a new mountain of debris was built up and landscaped.

The $325-million tunnel is the first on a highway in California since the third bore of the Caldecott Tunnel opened in 1964. Its opening is eagerly awaited by residents of the San Mateo County coast, who have endured many closures of Highway 1 during the rainy season in which the hillside earned its name. ■

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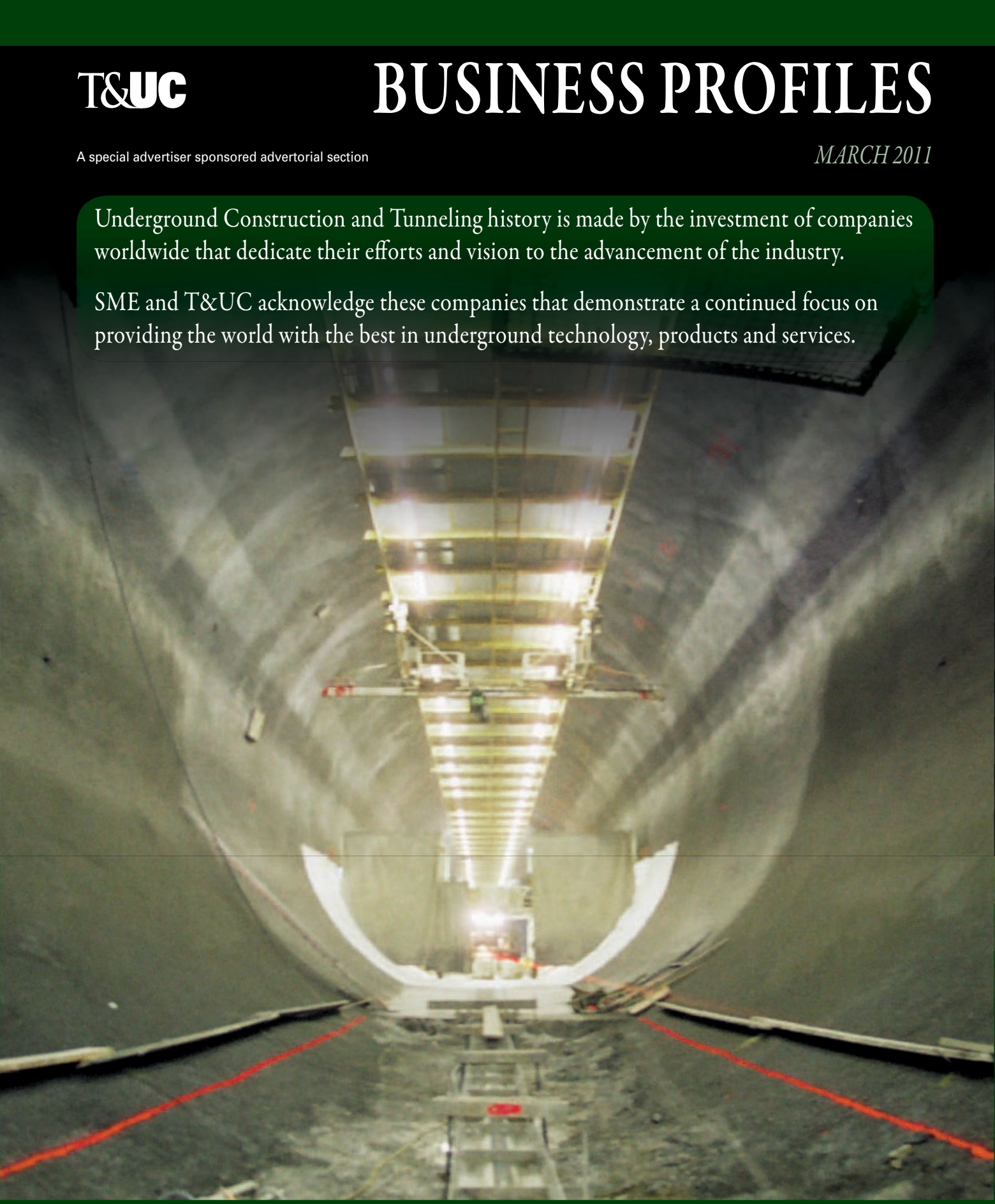

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New or Rebuild? Your Choice

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

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

TBM Bearings and More, Planning for the Future

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

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JENNMAR™ offers coal, hard rock and civil engineering customers the industry's finest, most technically advanced line of ground support and ground control products for use in the world wide marketplace. But that's only part of the reason for our success and primary-source status among deep mine operators. JENNMAR™ will do everything we can to improve roof control operations and ground control systems. We believe in developing closeness to our customers and keeping the lines of communication open at all levels. JENNMAR™ is a customer-oriented company, and that's the only way that we do business.

JENNMAR™ has manufacturing plants and distribution networks around the world, facilities that exist for one reason, to get you what you need…on time and on budget. JENNMAR™ is responsible for decades of innovations in roof support safety and efficiency. Word about JENNMAR™'s products has led the company to establish manufacturing and distributions plants on four continents with more to come.

JENNMAR™ now operates eleven manufacturing plants spread throughout the United States. Of the eleven facilities, ten are related to manufacturing ground control product's, and the eleventh being a steel service center that supplies JENNMAR™ and outside customers with a steady flow of flat steel products. Globally, JENNMAR™ operates six manufacturing facilities with three located in Australia, one in China, one in Chile, and its newest was opened in Ontario Canada in 2010. JENNMAR™ intends to continue to grow, and its focus will never leave the customer. Our goal is to be on the doorstep, supporting the end users every need and offering not only world class products and manufacturing practices, but "feet on the ground", who can get things done. JENNMAR™ will strive to make underground mining, tunneling and large civil projects safer and more productive in every market they serve by providing world class products, world class service and world class engineering solutions.

JENNMAR™ knows it is important for our customers to have their supplier near by, so we put our plants where you operate. JENNMAR™ is just a few hours from most of our customers, that way we can guarantee superior customer service and product availability.

World Class…..there is no better way to describe JENNMAR™ and the effect it has had on the mining industry for nearly 80 years.

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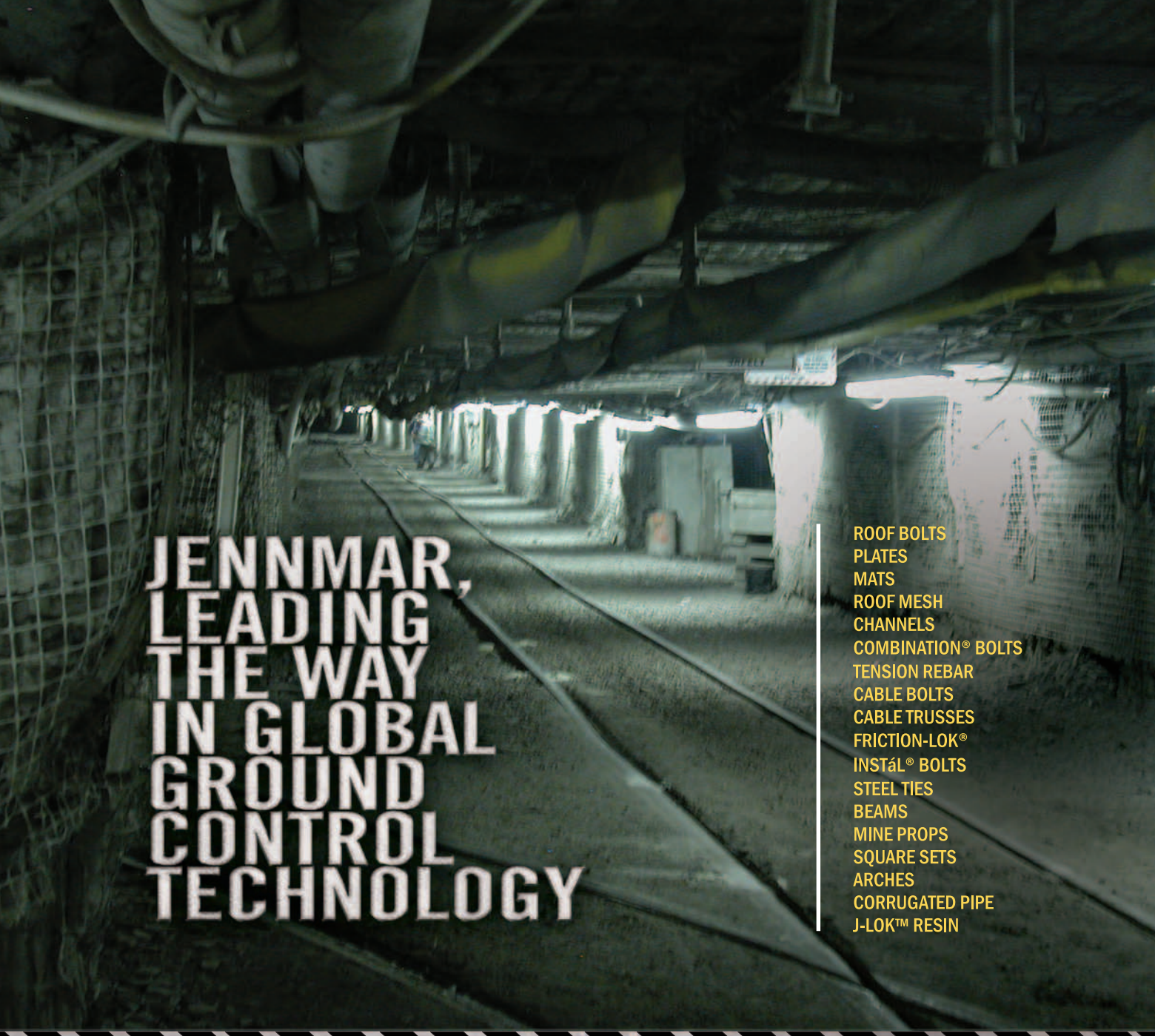
PYTHON™ Patent pending



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North America's Leader in Geotechnical Construction

However difficult the ground, only Hayward Baker, North America's leading specialty geotechnical construction contractor, has the diversity of ground modification techniques to solve your geotechnical problem. Tunneling services include: Earth Retention, Underpinning, Waterproofing, Bottomseals, Soil Improvement, and Ground Stabilization.

Hayward Baker has worked on hundreds of tunneling projects and has the right tools and experience for yours.

Seattle, WA
Brightwater Conveyance System

Construction of the Brightwater Conveyance System required surgical jet grouting to facilitate tunneling operations. Utilizing their proprietary jet grouting equipment, Hayward Baker created soilcrete blocks outside of four deep vertical shafts to assist with both TBM and handmined tunneling operations. The ground improvements allowed TBMs to be launched or received into and out of the shafts without the risk of water and ground run-in. Overlapping columns to depths up to 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
East Central (ECIS) & North East (NEIS) Interceptor Sewer Tunneling Projects

Extensive tunneling operations for ECIS and NEIS required numerous ground modifications. Hayward Baker provided chemical grouting and microfine cement grouting for four shaft breakins, five major freeway over-crossings, 27 manhole connections, and six major or sensitive utility crossings as well as for a major siphon structure and hand-mined access shaft, founded in silty soils containing less than 35% fines.

Other ground modification included locating and filling an abandoned water tunnel, and compaction grouting.

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 soilfrac compensation grouting to protect overlying structures. Heave and settlements were monitored by exterior remote robotic total stations and interior wireless tiltmeters.

Metro Gold Line

St. Louis, MO
Baumgartner Tunnel Alignment

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

Hayward Baker
Geotechnical Construction
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Compaction Grouting – Highway 85 Sinkhole above Utility Tunnel, Brighton, CO

Becker Wholesale Mine Supply

Becker Wholesale Mine Supply LLC is the world-leading supplier of wireless communication, tagging, tracking, proximity detection, and two-way radio communications for the tunneling industry. We specialize in UHF and VHF Leaky Feeder Systems and Wireless Node mesh networks that allow us to offer both I/S and Non-I/S solutions with Ethernet capabilities, which are second to none in performance and reliability. We are able to add video, PLC control, communications both voice and data all over one a wire or wireless backbone. Our tagging and tracking and technically advanced proximity detection systems have built in fail-safe features that are critical to safety and production.

BWMS is committed in providing you with the industry's leading technology and outstanding customer service. We have over 10 years of tunnel communications experience and understand the unique needs of our tunneling customers.

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The Right Pump for Every Underground Mining Application

Gorman-Rupp electric motor-driven and hydraulic powered submersible pumps rank among the most efficient and dependable in the mining industry. They range in size from 1 ½″ to 12″ with capacities to 7100 GPM (448 lps) and heads to 600 feet (183 m). They offer superior hydraulic design and deliver greater GPM with less horsepower which reduces operating costs.

The SM Series is a full line of submersible pumps approved by the Mine Safety and Health Administration (MSHA) and the Commonwealth of Pennsylvania for use in gassy mines or tunnels.

Gorman-Rupp self-priming centrifugal pumps are designed for the tough pumping requirements in the mining industry. Our self-priming centrifugal trash pumps are designed for handling tough solids. Depending on the model, they will pass up to 3″ diameter solids and can be installed high and dry above the liquid source for easy service.

Gorman-Rupp has an experienced staff of engineers dedicated to the design and construction of the most efficient and serviceable pumps in the mining industry. Call for assistance in selecting the proper pumps and repair parts for your specific application.

Distributors worldwide can provide additional resources to help with selection of the pumps and related equipment for your specific application. They are also available to offer suggestions on maintaining your equipment for maximum pumping performance for years of service.

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

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

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

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

Listen. Think. Create.

Fletcher engineers spend more time in the field, listening to customers telling what they like – and don't like – about mobile equipment. How can operations be made more efficient? How

can operators be kept safer, or more comfortable? Some of our best ideas begin when a customer asks, "Why can't..?" This eagerness to solve customer problems sets Fletcher apart.

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

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

Managing Risk

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

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Pacific Boring Inc. is a leading specialty contractor providing trenchless pipeline construction solutions in the western United States. Having focused exclusively on horizontal boring, pipe jacking, and tunneling, the company has the ability to complete the most difficult of projects safely, on time, and on budget.

Since its founding in 1982, Pacific Boring has built a loyal customer base by building the job right, using state of the art technologies, and providing a team with more than five centuries combined experience in the trenchless industry.

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"Year after year Pacific Boring Inc. has proven to be the "go to" tunneling contractor in our region. Their resume of successful projects is unmatched and they know how to complete the bore even in the most challenging of ground conditions. It is always good news for the project when PBI is the tunneling sub"

- GeoEngineers, Inc.

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Robbins TBMs Make Rapid Advance

With 60 years of experience, The Robbins Company is the world's foremost supplier of advanced, underground construction equipment. In 2011, Robbins Earth Pressure Balance Machines (EPB TBMs) are making swift headway on a variety of projects in multiple countries. Innovative concepts are expanding the company's scope, from efficient TBM assembly methods to optimized machine designs resulting in landmark performances through both soft ground and hard rock.

Innovative Onsite Assembly

Robbins' time-saving Onsite First Time Assembly (OFTA) method was first developed at Canada's Niagara Tunnel Project in 2006. The method results in significant time savings and cost reductions for the contractor, all by initially assembling the TBM at the jobsite rather than in a manufacturing facility. That first assembly, for the world's largest hard rock TBM (14.4 m /47.4 ft diameter), was accomplished in just 17 weeks.

While Robbins still maintains its workshops in locations around the world, OFTA is now being carried out on multiple projects and on all TBM types. The method has been used most recently on a 10.2 m (33.5 ft) EPB assembled for Mexico City's Metro Line 12, and a 10.0 m (32.8 ft) diameter Hybrid EPB for India's Sleemanabad Carrier Canal in Madhya Pradesh State.

Soft Ground Success

Throughout the past year, Robbins Earth Pressure Balance Machines have exceeded project requirements, achieving multiple project records. In densely populated Mexico City, the giant EPB boring the capital's new Metro Line 12 has outperformed expectations. The machine is currently tunneling under cover as shallow as 7.5 m (24.5 ft) with minimal settlement, while achieving advance rates up to 135 m (443 ft) per week.

Overseas, a 6.3 m (20.5 ft) diameter Robbins EPB boring China's Chengdu metro achieved astounding advance in permeable alluvium with cobbles and glacial boulders . The machine achieved records of up to 180 m (590 ft) per week—rates higher than any of the 11 other machines boring on the project.

Also in China, another soft ground project at the Zhengzhou Metro Line 1 experienced similar landmark rates. A 6.2 m (20.2 ft) diameter EPB drove through clay, fine sand, and loess to achieve 720 m (2,360 ft) in one month—one of the highest rates recorded for EPBs in China, and a record amongst the 9 other machines working on the project.

In 2011, Robbins is also set to launch three 8.9 m (29.3 ft) diameter EPB TBMs for Mexico's largest infrastructure project—the 63 km (39 mile) long Emisor Oriente waste water tunnel. The emergency tunnel will prevent potential flooding of downtown Mexico City due to deteriorating sewer lines.

Robbins innovations will continue to advance in 2011, with more major EPB projects planned for launch in the Dominican Republic, Azerbaijan, India, and China. For more information on recent tunneling and groundbreaking R&D, visit www.TheRobbinsCompany.com or call +1 440 248 3303.

The Robbins Company
Telephone: 440-248-3303
www.therobbinscompany.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
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Kiewit Construction Company

Kiewit is one of North America's largest and most respected construction and engineering organizations. With its roots dating back to 1884, the employee-owned company operates through a network of offices in the United States, Canada and abroad. Kiewit offers construction and engineering services in a variety of markets including transportation, water/wastewater, heavy civil, power, oil, gas and chemical, building and mining. With 2009 revenues of nearly $10 billion, Kiewit's workforce includes approximately 10,000 salaried and hourly staff along with more than 15,900 craft workers.

Kiewit's Underground District has been constructing underground facilities for over 50 years and is recognized as a leader in the tunneling industry with more than 100 underground-related projects ranging from fast-track mining jobs to a $1 billion undersea rail tunnel. Kiewit's underground team incorporates state-of-the-art technology with proven construction methods to ensure excellence and ongoing success. They serve virtually every segment of the construction industry, including projects related to transportation, environmental facilities, water/wastewater/storm water handling and treatment, power, mining and telecommunications.

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New York City Water System – Damascus Corporation

The New Croton Aqueduct went into service in 1890 with three times the capacity of the Old Croton Aqueduct. It supplies ten percent of New York City's water. Renovation of the New Croton Aqueduct began in 2009. In November, Frontier-Kemper Constructors, Inc. was awarded a contract by the Frontier-Kemper/Schiavone/Picone, JV for the design and fabrication of various shaft and aqueduct equipment while Damascus Corporation designed and manufactured transport vehicles for Frontier-Kemper. The MAC-2DT 4x4 diesel tunnel vehicle was developed to transport two pallets of material totaling 5000 lbs and allow the operator to easily steer in forward or reverse, a requirement as the tunnel has limited room to turn a vehicle around. Frontier-Kemper designed and fabricated movable work bridges that allow the 4 ft. wide vehicles to pass within the 12 ft., 3 in. I.D. brick lined aqueduct. The MAC-2DT comes equipped with an automatic fire suppression system, safety alarm, PTO, and forward and reverse cameras. The MSHA approved Deutz engine and four hydrostatic drive wheel units act as a transmission for smooth traveling while allowing for high ground clearance and room for the Air-Ride assisted heavy-duty leaf spring suspension. Damascus Corporation's MAC-4-ACT is a battery powered vehicle with seating for eight people and converts to haul six people and a pallet of supplies. The MAC-4-ACT uses a brushless AC motor that provides consistent torque throughout the battery discharge. No longer does battery charge determine battery speed. With the AC motor of the variable frequency drive, battery power is used efficiently to provide consistent and reliable transport.

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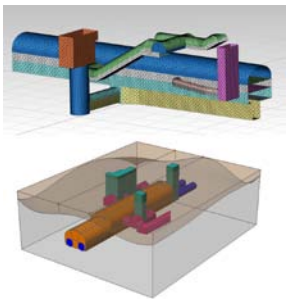
MidaSoft – Next Generation Solutions

Midas GTS is a 3D finite element geotechnical and tunnel analysis software program fully integrated with CAD, automeshers, solver and post-processing. Midas GTS handles geotechnical engineering applications, that include tunneling, mining, foundations, excavations, slope stability, soil-structure interaction, settlement, seepage (groundwater flow), consolidation, vibration and seismic analyses.

Midas GTS offers an intuitive GUI that enables the user to create complex geometry in the smallest number of steps based on CAD formats. Different structural and ground elements in conjunction with super pile elements can be incorporated in one model file. Moreover, there are various types of interface elements, which enable the user to simulate soil-structure interaction regardless of the complexity of geometry and interface positions.

All types of T-type and Y-type interconnections, curved tunnels, shaft-lateral-main tunnel connections and tunnel entrances, as well as subway stations can be easily modeled in detail. A special feature exists for defining automated and realistic construction stages for sequential activation and deactivation of excavation segments, structural parts, loads and boundary conditions.



Also, 3D excavation in real time construction sequence including a dewatering procedure may be simulated, and structural support systems including anchors and diaphragm walls may be generated automatically.

The newest version incorporates the robust and advanced DIANA kernel, which supports 64-bit OS & multi-core parallel processing. The solver has been used for over 30 years and proven to be reliable in all research and industrial fields solving complex nonlinear problems.

Midas GTS is a new generation finite element software tool for those who face complex geo-structural projects in urban environments. MIDAS operates and provides technical support worldwide.

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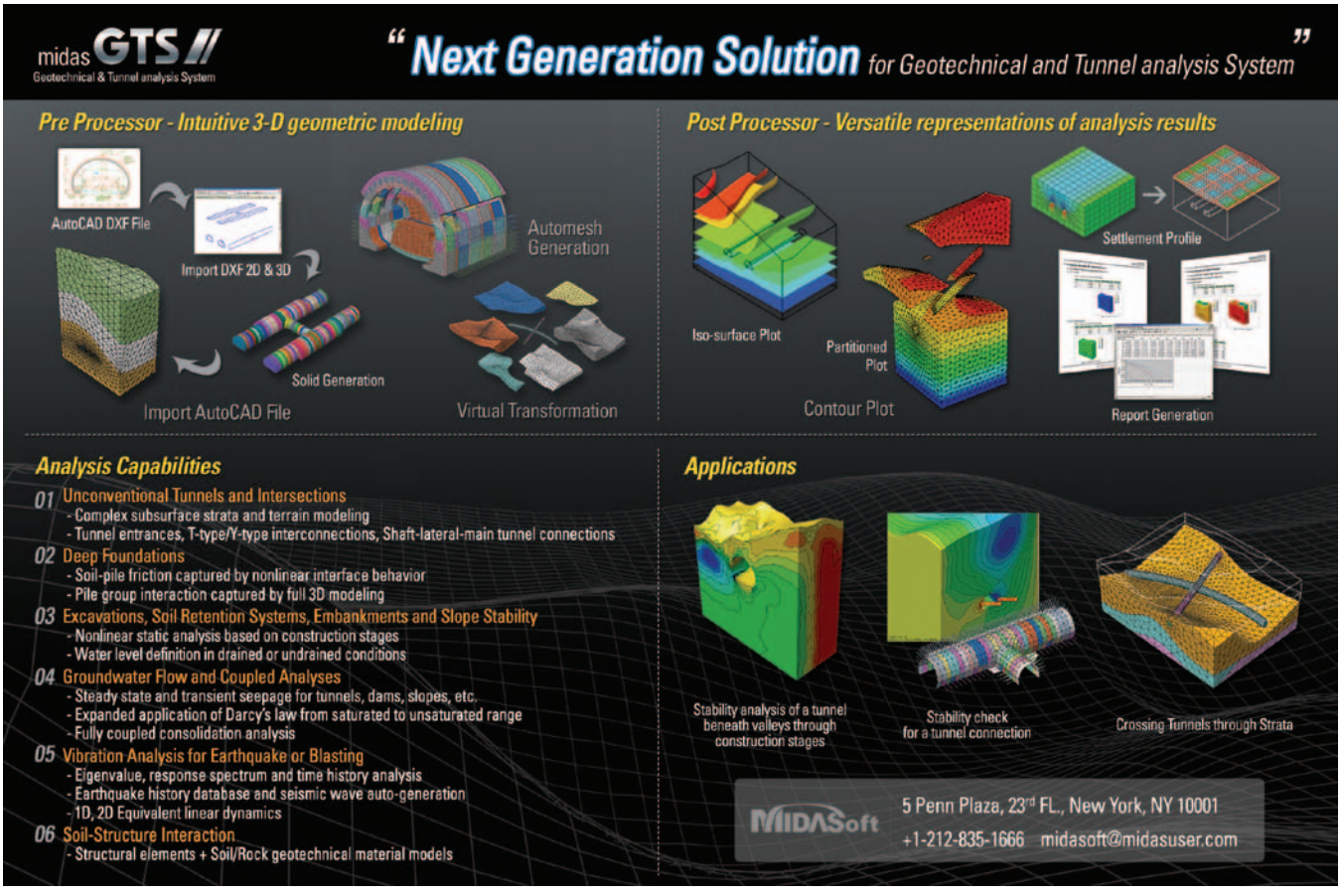

Rapid Set® Cement Products for Tunneling and Mining

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

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

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

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Rapid Set®
Construction Cement Products

Normet in North America - Equipment and Construction Chemicals for Tunneling and Mining

Normet produces solutions for demanding customer processes in underground mining and tunnelling.

For over 40 years we have developed, manufactured and marketed equipment and vehicles for underground applications. In addition, we provide a comprehensive range of Life Time Care services e.g. maintenance, service programs, spare parts and training around the equipment and the processes they are used for. With over 7500 delivered machines we have became one of the market leaders in our product areas.

One of Normet's key missions is to improve the safety and efficiency of workers underground, through solutions targeted to the work processes of:

- Concrete Spraying and Transport
- Explosive Charging
- Lifting and Installation
- Underground Logistics
- Scaling

Normet offers also a comprehensive range of constructions chemicals for underground mining and tunnelling processes. We distribute the TAM line of products, developed by our partner Tam International.

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

We are supported by our global head office in Finland (Normet Line Production, R&D and Group functions), Semmco Line Production in Santiago de Chile, and Sales, Marketing and Product Offering Development are headed from Switzerland. With global customer satisfaction in focus, we now employ over 540 business professionals in 23 locations worldwide.

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

Normet Americas, Inc
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Email: info@normet.fi
www.normet.fi

Geokon, Incorporated

Geokon, Incorporated, is a company based in Lebanon, New Hampshire, USA. It operates on a worldwide basis through a network of over 45 agencies for the manufacture and sale of geotechnical instruments. The company was founded in 1979 and currently has over 90 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*™ due to our quality, responsive customer service and industry-leading designs.

Geotechnical Instruments are used primarily for monitoring the safety and stability of civil and mining structures such as dams, tunnels, mine openings, foundations, piles, embankments, stable and unstable slopes, subway systems, underground powerhouses, bridges, culverts, pipelines, shafts, slurry wall excavations, braced excavations, tiebacks, nuclear waste repositories and groundwater remediation schemes.

Geokon manufactures a complete line of geotechnical instruments. The scope and variety of vibrating wire instruments is the most comprehensive of any manufacturer in the world. Approximately one million vibrating wire piezometers and vibrating wire strain gages, including sisterbars, have been utilized on various projects in over 100 different countries. In addition, Geokon manufactures extensometers, pressure transducers, crackmeters, jointmeters, load cells, settlement sensors, earth pressure cells, concrete stress cells, inclinometers and dataloggers, plus many other specialty items made to order.

Geokon's experienced staff is available to assist in instrument design, selection and installation. Please contact us at 1-603-448-1562 or visit www.geokon.com for further information.

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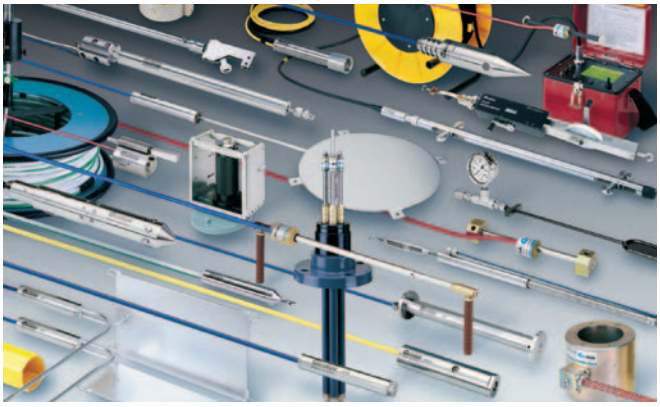

Bradshaw Offers Innovative Tunnel Engineering and Construction Technology

Bradshaw Construction Corporation is a leading contractor in the tunneling industry. With over four decades of experience, we've earned respect as technological innovators through the construction of highly difficult tunneling projects. We owe that success to our commitment to excellence, craftsmanship, safety, and earning our clients' trust.

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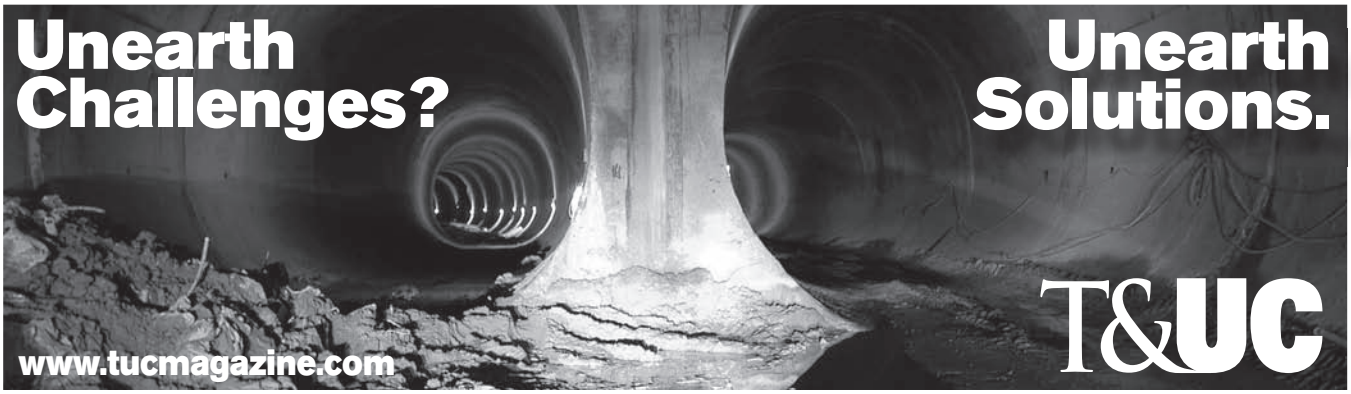

Mining Equipment – Serving the Industry for Over 25 Years

Mining Equipment has been supplying the mining and tunneling industries with quality rebuilt underground equipment for 30 years. The business has grown to encompass new rolling stock, C. S. Card and Moran Engineering and new ventilation equipment, Jetair fans.

Mining Equipment specializes in rolling stock. They have more than 300 diesel, battery and trolley locomotives in stock. Plymouth, Clayton, Brookville, Schöma, Goodman, Greenburg and General Electric locomotives are all in inventory. They have a huge inventory of muck cars, flat cars, mantrips, and specialty rolling stock ready to be rebuilt. Mining Equipment also builds new rolling stock to meet customer needs.

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Mine Hoists International is a fully-owned subsidiary of Mining Equipment. Based in North Bay, Ontario, Mine Hoists boasts the largest selection of used mine hoists and stage winches in the world. MHI has more than 35 mine hoists in inventory and 60 stage winches up to 80,000 lbs. capacity.

Mining Equipment, Jetair and Mine Hoists International are currently doing business in North and South America, Australia, Asia, Africa and Europe. To learn more about Mining Equipment, visit their website at: www.miningequipmentltd.com or www.jetairfans.com.

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CDM – Global Solutions Since 1947

CDM is a global full-service consulting, engineering, construction and operations firm founded in 1947. With more than 4,500 professionals in 110 offices worldwide, CDM maintains a global network of offices and affiliations.

CDM'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's tunnel services include:

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McDowell has been a leader since 1968 in providing the mining sector with their new and used heavy equipment requirements. The McDowell name is recognized worldwide for providing superior products and service.

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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.

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

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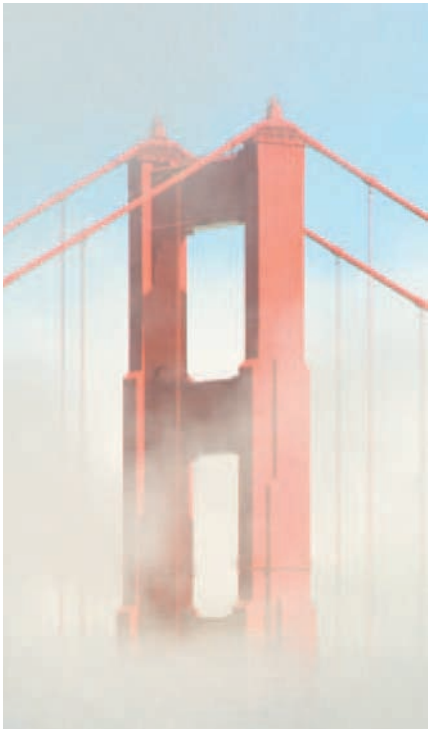

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Surecrete Inc. specializes in furnishing bagged cementitious materials, mixing and placing equipment, and related accessories to the heavy civil tunnel, geotechnical and mining markets. Our product lines include Nittetsu Super Fine ultrafine cement,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

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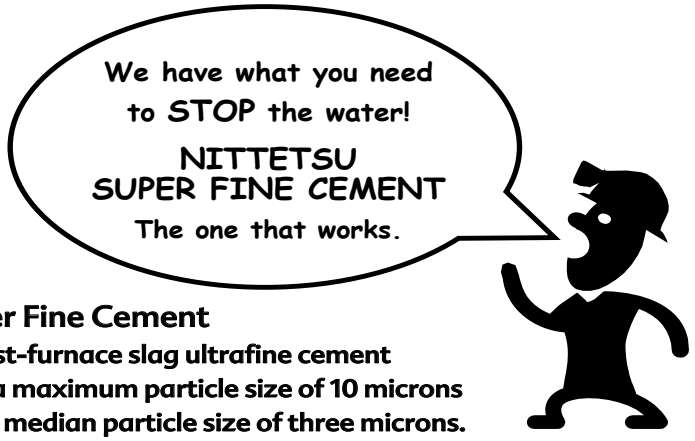

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New Crystal Springs Bypass Tunnel Now In Service

Jacobs Associates is providing Construction Management Services on a critical link in the San Francisco Public Utilities Commission's (SFPUC's) water conveyance system. The New Crystal Springs Bypass Tunnel was just completed and connected to the existing pipeline in San Mateo, California, during shutdown of the existing pipeline. The SFPUC relied on one water treatment plant while the two pipelines were being connected. Jacobs Associates worked with SFPUC and the contractor to accelerate the work to reduce risk. Through early completion of parts of this work, careful planning, and a 24-hour operation, the original 30-day shutdown was reduced to 4 days. The new tunnel was successfully put into service significantly ahead of schedule.

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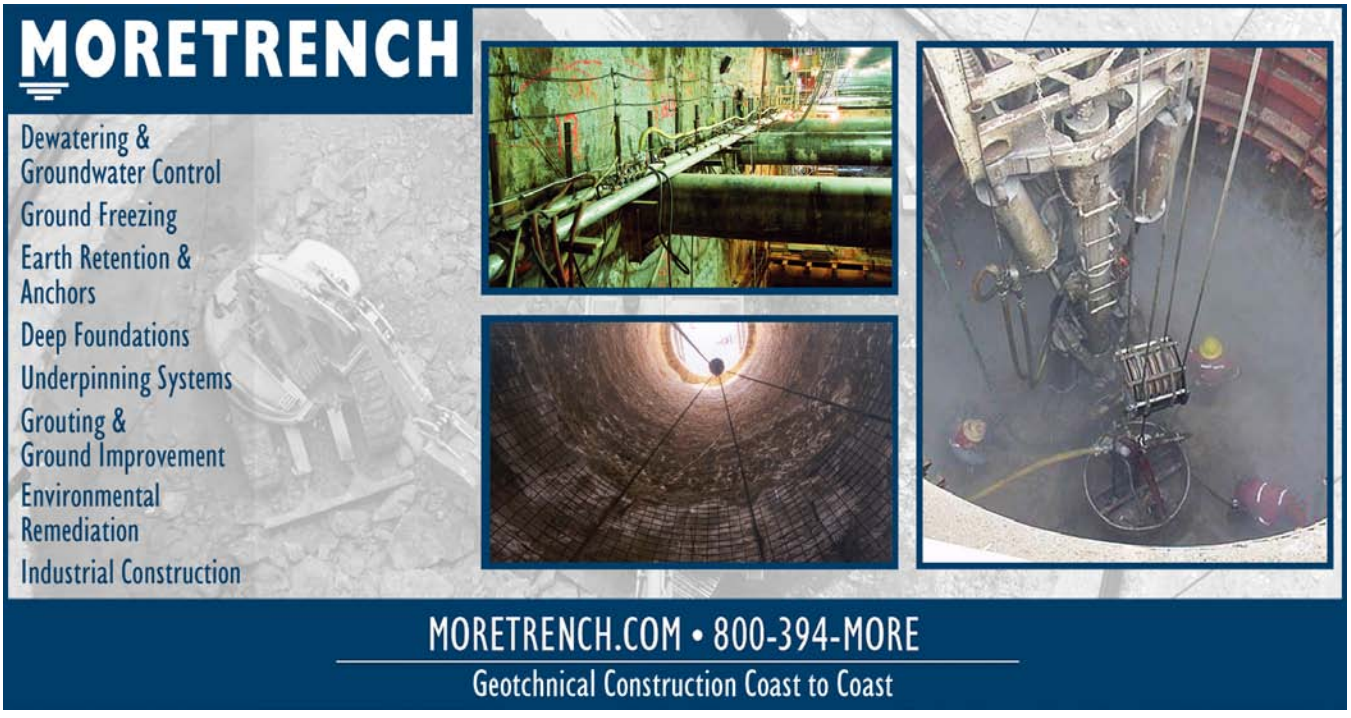

The Heintzmann Group

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, prestressing 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.

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ALPINE Cutters with a Bite

Founded in 1968, Alpine Equipment Corp. is North America's oldest and most experienced manufacturer of roadheaders, especially the Multi-Tool-Miner and those for the NATM, rock and concrete grinder attachments, cutter buckets, scalers, mixers, and shaft sinkers. Willy Kogelmann, Alpine's founder and President, holds numerous patents on these cutting machines. Mr. Kogelmann invented the quick-change transverse and inline axial cutter heads for roadheaders. Spur-gear type cutter transmissions, one of Alpine's unique features, are superior to conventional bevel-gear-type transmissions because they excel in hard rock cutting. The novel cutter buckets can be used for concurrent cutting, mucking, crushing, and sizing. Alpine's advanced cutters can excavate rock and minerals at the lowest-possible cost per ton. Alpine's products are backed by the most experienced team in the industry.

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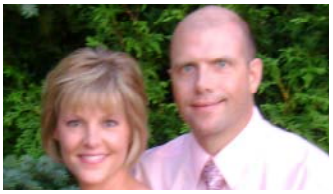

Kelley Engineered Equipment, LLC was founded in 2007 by Brian and Cindy Kelley. Brian, has extensive experience in tunneling and mining equipment design, with 7 years of experience at Robbins, and 13 years at Kiewit Underground Division. Brian is a licensed Mechanical PE in Nebraska, New York, and Washington State. The company has several standard products, such as cable reelers, premium quality rail trucks, skip boxes, and diesel power packs. In addition, Brian leads the design efforts for a broad range of custom equipment, including lifting systems, gantries, pipe carriers, trailing gear, custom attachments, conveyors, heavy load moving equipment, equipment modifications, personnel access systems, and more. KEE partners with select shops, or customers can choose the manufacturer.

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TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Hudson River Crossing	NJ Transit ARC Program	Newark	NJ	Subway	8,000 x 2	24.5	2010	Cancelled ?
Palisades Tunnel	NJ Transit ARC Program	Newark	NJ	Subway	5,400 x 2	24.5	2009	Cancelled ?
Manhattan Tunnel	NJ Transit ARC Program	New York	NY	Subway	6,000 x 2	24.5	2009	Cancelled ?
The 34th St. Cavern & Station	NJ Transit ARC Program	New York	NY	Subway	2,200	100 x 100	2011	Cancelled ?
2nd Ave. 86th Street Station	NYC-MTA	New York	NY	Subway	615	60	2010	Skanska-Traylor
2nd Ave. Phase 2-4	NYC-MTA	New York	NY	Subway	105,600	20	2012-20	Under design
Water Tunnel #3 by-pass tunnel	NYC-DEP	New York	NY	Water	20,000	15	2015	Under design
Water Tunnel #3 Stage 3 Kensico	NYC-DEP	New York	NY	Water	84,000	20	2017	Under design
Cross Harbor Freight Tunnel	NYC Reg. Develop. Authority	New York	NY	Highway	25,000	30	2013	Under design
Cross Sound Link Highway Tunnels	Sound Link	Long Island	NY	Highway	190,000	55	2014	Under design
Cross Sound Link Service Tunnel	Sound Link	Long Island	NY	Highway	95,000	38	2014	Under design
Clinton CSO Tunnel	City of Syracuse	Syracuse	NY	CSO	2,000	17	2011	Under design
Silver Line Extension	Boston Transit Authority	Boston	MA	Subway	8,400	22	2013	Under design
East-West Subway Extension	Baltimore MTA	Baltimore	MD	Subway	32,000	18	2012	Under design
WASA CSO Program Blue Plains Tunnel Anacostia River Tunnel Northeast Branch Tunnel Northeast Boundry Tunnel	DC Water and Sewer Authority	Washington	DC	 CSO CSO CSO CSO	 23,400 12,500 11,300 17,500	 23 23 15 23	 2011 2013 2018 2021	 Bids submitted Under design Under design Under design
North/South Tunnel	Georgia DOT	Atlanta	GA	Highway	77,000	41	2015	Under design
ISCS Dekalb Tunnel	Dekalb County	Decatur	GA	CSO	26,400	25	2013	Under design
Lockbourne Interceptor Sys. Tunnel	City of Columbus	Columbus	OH	Sewer	10,000	12	2012	Under design
OSIS Aug. & Relief Sewer Tunnel	City of Columbus	Columbus	OH	Sewer	25,300	18	2010	Kenny/ Obayashi JV
Olentangy Relief Sewer Tunnel	City of Columbus	Columbus	OH	Sewer	58,000	14	2012	Under design
Alum Creek Relief Sewer Tunnel	City of Columbus	Columbus	OH	Sewer	74,000	10 - 18	2014	Under design
Black Lick Tunnel	City of Columbus	Columbus	OH	Sewer	32,000	8	2013	Under design
Euclid Creek Tunnel	NEORSD	Cleveland	OH	CSO	18,000	24	2010	McNally/ Kiewit JV
Dugway Storage Tunnel	NEORSD	Cleveland	OH	CSO	16,000	24	2014	Under design

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Lower Mill Creek CSO Tunnel	M.S.D. of Greater Cincinnati	Cincinnati	OH	CSO	6,350	30	2015	Under design
Black River Storage Tunnel	City of Lorain	Lorain	OH	CSO	5,700	19	2011	Bid date April 2011
Water Treatment Plant #4	City of Austin	Austin	TX	Water intake	45,000	7 to 9	2010	Obayashi/Manson
Deep Rock Connector Tunnel	City of Indianapolis DPW	Indianapolis	IN	CSO	40,000	18	2011	Bid date July 2011
Pogues Run Tunnel	City of Indianapolis DPW	Indianapolis	IN	CSO	11,000	18	2013	Under design
Drumanard Tunnel	Kentucky DOT	Louisville	KY	Highway	2,200 x 2	35	2012	Under funding review
Drumanard Tunnel - Pilot Tunnel	Kentucky DOT	Louisville	KY	Highway	2,200	12 x 12	2011	Under funding review
Alaskan Way Highway Tunnel	Washington DOT	Seattle	WA	Highway	10,500	54	2011	Seattle Tunnel Partners
Central Subway Tunnel	S.F. Municipal Trans. Authority	San Francisco	CA	Subway	16,600	20	2011	Bid date 1Q 2012
San Francisco DTX	Transbay Joint Powers Authority	San Francisco	CA	Transit	6,000	35 to 50	2012	Under design
L.A. Metro Regional Connector	Los Angeles MTA	Los Angeles	CA	Subway	20,000	20	2012	Under design
LA Metro Wilshire Extension	Los Angeles MTA	Los Angeles	CA	Subway	24,000	20	2013	Under design
SVRT BART	Santa Clara Valley Trans. Authority	San Jose	CA	Subway	22,700	20	2011	Under design/ delayed
BDCP Tunnel #1	Bay Delta Conservation Plan	Sacramento	CA	Water	26,000	29	2014	Under design
BDCP Tunnel #2	Bay Delta Conservation Plan	Sacramento	CA	Water	369,600	35	2016	Under design
Kaneohe W.W. Tunnel	Honolulu Dept. of Env. Services	Honolulu	HI	Sewer	15,000	13	2012	Under design
Spadina Line Extension - South Tunnel	Toronto Transit Commission	Toronto	ON	Subway	11,000	18	2010	McNally/Kiewit/ AECON
Spadina Line Extension - North Tunnel	Toronto Transit Commission	Toronto	ON	Subway	11,000	6 m	2010	OHL/FCC JV
Eglinton West Tunnel	Toronto Transit Commission	Toronto	ON	Subway	10 km	20	2011	Under design
Yonge Street Extension	Toronto Transit Commission	Toronto	ON	Subway	15,000	18	2013	Under design
Port Mann	Greater Vancouver Regional District	Vancouver	BC	Water	3,300	10.5	2010	McNally/AECON JV
Evergreen Line Project	Trans Link	Vancouver	BC	Subway	10,000	18	2012	Under design
UBC Line Project	Trans Link	Vancouver	BC	Subway	12,000	18	2014	Under design
Kicking Horse Canyon	BC Dept.of Trans.	Golden	BC	Highway	4,800 x 2	45 x 32	2012	Under design
LRT Expansion North	City of Edmonton	Edmonton	BC	Subway	370 m x 2	6 m	2011	Bid date 2Q 2011

FEATURE ARTICLE

Dulles Metrorail extension includes short, complex tunnel

The Dulles Corridor Metrorail Project is a $3-billion project that will link Dulles International Airport with the downtown center of Washington D.C. by way of a single seat train ride. The project is mostly above ground, but it does include two short, yet complex, tunnels through the area of Tyson's Corner.

The project is being completed in two phases. The Dulles Transit Partners (DTP), led by Bechtel, was awarded the first phase, a $1.6-billion phase that includes 17 km (11 miles) of track with five stations.

At Tyson's Corner, the project includes twin 730-m- (2,400-ft-) long, 6-m- (20-ft-) diameter tunnels.

Bechtel is self-performing construction for the $1.6-billion design-build job. Gall Zeidler Consultants was hired by DTP as designer for the NATM tunnel portion of Phase 1, and Beton-und-Monierbau was hired as tunnel subcontractor.

Tyson's Corner is an affluent and congested area that sits 152 m (500 ft) above sea level. To get through the area, it was decided that tunnels would be the best option with the least amount of disturbance to the surrounding areas.

The tunnels at Tyson's Corner, part of the Metrorail extension project, were built with as little as 3 m (7 ft) of cover.

However, with extremely shallow groundcover above some points as well as soft soil throughout, the tunnels are also the most complex aspect of Phase 1. About 213 m (700 ft) was constructed utilizing the cut-and-cover method. The remaining 518 m (1,700 ft) is being constructed using the New Austrian Tunneling Method, which integrates the principles of the behavior of rock and soil masses under load, and monitoring the performance of underground construction during construction.

"The tunnel only falls 2 m (7 ft) from one end to the other and we pass through two soil conditions, they are both soft ground," said Dominic Cerulli, tunnel task manager for Bechtel. "Soft ground is very tricky because you have to close the ring in a timely manner to minimize settlements at the surface. If you don't close the ring quickly to achieve a round structure that's good in compression, the tunnel could start necking and squatting and the ground above it will settle. We are under major roadways, so excessive settlement would be a bad thing."

William Gleason,
Senior Editor

Because of the complexity and location of the tunnels, monitoring of the project was crucial to ensure that any settlement that did occur was within design expectations.

A real-time monitoring system was required by the Virginia Department of Transportation (VDOT) and helped protect not only VDOT facilities, but third-party utilities, including gas, communications, sewer and water infrastructure. At one point, the tunnels come within one tunnel diameter of a multi-story underground parking structure.

The project had 10 types of instrumentation on this job both in the tunnels and outside of the tunnels. The design of the tunnels called for the installation of the pipe arch canopy 18-m- (60-ft-) long with 27, 28-cm- (4-in.-) diameter pipes in a circle arrangement that created the roof support. A double-row pipe arch canopy was used where the cover was the shallowest. The double-row pipe arch canopy comprised 56 pipes — 27 pipes in one row and 29 in the other — placed on 30-cm (12-in.) centers above the crown. Pre-support pipes were 11.4 cm (4.5 in.) in diameter and drilled in radially at lengths of 18 m (60 ft).

Once the canopy was in, Cerulli said the excavation sequence could begin.

The top heading excavation of about 1 m (3 ft) was completed and then sprayed with 5 cm (2 in.) of steel fiber reinforced shotcrete to support the ground in order to erect each lattice girder.

Once the segmental girders were set on line and grade, the area around and between the girders was sprayed with an additional 21-cm (8-in.) of fiber-reinforced shotcrete mix to further stabilize the tunnel to do another top heading. After a maximum of four top headings were complete, crews could drop down and complete a 2-m (6-ft) bench excavation. Bench excavation was followed by bringing the girder down, closing the ring and then crews sprayed that to make a 25-cm (10-in.) steel fiber-reinforced liner.

"You always have to close the ring as quickly as possible," Cerulli empahsized.

For a soft soil project with such little ground cover, the early shotcrete strength gain was extremely important in the effort to close the ring quickly.

A Liebherr-Easymix 1.0 batch plant was chosen for the shotcrete part of the job.

"We wanted to make sure the batch plant could match our mix design consistently," said Cerulli. "Our mix consists of cement, micro silica, sand, stone, water, super plastsizer, retarder, steel fibers and an accelator that is applied at the nozzle. Everything else is mixed at the plant in a mixer. This is unique to the U.S.

"We did test batches in Germany and found that, because of the micro silica, we were not getting a good homogeneous mix, so we had to upgrade the mixer motor size and it has worked well," Cerulli said. "Overall, our shotcrete performance has been outstanding, our mix has been reliable and the plant has performed well, which is crucial because, without shotcrete, we cannot mine."

The shotcrete mix achieves a high strength quickly. The mix has a flow table spread of about 600 mm (23.6 in.), plus or minus 50 mm (2 in.) to ensure a proper workability in connection with the shotcrete pump but is also sticky enough to avoid excessive rebound.

The Easymix 1.0 has been designed as a standard 10-cm (40-in.) container with CSC approval. The mixing system, bins for the aggregates, the water tank and control room with the latest microprocessor controls are all fully integrated into the container. This makes the plant a good choice for placing it onto a jobsite with limited space, such as Tyson's Corner.

The only parts to transport separately are the water and cement weigher module and the cement feeding components. Since the container element stands on a steel foundation, no additional concrete foundations are needed for operations.

The standard 1-m^3 (1.3-cu yd) ring-pan mixer from Liebherr is upgraded in the Dulles Corridor Metrorail Project with a rotary agitator, which inserts a considerably higher energy into the mix, in order to ensure a continuous high quality of shotcrete. The mixer motor provides a power of 48 kW (65 hp).

"In the U.S., we did more testing on our mix and it was worth it to upsize the motor," Cerulli said. "The last thing you want in a shallow tunnel is to not have shotcrete … all you can do then is get out of the tunnel and watch things collapse."

A Liebherr batch plant is used to mix the shotcrete for the complex tunnel under Tyson's Corner.

Micro silica is stored and batched using a specialized silo, screw and weigher system. A vibration bowl with a conveyor belt delivers steel fibers directly into the pan mixer. With a batch cycle of only 120 seconds, the production output is about 30 m^3/h (40 cu yd/hour), which easily matches the volume requirement for the project.

The modern Litronic BCS II control, which is based on a Panel pc with Microprocessor, and the Litronic FMS-II moisture control are further elements to ensure a concrete quality that follows the recipe precisely.

More than 15,300 m^3 (20,000 cu yd) have been sprayed without a failure at the project.

The pan mixer discharges the shotcrete mix onto a concrete belt for loading special low-built truck mixers, which commute between batch plant and tunnel.

Phase 1 of the project is expected to be completed in 2013. It will include four stations in Tysons Corner-Tysons East, Tysons Central 123, Tysons Central 7 and Tysons West.

Phase 2 will run from Wiehle Avenue to Ashburn in eastern Loudoun County. A construction date has not been set for the extension that will serve Reston Town Center, Herndon, Dulles Airport, Route 606 and Ashburn.

The purpose of Dulles Metrorail is to provide high-quality, high-capacity transit service in the Dulles Corridor. New Metrorail service in the corridor will result in travel time savings between the corridor and downtown D.C., expand the reach of the existing regional rail system, offer a viable alternative to automobile travel and support future transit-oriented development along the corridor. ■

FEATURE ARTICLE

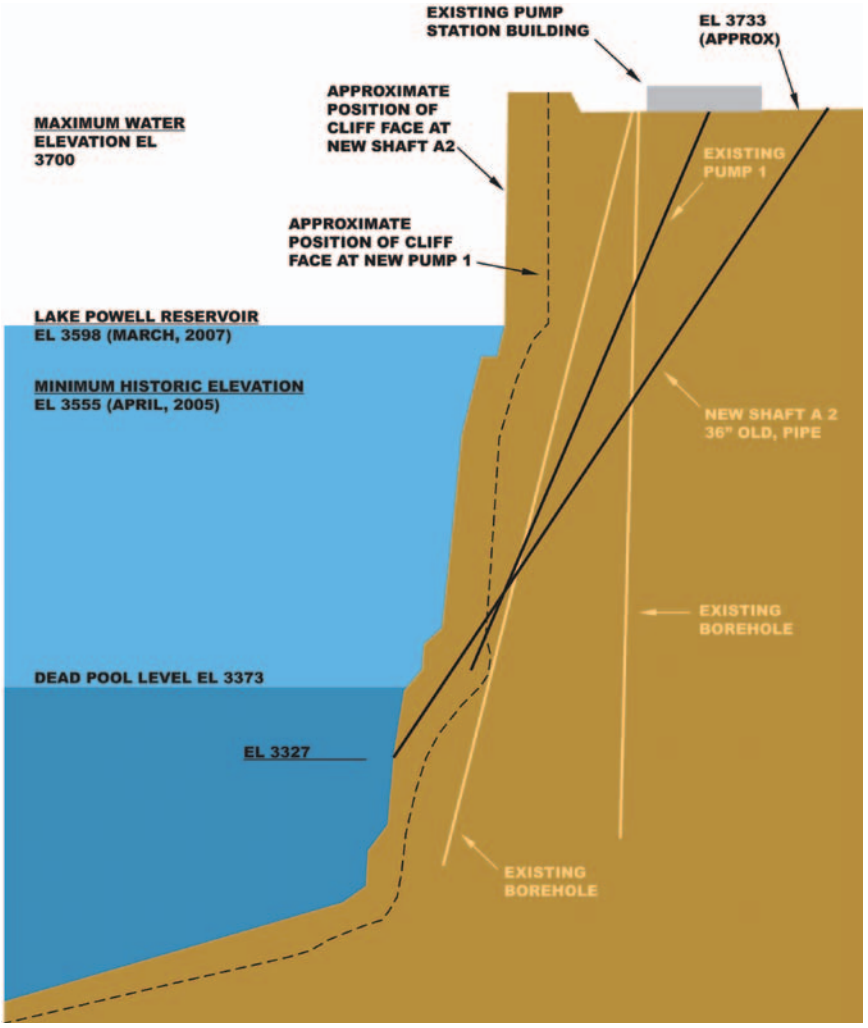
Deep inclined water intake shafts at the Navajo Generating Station

The 2,250-MW, coal-fired Navajo Generating Station located in Page, AZ draws water from Lake Powell using submersible pumps installed in five inclined shafts. Drought threatens to lower the reservoir to below the existing intakes.

A system of new steel-lined intake shafts located on the same site was required for uninterrupted plant operation. The small size of the site, and the need to keep the existing system in operation, required detailed designs and placed significant limitations on construction equipment and activities. The Navajo Sandstone that forms the near vertical shoreline of the reservoir is 98 percent very fine grained quartz, highly abrasive and contains highly fractured intervals that presented numerous challenges to drilling the new 152-m (500-ft) deep, 109-cm (43-in.) diameter intake shafts inclined 23° to 26° from vertical. Spatial constraints, submersible pump design and operational criteria required that each shaft have a unique inclination and orientation and hit a small breakout target located 76 m (250 ft) under water. Sophisticated drilling equipment and techniques as well as state of the practice downhole survey technology and methods were used to make adjustments and maintain drilling accuracy with less than 1 percent deviation. Environmental requirements mandated water as the drilling fluid and grout was not allowed in to the lake under any circumstances. The shafts were videotaped and the breakout locations were examined using an underwater remotely operated vehicle (ROV) to verify shaft locations and rock conditions, and to guide placement of pneumatic packers to ensure grout did not transmit to the lake during the steel liner installation. In anticipation of the invasion of quagga mussels, the shaft design included an allowance for a chemical dosing system and a copper-rich alloy at the exposed portions of the steel liner.

FIG. 1

Shaft A2 typical elevation showing existing shafts and boreholes.



Albert Ruiz , David Jurich and Guy Leary

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Background

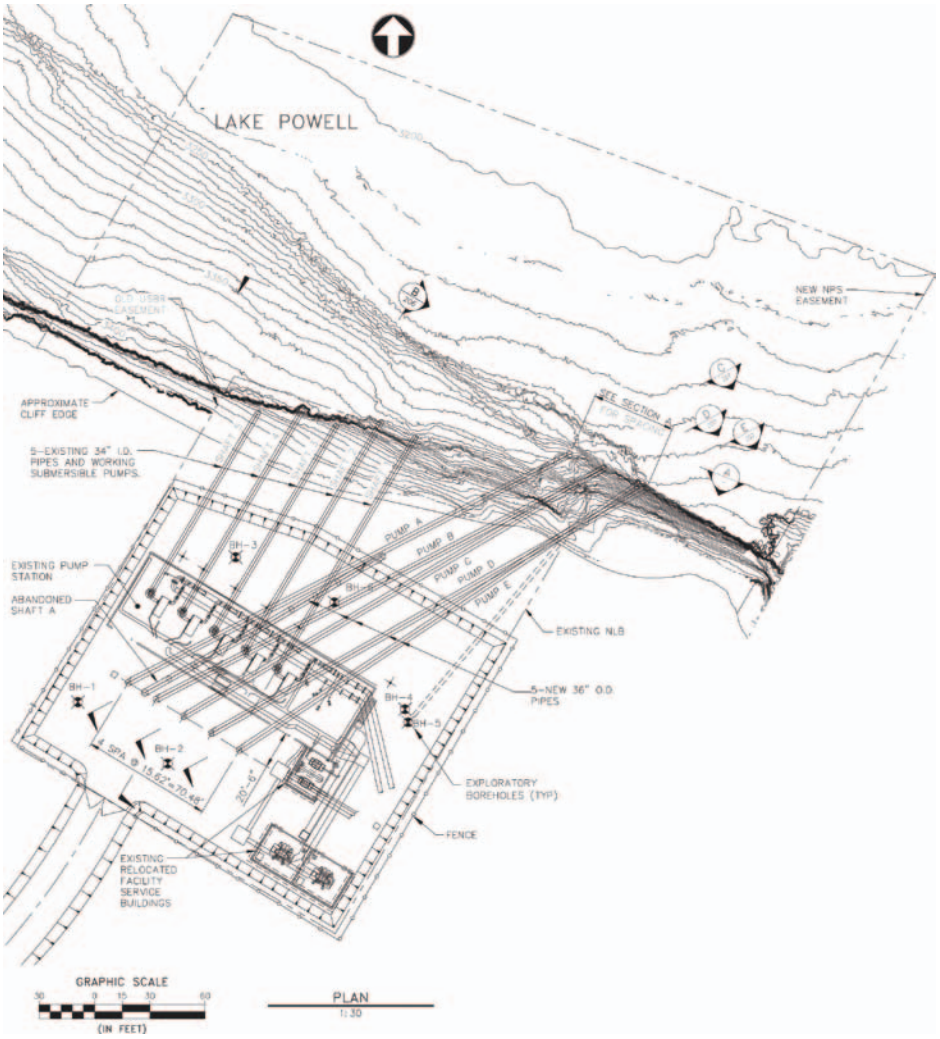
The Navajo Generating Station (NGS) is a coal-fired power plant located on the Navajo Indian Reservation near Page, AZ. Built in 1974, the power plant supplies electricity to the states of Arizona, Nevada and California. The plant also provides the energy necessary to

operate the pumps for the vital Central Arizona Project, which supplies 1.5 million acre-ft of water to arid Arizona. Scrubbers were installed to the plant in the 1990s as part of a $420-million environmental upgrade. Because of this upgrade, the NGS is now one of the cleanest operating coal-fired power plants in the country. The plant is also essential to the economy of northern Arizona, providing many jobs for residents of Page and the Navajo Indian Tribe.

The NGS currently draws cooling water necessary for operation from nearby Lake Powell. An ongoing multiyear drought has been steadily lowering the water levels in the Lake Powell reservoir and has begun to approach the level of the existing cooling water intakes. In 2003, the managing owner of the plant, Salt River Project (SRP), developed a plan to add new lower water intakes. After completing the initial environmental impact report and an initial geotechnical site investigation, SRP contracted consultant Hatch Mott MacDonald (HMM) in 2004 to develop and assess different alternatives and to fully design the selected concept.

FIG. 2

Pump station site with easements and shaft arrangement.



The five existing 107-cm (42-in.) diameter cooling intakes are the only source of cooling water available to the plant. Four of the five intakes must always be in service for continued operation of the plant, while the fifth serves as a backup. The intakes are composed of low-carbon (mild) steel liners with cement grout in the annular space. Each intake houses a single pump. The permitted flow of the intake system is approximately 1,900 L/s (30,000 gpm). The tops of the shafts are evenly spaced 6 m (20 ft) on centers, positioned inside a pump house located at the top of a cliff overlooking Lake Powell at an elevation of 1,138 m (3,733 ft). The site of the pump station is approximately 3,250 m^2 (35,000 sq ft) and recessed into the ground as much as 5 m (16 ft) so that it is not visible from the lake below. The original shafts were drilled at an incline and penetrate the cliff at elevations ranging from 1,058 m (3,473 ft) for Intake #1 to 1,031 m (3,383 ft) for Intake #5. The water surface elevation for Lake Powell can range from a maximum full pool elevation of 1,130 m (3,700 ft) to the absolute minimum dead pool level of 1,030 m (3,373 ft). In April 2005, the water surface was at an elevation of 1,083 m (3,555 ft), bringing it within approximately 17 m (57 ft) of the minimum operational level for Intake #5. Figure 1 shows an elevation of one of the new shafts and the existing shafts and boreholes that needed to be avoided. This was typical of all the new shafts. The options available for the new intake system were limited by a number of constraints. All land-based components of the new system had to be located within the pump station site to remain within the existing Navajo Lease Boundary land easement. Approximately one-quarter of the existing pump station site was available for use, as the existing system had to remain in service at all times during construction occupied the remainder of the site. The easement in Lake Powell available from the Department of National Park Services for the water

FIG. 3

The RD-20 drill rig during drilling of the new 110-cm (43-in.) diameter inclined shafts.

intakes to penetrate into the reservoir was located immediately adjacent to the pump station site and was 122 m (400 ft) wide and centered with respect to the existing pump station building. Within this easement, the new water intake system had to penetrate the cliff in an area with a near vertical slope and at least 7.6 m (25 ft) lower than the dead pool elevation of the reservoir at 1,030 m (3,373 ft). This penetration elevation is necessary to provide sufficient pump inlet pressure for the five new pumps that would be drawing water at up to 1,900 L/s (30,000 gpm) from the lake. The pump station site with easements and shaft arrangement is shown in Fig. 2.

Permit requirements also dictated that no part of the intake system could be visible from Lake Powell. Furthermore, the client wished that the new intake system not be readily accessible to the public due to security concerns.

HMM and SRP developed 15 alternative solutions for a new cooling water intake system. These concepts ranged from floating intake pump barges, to pipes attached to the side of the cliff, to a single vertical, large-diameter shaft with multiple lateral tunnels to tap into the lake. After comparing the concepts based upon the constraints, it was decided that the best solution would be five new inclined drilled shafts in a similar configuration to the existing system.

Geology

Numerous exploratory methods were undertaken to investigate the geologic conditions at the site. The geotechnical investigation program was comprised of field inspections, exploratory core holes, packer permeability tests, and underwater ROV and sonar surveys. Field observations by AMEC geologists from the top of the cliff and by rappelling down the cliff face revealed that there were large and potentially unstable blocks on the cliff face adjacent to the pump house building. SRP completed a risk assessment and determined that it was necessary to remove the blocks prior to construction activities.

Six exploratory boreholes were completed as part of the geotechnical program on the pump station site. Four of the six holes were inclined from vertical, and all of the boreholes were advanced to approximately 122 m (400 ft) below ground surface. During drilling operations for two of the boreholes, a drilling rod became stuck in the hole. Part of the rod was recovered from both holes, however, 37 and 11 m (120 and 35 ft) of drill rod were abandoned in the respective holes and new core holes were redrilled within 3 m (10 ft) of the abandoned holes. Caliper and geophysical surveys were performed on all of the holes as well as optical televiewer and video surveys. All core holes were backfill grouted.

Laboratory testing was performed on select samples of the recovered core for unconfined compressive strength, split tensile strength, density, porosity, permeability and determination of Young's modulus and Poisson's ratio. The corrosive potential of the rock was tested by measuring the pH, resistivity, sulfate content and chloride content to evaluate long term performance of the shaft steel casing.

The Navajo Sandstone formation that composes the cliff shoreline of Lake Powell is a massive, medium grained, quartz-rich sandstone deposit. The Navajo Sandstone core samples recovered from the boreholes at the pump station generally consist of moderately indurated fine to medium-grained quartz sand. The rock is moderately soft to moderately hard with an unconfined compressive strength that ranges from 451 to 4,672 psi and an average value of 2,378 psi. The average dry density is 1,968 kg/m^3 (122.9 lbs/cu ft) and the average tensile strength is 554 psi. Core recovery during drilling operations was close to 100 percent, and the sandstone had a high rock quality designation (RQD) with values that range from 80 to 100 percent, with less than 10 percent of the cores having values lower than 80.

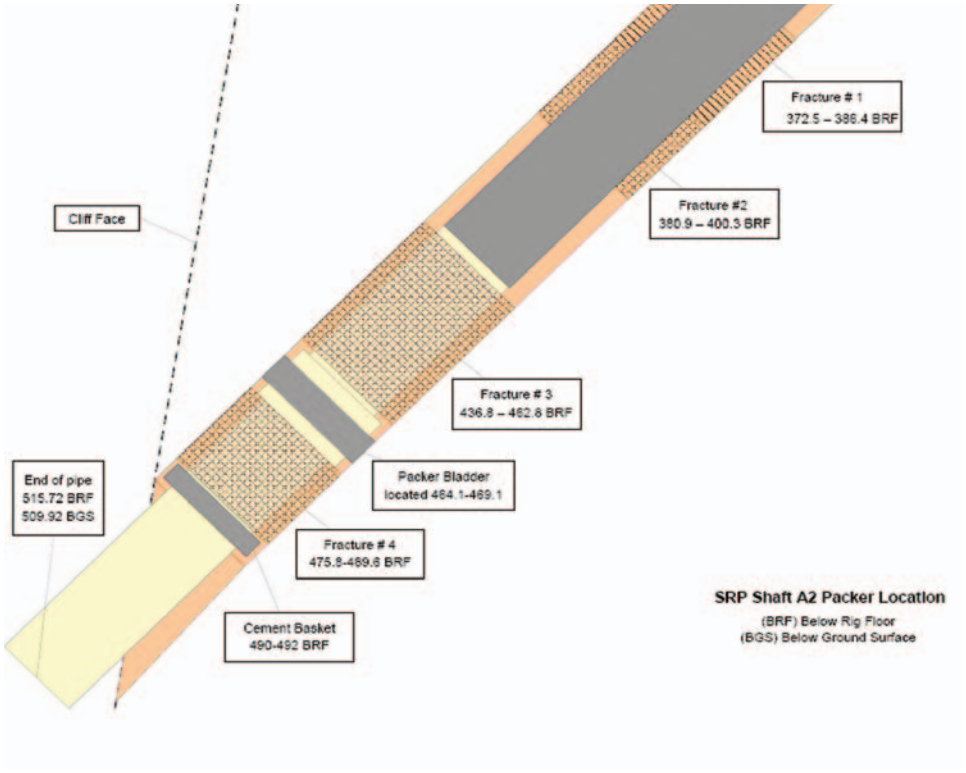
Drilling fluid recovery was generally 90 to 100 percent in all of the holes with the exception of a zone where circulation was completely lost that ranged from 100 to 110 m (330 to 362 ft) below ground surface and was

encountered in at least three of the boreholes. This was attributed to a 12.7-cm (5-in.) zone of fragmented rock at 103 m (337 ft) below ground surface in boring BH-1. In boring BH-2, a 12.7-cm- (5-in.-) wide fracture filled with dark-brown, silty, fine-grained sand located at 111 m (365 ft) below ground surface caused the loss of circulation. In boring BH-3 the loss of circulation was due to an approximately 0.6 m (2-ft) thick broken limestone lens at a depth of 110 m (362 ft) below ground surface.

Underwater ROV surveys were used during the preliminary geotechnical investigation to inspect the condition of the existing intakes and to locate features of the cliff that could represent a risk to construction of the new intakes. Side scan underwater sonar was used to map the underwater cliff profile. The underwater contours were matched with the land based surveys to produce a 3D model of the terrain in the area of the pump station and proved critical to accurately locating the new shafts as discussed in more detail below.

FIG. 4

Diagram showing fractured intervals at the breakout of Shaft A2.



Design challenges

The lake pump station site is located on the edge of a cliff that overlooks the Lake Powell reservoir. Only 854 m^2 (9,200 sq ft) of the site was available to be used as a work area for drilling and grouting operations. An adjacent area approximately 10,700 m^2 (116,000 sq ft) in size was available as a staging yard. The small size of the drilling area created a challenge in placing the drill rig, and the drill rod carrier of the rig was within inches of the building in some cases. Access to the pump building and surrounding equipment had to be maintained during the entire length of construction for inspection and maintenance of the existing intake system. This placed further restrictions on the usable space during construction.

Investigation and analysis of the underwater cliff profile revealed that the cliff face at the minimum breakout elevation in front of, and west of, the pumping site was sloped at too great of an angle to be used for breakout. The only portion of the cliff face that was suitable for breakout started at the east edge of the property line of the existing pump station site and extended to the east edge of the NPS easement. Therefore, the shafts had to angle across the property towards the northeast corner. Two of the shafts also had to pass next to the corner of the existing Navajo land easement.

The target area where the new inclined shafts had to breakout in the cliff was 14-m- (45-ft-) high by 21-m- (70-ft-) wide. All shafts had to breakout within this zone and remain at least 3 m (10 ft) apart from each other for optimum pump performance. The drilling contractor was allowed a 2-percent tolerance in deviation from the planned alignment and could not have any kinks or sharp turns within the hole that would prevent the 12-m (40-ft) long, 61-cm- (24-in.-) diameter pump assembly from being lowered down the shaft.

These constraints drove the final design of the new intake system to consist of five new 109-cm- (43-in.-) diameter inclined shafts designated A through E. Each shaft was drilled at a unique inclination and bearing (about 32° from vertical) to intersect the small target zone approximately 76 m (250 ft) under water. The shafts are lined with a 91-cm- (36-in.-) diameter thick steel pipe with the annular space between the pipe and shaft wall grouted. At the surface, the shafts are equally spaced roughly 4.7 m (15.5 ft) center to center and are 6.2 m (20.5 ft) from the edge of the existing pump station building. The shafts range from approximately 148 to 158 m (485 to 517-ft) long. They penetrate the cliff face at elevations between 1,014 and 1,005 m (3,329 and 3,300 ft).

In recent years, the invasive quagga mussel species

FIG. 5

Final connections of new shafts to the existing pump station.

has been appearing in reservoirs around the United States. This species' tendency to rapidly colonize surfaces that it attaches to has caused numerous problems and reductions in capability for other intake and underwater structures. Because of this, SRP required the ability to retrofit the shafts with a system to address the quagga mussel issue. To that end, each shaft was designed with a 2-cm- (0.75-in.-) diameter PVC pipe grouted in the annular space for a chemical dosing delivery system to prevent quagga mussels from attaching to the intakes. Additionally, quagga mussels are known to avoid copper. Therefore, the shafts were designed with a copper-rich alloy for the exposed portions of the steel liner.

Construction — drilling challenges

The contractor's initial approach to drilling the new inclined shafts was to use a single pass method starting on Shaft A. The RD-20 drill rig used a dual rotary reverse-circulation system to drill the shafts with an 8,100-kg (18,000-lb), 2.7-m- (9-ft-) long downhole hammer. The procedure was to drill an oversized starter hole to approximately 7.6 m (25 ft), as shown in Fig. 3 and grout in a steel surface casing. Once this was completed, the drilling of the shaft would be advanced out of the bottom of the surface casing. As is the tendency for inclined drilled shafts, significant downward gravitational forces act on the drill string and cause the hole to droop off alignment, the problem worsening the further the hole is drilled. In an effort to mitigate the effects of this, the contractor stiffened the drill string by adding 104-cm- (41-in.-) diameter stabilizers in place of drill rod.

Initially, the drill string consisted of the 2.7-m- (9-ft-) long hammer, a 1.5-m- (5-ft-) long stabilizer and a 6-m (20-ft) long stabilizer, then alternating segments of 6-m- (20-ft-) drill rod and 1.5-m- (5-ft-) long stabilizers for 37 m (120 ft), which was then followed by drill rods for the rest of the hole.

The hole was surveyed every 6 m (20 ft) of advance to monitor its position relative to the designed alignment. If the hole started to deviate out of tolerance, a steering bit attachment could be added to the hammer to correct the alignment. Drilling alignment was monitored in real time using a Gyro Smart tool and the data was then forwarded to HMM engineers. HMM created real time 3D models of the shaft position compared to designed alignment as well as the other possible obstructions such as the existing drilled shafts and abandoned core hole with drill rod. These 3D models were used to evaluate drill bit location, trends in deviation, and to calculate adjustments and determine if other corrective actions to be taken.

During the drilling of Shaft A, the hole began to dip exponentially and dropped almost 0.6 m (2 ft) from 36 to 43 m (120 to 140 ft) below ground surface. The contractor attempted unsuccessfully to solve the problem by adding more stabilizers to stiffen the drill string. At 86 m (281 ft) below ground surface the hole was 2 m (7 ft) low and was projected to breakout as much as 8.5 m (28 ft) below the target area. At this point, the contractor grouted the hole to 20 m (67 ft) below ground surface and attempted to re-drill the hole after stiffening the drill string and increasing the diameter of the hammer to 109 cm (42.75 in.) and the stabilizer diameter to 107 cm (42 in.). After drilling to 38 m (126 ft) below ground surface, it became apparent that the drill was following the previously drilled hole. The contractor re-grouted the hole to 11 m (35 ft) below ground surface and allowed the grout more time to cure before attempting to re-drill the hole. Once again, however, the drill followed the previous hole. It was decided to abandon and backfill Shaft A with cement grout and a replacement shaft labeled A2 would be attempted in its place.

The contractor proposed drilling Shaft A2 using a two-pass method by first drilling a 56.3-cm- (22.25-

in.-) diameter pilot hole to breakout into the lake before reaming it to the full 110-cm- (43-in.-) diameter. The pilot hole used 24 m (80 ft) of stabilizers directly behind the hammer with an additional stabilizer every 18 m (60 ft) to reduce rod droop. The contractor aimed 4 m (13 ft) above the target breakout to account for droop in the hole. This, combined with constant monitoring of the pilot bore during drilling as was done with Shaft A, ensured that Shaft A2 hit the target breakout elevation.

The reamer consisted of the original hammer with a custom bit attached to the front to keep the reamer following the pilot hole. The attachment had a polymer ring seal at the base to ensure that no cuttings or fluids traveled down the pilot bore during the reaming process.

FIG. 6

Completed new intakes at the pump station.

The remainder of the shafts were completed successfully on the first attempt using the two-pass method. All of the shafts broke out within the target area and within the allowed tolerance. Upon drilling completion, each shaft was alignment tested for compliance with design parameters. Prior to installation of the casing, a downhole caliper test was performed to make sure that the shafts were not overly out of shape or there were any rock wedges that created blockages. Downhole videos were taken the entire length of each shaft and each fracture zone was logged. Underwater ROV videos were taken of each shaft breakout to check the status of each and verify that there were no underwater features that would pose possible hazards or impairments.

As a result of strict adherence to approved drilling procedures, drilling fluid (clean water) transmitted into the lake was kept to a minimum.

Construction — grouting

Once drilling of each shaft was complete and tests verified that it was within design parameters, the bore had to be lined and grouted before drilling could commence on the next shaft. A sacrificial dual packer assembly was specified to prevent grout leakage into the lake. Using a combination of the videos from the underwater ROV survey and the downhole survey, the packers for each shaft had to be precisely located so that grout did not flow through fractures and in to the lake. To accomplish this, each fracture location was recorded and then mapped to create a diagram for acceptable packer locations (Fig. 4).

The 91-cm (36-in.) diameter, 1.27-cm (0.5-in.) thick wall steel pipe was lowered into place and centered in the hole. The contractor-designed dual grouting assembly of a lower gravel/sand basket with an upper inflatable pneumatic packer provided a redundant system that prevented grout leakage in to the lake. The grout was poured in less than 30-m (100-ft) lifts so that the hydrostatic pressure of the wet cement did not buckle the steel liner. Lastly, a 12-m- (40-ft-) long, 61-cm- (24-in.-) diameter mandrel modeled to be the same size as the intake pumps that the shafts would house was lowered and raised within each of the shafts to ensure that the pump would fit and there were no kinks that would impede installation or removal.

Conclusion

Construction of the five inclined shafts was successfully completed in March 2009 after which SRP constructed an interface to the existing pump station conveyance system and installed the new submersible pumps (Figs. 5 and 6). The new intakes were put into service in December 2009. The chosen intake design met the spatial constraints of the site, several construction challenges were overcome by the contractor, and the NGS has been upgraded with a new water intake system that meets all of the operational requirements and mitigates the risk of the ongoing drought. ■

FEATURE ARTICLE

Toward precise underground mapping system in Canada

It is clear that precise overground and underground mapping is an important factor for all designers. Due to rapid changes in underground construction, tunnel designers are increasingly in need of updating project information. This article explains the latest techniques for detecting underground utilities as well as underground mapping.

Global Positioning System (GPS) is a very accurate and popular navigation and mapping system that has been used extensively above ground, but is not used for underground mapping as signals are not strong enough to pass through ground or water.

Most underground techniques were developed for military applications during the first and second world wars. Later, the techniques became public. For example, ground penetrating radar was developed for the military in 1970 to be used for locating tunnels under the demilitarized zone between North and South Korea. Later, the same technique was used for detecting unexploded ordinance such as plastic land mines.

FIG. 1

Underground utilities.

Positioning system

Generally, positioning systems are categorized into three main areas:

- Above ground positioning systems.
- Underwater positioning systems.
- Underground positioning systems.

Above ground positioning system. This positioning system is a technology that has been around for many ages. This method requires the use of stars and astronomical tables. Typical surveying equipment consists of measuring tapes, theodolites, distomats, levels and compasses. Other old technology such as nautical brass sextants are a classic nautical tool that also measure the altitude of the stars above the horizon to calculate position.

New technology for above ground positioning systems has developed in the past few decades, including laser total stations, aerial photography taken by flying over the areas of interest, LIDAR surveying, satellite positioning and mapping (GPS, GLONASS, GALILEO).

Global positioning system (GPS) is a U.S. space-based global navigation satellite system, which was developed by the U.S. Department of Defense in 1973. GPS was originally designed to assist soldiers and military vehicles, planes and ships in accurately determining their locations worldwide. GPS provides reliable positioning, navigation, and timing services to worldwide users on a continuous basis in all weather, day and night, anywhere on or near the earth. GPS is made up of three parts: between 24 and 32 satellites orbiting the Earth, four control and monitoring stations on Earth and the GPS receivers owned by users. GPS satellites broadcast signals from space that are used by GPS receivers to provide three-dimensional location (latitude, longitude and altitude) as well as the time.

Global navigation satellite system (GLONASS) is a system of satellites operated by the Russian government, enabling someone with an appropriate receiver to determine their position - some of the time. Development on the GLONASS began in 1976, with a goal of global coverage by 1991. The complete nominal constellation consists of 24 satellites, 21 operating and three on-orbit "spares," in three orbital planes, at a mean orbital height of 19,100 km (12,000 miles).

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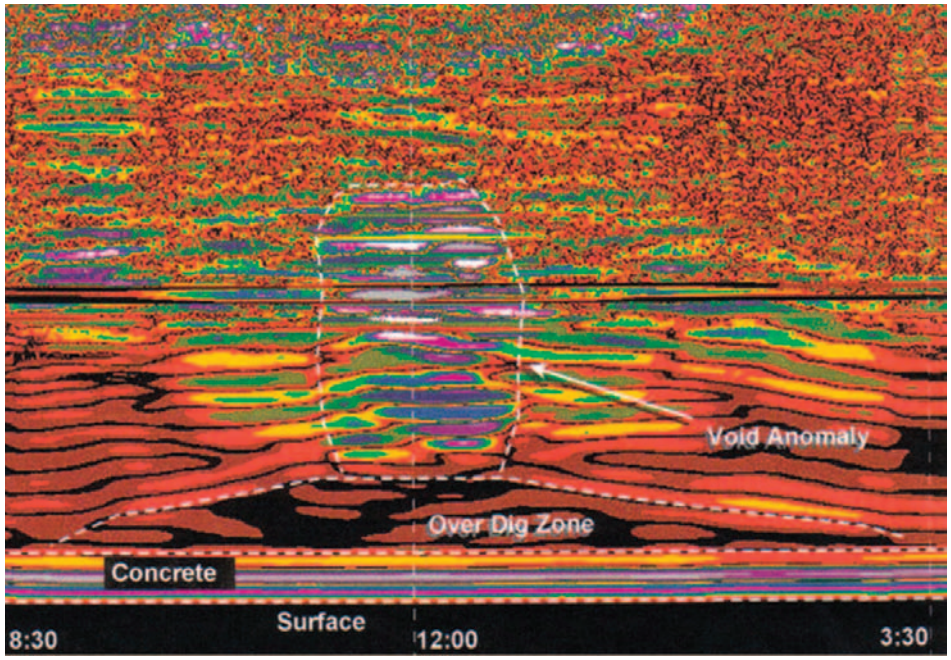
Galileo is the informal name for the European Global Navigation Satellite System (GNSS), a system that will offer users anywhere in the world "near pinpoint" geographic positioning. It became fully operational by 2009. Designed to be interoperable with the other two such systems, GPS and GLONASS, Galileo will enable a user to take a position from any combination of satellites with a single receiver. GLONASS and GPS are run by the defense departments of their respective countries.

Galileo will be a civilian-operated system, which will consist of 30 satellites orbiting the earth at a height of 24,000 km (15,000 miles), is expected to pinpoint a geographical position to within a single meter. High accuracy (as low as ±1cm), positioning anywhere on the earth and working in any weather conditions are the advantages of satellite positioning.

FIG. 2

Void detected by GPR in Hamilton Tunnel.



Limitations of the Galileo system include:

- A minimum of five satellites are required for precise positioning.
- Accuracy can be lowered to 1 to 10 m (3 to 33 ft) when positioning in close proximity of tall buildings.
- Lower accuracy will be encountered when positioning in forested areas.
- Signals can be jammed by other interfering signal users.
- Does not work under water.
- Does not work underground or in tunnels.
- Satellite signals can be unintentionally switched off in low signal strength areas or the accuracy can be changed by the satellite owner accidentally.
- It is operated and maintained by military services.

Underwater positioning system. Some of the older technologies used for underwater positioning include: Diver searches, use of compasses, gyro stations combined with mechanical inertial systems. Some of the new technologies used for underwater positioning include remotely operated underwater vehicles (ROV), new generation gyro stations combined with digital inertial systems, balloon GPS, side scan sonar units, magneto meters, sub bottom profilers, sonar positioning combined with GPS.

Sound signal (Sonar) is the best way for positioning the underwater objects. If the utility pipelines are located above the sea floor, then ROV and side scan sonar would be best suited for this positioning requirement. If the utility pipelines are located under the sea floor, the use of magnetometer and subbottom profilers would be suitable.

Underground positioning system. Current practices for mapping utilities including water, sewer, telecom, fiberoptics, electrical cables, oil and gas pipelines is a challenge for surveyors and engineers (Fig. 1).

The oldest way for detecting the objects and mapping them is by test pitting. However, most times it is not possible to dig the area due to environmental constraints and political issues. Since GPS signals cannot travel through the ground, it is necessary to combine other techniques to detect and map the underground objects. That being said, underground objects can be categorized as either ferrous objects or nonferrous objects.

In general, ferrous objects can be detected by metal detectors (magnetometer) if they are located near the surface. Current metal locators can detect objects up to a maximum depth of 3 m (10 ft). Most metal locators are not able to determine the depth of objects but the depth of ferrous objects. However, they can be observed with the use of vector magnetometer techniques, which are fairly expensive. Another technique for detecting underground ferrous objects is by using a pulse transmitter and receiver. In this technique, a generator emits a pulse that can be detected by a receiver on the ground surface. This technique is used for horizontal directional drilling (HDD) and can detect metal utilities well. In general,

FIG. 3

Gyro probe.

detecting and mapping metal objects is much easier than nonmetal objects.

Nonferrous objects, such as concrete pipes, brick pipes, PVC and HDPE pipes cannot be detected by magnetic detector techniques. Depending on the size and depth of the nonferrous pipe there are several other techniques for locating nonferrous pipes as follows:

Ground penetrating radar (GPR): In the early 1970s, several different teams of scientists began to develop radars for viewing into the earth. GPR use in locating and mapping utility lines has been the subject of ongoing research, primarily by military contractors as well as commercial organizations.

A GPR is also known as an "impulse radar" because the transmitted pulse is very short and is ordinarily generated by the transient voltage pulse generated from an overloaded avalanche transistor. Ground-penetrating radar in principal is capable of locating plastic pipes as easily as metallic pipes since the radar signal reflection from the pipe depends on contrasting dielectric properties of the soil and pipe, not just a high electrical conductivity for the pipe. GPR normally has accuracy of several feet or less when measuring the depth of a buried object.

The performance capability of this type of radar is strongly dependent on the soil's electrical conductivity. If the soil conductivity is high, attenuation of the radar signal in the soil can severely restrict the penetration depth of the radar signal.

In California, where soils in many areas have a high clay content, the soil absorption losses can be high. Soil moisture, especially in soils with high clay content, can increase radar attenuation rates, further limiting radar performance.

GPR has been used to detect sinkholes and voids above a tunnel and voids behind tunnel linings. GPR was used with acceptable results on a tunneling project in Hamilton, Ontario, Canada. It should be noted that GPR signals are not able to pass metal objects. Therefore, if the tunnel is covered by liner plates, it will not be able to penetrate into the ground. The use of GPR is not recommended from the ground surface to detect deep tunnels, greater than 10 m (33 ft) in depth.

If GPR technology is being considered for a tunnel project, the designer must consider many factors to enhance the expected results of using the GPR technology to achieve the desired results. GPR has been used by mining companies for detecting objects in front of tunnel boring machines (TBM) to confirm ground conditions anticipated. Kawasaki has performed some experimental work on TBM cutter head mounted radar equipment to determine the effective forward looking distance in front of a TBM. The results suggest that only a couple of meters distance or penetration could be achieved, which does not provide an adequate warning.

Some advantages using GPR include: locating buried objects; it has been used with success for structural investigations; good results for shallow investigation. Some limitations with the use of the technology include: difficulty in determining the objects material type; limited penetration (shallow depth of observation); interpretation is not simple; depth of the object is difficult to accurately determine and it is rendered useless in tunnels with metal liner plate or metal casing support systems.

Gyroscope probes: Gyroscope probes have been used by oil companies for the past two decades and more recently with horizontal directional drilling contractors. Gyroscope probes are used for directional drilling rigs used for both onshore and offshore work as well as re-surveying of oil wells.

Recently, a few companies have used this technique for mapping underground pipelines. It can also be used for pipelines of diameters greater than 5 cm (2 in.). This technique is being used more frequently in North America in recent years.

This technique requires that the probe is sent from one end of the pipe and is received at the opposite end of the pipe. The gyroscope probe technique can be used for pipes up to 2 km (1.2 miles) in length and can acquire approximately 500 data points per second. Once the probe reaches the end of the pipe the collected data can be downloaded from an onboard data logger. New gyro probes do not need the launching and retrieval position and can calculate their position of the drilling head via gyro data and progress distance.

In subsea operations, ROV's can be used to place the survey probe in conductors.

Recently gyroscope probes have been combined with closed circuit televisions cameras (CCTV) to provide a visual inspection of the pipe that matches the tunnel alignment. If damage to the existing pipe is seen on the CCTV, then the exact position of the damage is known.

The advantages of using Gyroscope probes include: Positioning of the pipe with any material is possible (PVC, iron, concrete, brick, steel, HDPE, etc); magnetic field cannot affect the Gyro data, X,Y, Z can be extracted along the pipe alignment in centimeter intervals; applicable in small size pipe (5 cm or 2 in. and above); can be used in live pipes as well as abandoned pipes and it is applicable for micro tunnels and horizontal directional drilling. Some limitations with the use of this equipment include: exclusive market (Gyro probes are not for sale to the

public, leasing possible); calibration is very costly, leasing is very costly and the precision of the data will be decreased with increasing the distance from the source.

3D Laser Scanner-LIDAR:

This is a relatively new technology used for mapping new and existing tunnels. It is recommended for tunnel diameters greater than 1.5 m (5 ft). High precision mapping (±5 mm) and full coverage of the tunnel are the main advantages of this technique over traditional surveying techniques. This technique was used on York Region's YDSS Interceptor Sewer Tunnel project located in Richmond Hill, Ontario, just north of Toronto.

The advantage of using 3D Laser LIDAR scanners is that they are very fast; 3D modeling can be used to generate as build details; accurate volume calculations can be calculated quickly; they generate high accuracy images; fly through imaging can be generated quickly using a GIS add-on software and they are excellent for presentation of conditions to clients and the public. Limitations of this equipment is that it is costly; it is not recommended for tunnels with very smooth surfaces; long tunnels require a number of equipment set-ups; it cannot be used within a live flow tunnel and construction activity within the tunnel must be shut down during the data acquisition period.

FIG. 4

3D laser scanner image from 19th Avenue tunnel project in Toronto.

Gyroscope stations

Gyroscope stations (north finder) were used widely in submarines, ships and radar sites and came to tunneling projects in 1940. At that time, the weight of a gyroscope station was around 150 kg (330 lb) and equipment warm up time was approximately four hours. Modern gyroscopes stations are very light (around 15 kg or 33 lbs) and need only 15 minutes to warm up.

This technique has been used in many tunnels around the world. The Euro Tunnel is one example. This method was also used on York Region's YDSS Interceptor Sewer Tunnel project located in Richmond Hill, Ontario. On the York Region project, the breakthrough accuracy was less than 2.5 cm (1 in.) for 1.5 km (1 mile) of mining using a 3.2 m (10.5 ft) diameter earth pressure balance TBM.

Some advantages include: precise north finder; works under any conditions; magnetic field does not affect the data; works in any kind of tunnel and pipe (concrete lining, steel lining, rock tunnel, etc); saves cost and time for underground projects; alignment holes are not required; recommended for long tunnels (more than 2 km or 1.2 miles) and recommended for underwater tunnels. Some limitations of this equipment include: it is expensive; it is difficult to transport in a regular size vehicle; it is very sensitive to temperature, wind and motion; transportation needs to be taken with care; calibration is costly; it has to be operated by trained experts; it requires a latitude benchmark close to the project area, and it must be setup on a stable station with minimal vibration.

Conclusion

As the global population increases, the quantity and complexity of the underground utilities will rise to meet the demand, particularly in urban areas.

There are various nondestructive detection techniques including magnetometers, GPR, electromagnetic line locators and acoustic systems that are available. As a matter of course, it is prudent to review a number of project related features before choosing the detecting tools and mapping software. The following are a number of considerations that should be reviewed carefully:

- Geology of the area should be investigated.
- Depth of the object should be estimated.
- Type of object materials to be detected should be inventoried.
- Construction access to the site work areas.
- Political issues.
- Traffic impacts.
- Environmental issues.

And total time-saving, cost-saving and achieving the best results needs experienced designers and contractors. ■

FEATURE ARTICLE

Robbins tunnel boring machines at work in Laos and Malaysia

In late November 2010, a Laotian landmark was achieved for the country's first tunnel boring machine - (TBM) driven tunnel. Italian contractor CMC di Ravenna celebrated the breakthrough of a 7.6-m- (25.1-ft-) diameter Robbins single shield TBM for a hydroelectric tunnel on the Nam Theun River. The Theun Hinboun expansion project and 5.5 km (3.4 miles) headrace tunnel will bring much needed power increases to Laos and Thailand.. "Since this is the country's first machine, it has awakened people's curiosity and interest. We had experienced Italian and Chinese crew members, but we also trained many Lao workers during the course of the project, as this was something they had not seen before," said Luca Barbàra, Far East Manager for CMC di Ravenna.

The machine broke through on Nov. 21 into an exit shaft close to the intake structure on the river.

The machine is now being disassembled and removed — CMC hopes to use it on upcoming projects in the region. Due to the current rainy season and relative low level of the tunnel, the last 100 m (330 ft) up to the intake structure will be completed using drill-and-blast after the waters recede below the tunnel invert.

Contractor CMC di Ravenna utilized the Robbins single shield to achieve rates of up to 37 m (121 ft) in one day.

The Robbins TBM was launched in February 2010 to excavate the 5.5-km- (3.4-mile-) long hydroelectric tunnel that will supply power to Laos and Thailand.

During excavation, the Robbins single shield TBM averaged about 19 m/day (62 ft/day), with a peak advance rate of 37 m (121 ft) in one day. Ground conditions consisted of fair to good rock for 95 percent of the tunnel length, with some small sections of poorer rock quality. "We encountered an anticipated 15 m (50 ft) wide fault zone at about the 4,700-m (2.9-mile) mark with flowing water. We were able to drill a borehole and use expanding foam to consolidate the ground, allowing us to resolve the problem and continue boring in about one week," said Luca Barbàra, Far East Manager for CMC di Ravenna.

Much of the geology for the new headrace tunnel was learned during an earlier excavation of the existing nearby headrace tunnel. Ground on the latest tunnel consisted of fairly soft, layered mudstone, siltstone and

sandstone, with cover ranging from 26 to 380 m (85 to 1,200 ft). To combat possible squeezing conditions in soft rock, the machine used an articulating cutterhead with over-cutters — a design that allowed the machine to excavate up to 10 cm (4 in.) beyond normal tunnel diameter. The 43-cm (17-in.) disc cutters were back-loading for improved worker safety and project efficiency. A probe drill was used to check ground conditions up to 60 m (200 ft) ahead of the machine. To support the ground and provide final lining, 28-cm- (11-in.-) thick, pre-cast concrete segments are being used in a 5+1 arrangement, making a finished tunnel diameter of 6.9 m (22.6 ft).

A ceremony was held for the first of three Robbins high performance main beam TBMs launched at Malaysia's largest infrastructure project, the Pahang Selangor raw water tunnel.

CMC di Ravenna constructed the tunnel for project owner Theun Hinboun Power Co., Ltd. — a joint venture of Electricite du Laos (EDL), Norwegian contractor Statkraft and GMS Lao. Due to go online in 2012, the Theun Hinboun Expansion Project will address increased power demands by adding an additional 280 MW annual generating capacity to the output of an existing power station. Electricity will be shared, with approximately 220 MW going to Thailand and 60 MW to the Laotian national power company, EDL.

Robbins rallies at Malaysian water tunnel

The second in a trio of 5.2-m- (17-ft-) diameter Robbins main beam TBMs commenced boring on Dec. 30, 2010 near Malaysia's capital Kuala Lumpur. The machines are being delivered to the joint venture of Shimizu Corp., Nishimatsu Construction, UEM Builders and IJM Construction (SNUI) to begin excavation of the country's largest infrastructure project. The 44.6-km- (27.7-mile-) long Pahang Selangor raw water tunnel will address projected water shortages due to the area's rapidly growing population.

The project's first TBM was launched on Nov. 10, 2010, and is advancing as scheduled while the total backup is being installed. A third machine will begin boring in March 2011. All of the machines are being assembled outside of their particular adits, then 'walked' down a 6- to 10-percent grade to an NATM-excavated starter tunnel. Two of the machines are being launched with a shortened backup configuration of 10 decks and a temporary transfer conveyor, while the third machine, for logistical reasons, is using trucks for muck removal in the preliminary boring phase. After boring ahead about 100 m (330 ft), the remaining backup decks and permanent Robbins continuous conveyor are being installed, due to the adit configurations.

During the initial stages of advance, the machines have achieved rates of up to 3.5 m/h (11.5 ft/hour) in hard, abrasive granitic rock up to 200 MPa (29,000 psi) UCS. Each high-performance (HP) main beam TBM is fitted with 48-cm (19-in.) back-loading cutters for effective excavation in the hard ground.

The cutters are being carefully monitored in the hard, abrasive conditions using Robbins remote cutter monitoring systems, installed on each of the three TBMs. The wireless system allows the crew to plan cutter changes and keep track of cutter wear by recording several variables on each cutter, including cutter rotation (which is computed to percentage wear), temperature, and vibration. Each 48-cm (19-in.) face and gage cutter is equipped with a sensor bolted inside the cutter housing, allowing raw data to be sent to a program display in the operator's cabin.

Tunneling is taking place in high cover conditions, up to 1,200 m (3,900 ft) below the Titiwangsa mountain range. The three tunnels, measuring 11.77, 11.8 and 11.3 km (7.31, 7.33 and 7.02 miles) in length, will be supported with ring beams, rock bolts, and shotcrete depending on the conditions. If unstable ground is encountered, invert thrust systems can be utilized to avoid gripping against the tunnel walls. The precast concrete invert segments are being manufactured onsite.

The Pahang Selangor raw water tunnel will convey raw water from the Semantan River in Pahang to the South Klang Valley area of Selangor state. Once complete, the tunnel will transfer 27.6 m^3/s (7,300 gps) of water to a new treatment plant supplying about 7.2 million people by 2013. ■

International Tunneling Association report

by Brenda M. Bohlke

The Underground Construction Association held the North American Tunneling Association Conference in Portland, OR a month after the 2010 World Tunneling Congress in Vancouver, BC, Canada. Good attendance at the conference and short courses, plus reports, indicate a continued interest in and a high demand for tunneling and underground construction by many sectors of the infrastructure market.

At the meeting, Ed Plotkin received the Lifetime Achievement Award; Refik Elibay received the Outstanding Individual Award and the Los Angeles Metro Gold Line received the Project of the Year Award. In addition, Jim Monsee received two prestigious awards, Tunneler of the Year and the Beavers awards. These were given in recognition of a career of excellence and contributions to the industry and collegiality.

In 2010, the tunneling industry had continued good fortune with many of the large tunneling programs across the United States making advances and breakthroughs. In the transportation sector, the United States has extensive tunneling and cavern works using all methods of construction.

These transit programs include the New York subway lines, the No. 7 Line extension, Second Avenue subway and the East Side access for the Long Island Railroad; the LRT SoundTransit in Seattle; planning for the Los Angeles metro extensions; and the Washington, D.C. Metro extension to the airport.

Highway tunnels also made the news with the awarding of a contract for Seattle's large, single-bore, double-stack SR99 tunnel that will replace the waterfront viaduct. The Port of Miami Tunnel, a design, build, operate, maintain contract, is under way and will provide an easier access for trucks and cars to the Port of Miami. Immersed tubes are still in the works for Hampton Roads, VA highway tunnels. The San Francisco area Devil's Slide bypass tunnels holed through this year, as the fourth bore of the Caledott tunnels in Oakland, CA got under way. Southern California is advancing plans for a private, tolled tunnel for the Route 710 connection. Also included in the 2010 tally were the San Francisco Municipal Railway's light rail tunnels and the East Side access for the Long Island Railroad.

The exception to all this good news was the cancellation of the $8-billion New York-New Jersey regional rail program, called Access to the Regional Core, near the end of the year.

Wastewater programs, funded through rate payers and often under consent decree dates for completion, continue to quietly advance across the United States. These include a $3-billion Washington, D.C. water project; the Columbus CSO, Cincinnati, Northern Kentucky Regional Conveyance tunnel; and the continued work to near completion of the 21.8-km (13.5-mile) Brightwater wastewater conveyance tunnels.

Waterworks include the impressive New York City Third Water Tunnel and the Harbor Siphon, bi-county water tunnel by the Washington Suburban Sanitation Commission in Maryland, the third intake for Lake Mead near Las Vegas, NV and the Vicente water tunnel in California. Other water tunnels are in the planning and design stages throughout the United States. ■

MEETINGS

Helsinki hosts 2011 World Tunneling Congress

The annual World Tunneling Congress (WTC), sponsored by the International Tunneling Association (ITA) and the Tunneling Association of Finland, will be held May 20-26 in Helsinki, Finland. The tunneling business is no longer isolated, but it is truly global, whether by ownership, client base or the talent pool. The WTC provides a venue to network with tunneling industry representatives from around the world and to exchange the latest information about state-of-the-art technology, materials, equipment, methods and contracting practices.

The United States is a founding member of the association, and more than 58 nations are now an active part of the group. U.S. members who are major contributors to the organization include Henry Russell, Christian Ingerslev, Jon Kaneshiro, Harvey Parker, Ray Sterling, John Reilly and Rick Lovat, to name only a few. Working groups will address issues common to all, such as seismic events and their effects on tunnels, tunnel rehabilitation, fire safety, shotcrete and conventional tunneling methods. Amanda Elioff, of ParsonsBrinckerhoff, was elected to the ITA Executive Council, the organization's governing body.

Committees on education and training, technology, operational safety in tunnels and the use of underground space will address issues unique to the underground construction and tunneling industry. Information about ITA and the WTC can be found at www.ita-aites.org or www.wtc11.org. ■

Reisinger receives the Brierley scholarship

The $1,500 2010 Brierley Scholarship was awarded to Benjamin Reisinger on Dec. 1, 2010 during the student chapter meeting of the Underground Construction Association (UCA) of SME at the Colorado School of Mines (CSM). Reisinger is a senior at CSM majoring in mining engineering who has an interest in tunneling and underground construction.

Gary Brierley, from Brierley Associates in Littleton, CO, gave a talk at the UCA student chapter meeting on the building of the Hoosac Tunnel in Massachusetts in the 1800s. Brierley also told them that he hopes to award the $1,500 scholarship each year to a qualified graduate student who is a member of the UCA of SME student chapter at Mines. Awardees must be studying in the area of the development of underground space and the design of underground excavations. The recipient must be a member of the UCA student chapter and an active participant in meetings and events. The recipient should also demonstrate a need for financial assistance.

Ray Henn (l) and Gary Brierley (r) present the check to Benjamin Reisinger (c).

Ray Henn, a senior consultant with Brierley Associates, is the UCA student chapter's faculty advisor and is also an adjunct professor at CSM. ■

PERSONAL NEWS

CHRIS BURKE and **GEOFFREY HUGHES** (SME) have joined Jacobs Associates in its Boston, MA office. Burke joined the claims group in October. He has more than 10 years of experience as a claims consultant, providing services to owners, contractors, architects/engineers and their counsel. He has testified in mediations, arbitrations, and in State Superior Court. Burke has provided services on construction claims preparation and evaluation, forensic delay analysis, quantification of damages, loss of efficiency analysis and quantification, assessment and valuation of errors and omissions, contract administration and alternative dispute resolution. Hughes joined the design group in January. He has more than 20 years of experience in the planning, design and installation of water and wastewater infrastructure projects. His areas of expertise include program management, design management, resident engineering and inspection, geotechnical investigation, dispute resolution and the selection and application of underground construction techniques. Hughes recently served as the principal tunnel engineer for the program management team on the Narragansett Bay Commission Combined Sewer Overflow Abatement Program in Providence, RI.

BURKE

HUGHES

Allentown Shotcrete Technology has appointed **ALFONSO ROA** as its mortar equipment product manager for Latin America and the Caribbean. Roa has managed the sales and marketing of mortar machines for Putzmeister Ibérica for the past five years.

ROA

LARRY ECKERT (SME) has joined Parsons Corp. as tunnel subsector manager within the Parsons Transportation Group. He will supervise project managers and operations staff to ensure project performance meets or exceeds all contract requirements and client expectations. Eckert is a professional engineer with more than 30 years of experience in heavy civil underground construction. As an expert in the design of structural support systems for major construction projects in the United States and South America, he evaluated contract specifications, geotechnical data, methods of excavation and assisted in the selection of underground support systems for water resources and sanitary facilities, highways, railroads and transit systems. ■

ECKERT

March 2011

16-18, INTERtunnel 2011, Moscow, Expocenter, Moscow, Russia. Contact: Natalia Charman, Mack Brooks Exhibitions, Romeland House, Romeland Hill, St Albans, AL3 4ET, Great Britain, phone 440-1727-814-400, fax 440-1727-814-401. e-mail: intertunnelrussia@mackbrooks.com, website www.intertunnelrussia.com.

27-31, NASTT's 20th No-Dig Show, Gaylord National Resort & Convention Center, Washington, D.C. Contact: Michelle Hill, Benjamin Media, Inc. 1770 Main St., P.O. Box 190, Peninsula,OH 44264-0190 USA, phone 330-467-7588, fax 330-468-2289, e-mail mmagyar@benjaminmedia.com, website www.benjaminmedia.com.

May 2011

2-5, 29th International No Dig Conference and Exhibition, Berlin Exhibition Grounds, Berlin, Germany. Contact: Dagmar Eichorn, German Society for Trenchless Technology, Messedamm 22, 14055 Berlin, Germany, phone 490-30-3038-2398, e-mail eichorn@gstt.de, website www. nodigberlin2011.com.

21-26, ITA-AITES World Tunnel Congress, Helsinki, Finland. Contact: Congrex/Blue & White Conferences Oy, P.O.Box 81, FI-00371 Helsinki, Finland, phone 358-9-5607500, fax 358-9-56075020, e-mail wtc11@congrex.fi, website www.wtc11.org.

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

June 2011

19-22, RETC, San Francisco, CA. Contact: Meetings Department, SME, 8307 Shaffer Parkway, Littleton, CO 80127 USA, phone 800-763-3132 or 303-979-3461, e-mail sme@smenet.org, website www.smenet.org.

September 2011

19-21, Colorado School of Mines Tunnel Short Course, Golden, CO. Contact: Office of Special Programs and Continuing Education, Colorado School of Mines, 1600 Jackson Street, Suite 160A, Golden, CO 80401, phone 303-279-5563, fax: 303-277-8683, e-mail: space@mines.edu, website www.csmspace.com.

May 2012

18-23, ITA World Tunnel Congress, Bangkok Thailand. Contact: Thailand Underground & Tunnelling Group (TUTG), e-mail: info@wtc2012.com, website www.wtc2012.com. ■

UCA of SME

Rapid Excavation and Tunneling Conference (RETC)
June 19-22, 2011
San Francisco Marriott,
San Francisco, CA USA

FOR ADDITIONAL INFORMATION CONTACT: Meetings Dept., SME 800-763-3132, 303-948-4200 fax 303-979-4361, e-mail sme@smenet.org

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Rocky Mtn. Coal Mining Institute	Jun 26 - 28, 2011	Keystone, CO, USA
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International Tunnelling Association	May 21 - 26, 2011	Helsinki, Finland

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September

EDITORIAL FEATURES

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Tunnel Linings	Grouting

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NWMA Annual Meeting	Dec. 5 - 10, 2011	Spokane, WA, USA

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Ground Control	Underground Support Systems

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George A. Fox Conference	Jan., 2012	New York, NY, USA
Canadian Mineral Processors Annual Conference	Jan., 2012	TBD
UCT Annual Conference	Jan., 2012	TBD
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