T&UC

TUNNELING & UNDERGROUND CONSTRUCTION

THE OFFICIAL PUBLICATION OF UCA OF SME   WWW.TUCMAGAZINE.COM   VOLUME 5 NO 4   DECEMBER 2011

Pearl River CSC storage

Large diameter microtunneling

Ultrafine cement grouts

Special Editorial Section from the publisher of *Mining Engineering*

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AN OFFICIAL PUBLICATION OF UCA OF SME | WWW.UCA.SMENET.ORG | VOLUME 5 NO 4 DECEMBER 2011

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COVER STORY

COVER — A plan to build a new sewer and replace two aging lift stations in Lafayette, IN became much more complex during the planning stages when a major user indicated it would be increasing its flows to the system. At the same time, planners discovered major restrictions in the existing system. The solution to these challenges was a combined sewer overflow system tunnel. See story on page 55.

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DEPARTMENTS

CHAIRMAN'S COLUMN

As the year draws to a close, it's time to focus on the future

It is hard to believe that another year will soon come to an end. I know that many people and businesses in our country have not done as well as they would have liked during this past year, but it seems that everyone I talk to in our industry has not changed their opinion that there is a lot of work out there in the underground market. Because of this, most people have kept very busy in their aspect of the business. That's a good thing.

With that in mind, I was pleased to read in the news recently that all the predictions of the world as we know it coming to an end in 2012 are not true. It seems that 2012 was the year that a gigantic fire ball from the sun would strike Earth — something about highly increased solar activity that occurs every 11 years or so. However, NASA scientists have looked into the details of this and are certain that it just won't happen in 2012. There is simply not enough energy there for a killer fireball to make it 93 million miles to Earth. This is also a good thing, in my opinion. So now there are no excuses to not get our business plans completed and start working on all of those goals and New Year's resolutions for 2012.

One of those goals we have set within the UCA is for improved education and training within our industry to address the shortage of people that will be available to take on the increased demand in the coming years.

I want to take this opportunity to share news about a developing program I recently learned about to address this very issue.

The Colorado School of Mines (CSM) in Golden, CO is launching the Center of Excellence in Underground Construction and Tunneling. I recently traveled to the school to learn more about this program and am very excited to see the start of what I think will be an excellent development in our industry. This center will be an interdisciplinary program to address the many different technical needs of the underground industry in education, training and technical research as a minimum.

But don't just take my word for it; check out the article by Mike Mooney in this issue of *T&UC* (page 71)to learn more. Programs such as these will not survive on their own. I encourage you to reach out to CSM, or any other school for that matter, to see what you can do to help develop or improve the training and development that exists for all aspects of our industry.

■

On Jan. 24, the UCA of SME will host the annual George A. Fox Conference at the Graduate Center, City University of New York.

This year, the conference will be a little different and take an international perspective. There will still be dicussions about some domestic projects, especially those on the East Coast, but attendees will also be treated to presentations about international projects such as the Gotthard Tunnel in Switzerland, a high-speed rail project in Spain and Crossrail, the largest infrastructure project in Europe. There will also be a much anticipated keynote address from In-Mo Lee, professor at Korea University. He will speak about challenges of tunneling and underground structures.

I hope to see you all at the George Fox Conference. Be well, and be safe. ■

Jeffrey Petersen,
UCA of SME Chairman

Funding for New Jersey-New York rail tunnel design approved by US Senate

Funding for the Gateway Tunnel project that would expand commuter railroad capacity between New York and New Jersey and pave the way for more high-speed rail service along the Northeast Corridor, won approval from the U.S. Senate.

The approved funding measure includes a minimum of $15 million for Amtrak to begin design and engineering work on the project that will closely follow the footprint of the Access to the Regions Core (ARC) Tunnel project that was cancelled by New Jersey Gov. Chris Christie in 2010. The Gateway project would connect to an expanded New York Penn Station rather than ending deep under West 34th Street in Manhattan.

"The Gateway Tunnel is critical for New Jersey commuters and the economy of our state and the entire region," said Sen. Frank R. Lautenberg (D-NJ). "The existing tunnel is more than a century old and not capable of adequately servicing our region's growing number of transit riders. This funding will allow Amtrak to begin moving the Gateway Tunnel project forward to create jobs, increase access to commuter trains and bring America's first real high-speed rail project to New Jersey and the Northeast Corridor."

"Building our mass transit infrastructure is vital to the long-term economic competitiveness and growth of our metropolitan region," said Sen. Charles E. Schumer (D-NY). "The fact that even Amtrak is working to make this happen shows how important it is to the region's job growth and economic future. This proposal is a positive step in the effort to cover a gaping hole in our cross Hudson transportation system."

Increased traffic and congestion into midtown Manhattan and in New York City threatens the regional economy. The existing 100-year-old rail tunnels into midtown Manhattan are already operating at capacity during rush hour, and ridership is expected to double in the next two decades.

To address these immediate concerns following the cancellation of the ARC Tunnel project, Amtrak expedited plans to build the new trans-Hudson rail tunnels. The Gateway Tunnel project is expected to increase NJ Transit commuter rail capacity into New York by 65 percent (increase from 20 to 33 trains per hour during peak hours), in addition to adding eight additional Amtrak trains during peak hours.

In addition to increasing the number of NJ Transit and Amtrak trains into and out of New York, the project will also expand high-speed rail service on the Northeast Corridor.

The funding bill that contains $15 million for Gateway must now be merged with the House of Representatives' version of the bill. ■

DC Water breaks ground on Clean Rivers project

The District of Columbia Water and Sewer Authority (DC Water) broke ground Oct. 12 on the $2.6-billion Clean Rivers project, the largest construction project ever and the District's largest since the Metro was built.

The project intends to nearly eliminate combined sewer overflows to the Anacostia and Potomac rivers and Rock Creek, also improving the health of the Chesapeake Bay.

As in many older cities, about one-third of the district has a combined sewer system. CSOs direct about 2.5 billion gallons of combined sewage into the Anacostia and Potomac rivers and Rock Creek in an average year.

DC Water has already reduced CSOs to the Anacostia River by 40 percent with improvements to the existing sewer system. The Clean Rivers project consists of massive underground tunnels to store the combined sewage during rain events, releasing it to the Blue Plains Advanced Wastewater Treatment Plant after the storms subside. Similar CSO tunnels exist in Chicago, IL; Indianapolis, IN; Atlanta, GA and other cities.

The first tunnel system, and the largest, will serve the Anacostia River. The first part of that system, named the Blue Plains Tunnel, is 7 m (23 ft) in diameter and runs more than 30 m (100 ft) deep. It will extend from Blue Plains in southwest D.C., roughly along the east bank of the Potomac River, crossing under the Anacostia River and extending along the west bank to about RFK Stadium.

From there, it extends north and west to form a segment known as the Northeast Boundary Tunnel. The tunnel segments south of RFK Stadium, together with their surface hydraulic facilities and a tunnel dewatering pump station, are scheduled to be put into operation by

(Continued on page 6)

Herrenknecht to provide world's largest TBM to River Neva project

Herrenknect president Martin Herrenknecht met with Russian Prime Minister Vladimir Putin in August in St. Petersburg to discuss the River Neva tunnel project. The tunnel is an extremely challenging construction project under the River Neva, which will be carried out using the world's biggest tunnel boring machine (TBM), a 19.25-m- (63-ft-) Herrenknect mixshield machine.

The contract, signed by Nevskaya Concession Co. (NCC) and Herrenknecht AG, is the biggest single order in Herrenknecht's history and represents a huge technical challenge.

Including the backup, the Herrenknecht mixshield will be a total of 82-m- (270-ft-) long. On its own, the tunneling shield will weigh around 3.8 kt (4,200 st) and deliver 8,400 kW drive power to the cutting wheel. The leap in diameter to 19.25 m (63 ft) will enable the machine to excavate 600 m^3/hour (785 cu yd/h) of soil hourly. The excavation area is more than 50 percent larger than that for the largest TBM currently in operation in the world. A mixshield is the quickest and safest solution for driving the 1-km- (0.62-mile-) long tunnel bore under the Neva in the face of the high ground water pressures. An ambitious timetable has been set for implementation of the project. Tunneling is set to begin in St. Petersburg in the spring of 2013, with the tunnel due to be taken into operation in 2016. The aim of this new and world's largest mechanically bored tunnel is to provide significant relief in the center of St. Petersburg and allow a continuous traffic flow in the city divided by the river.

Vehicles have had to use the various bridges in order to cross the River Neva from the city center to the northern districts and the orbital freeway. The city needed a Neva crossing for motor vehicles round the clock, especially during the shipping season. In addition to linking the banks of the Neva with one another, the Orlovski Tunnel would make a contribution to the economic development of Russia.

Allowing longer bridge opening times would allow the intensity of shipping on the Volga/Baltic waterway and the River Neva to increase. The mega-tunnel, with two three-lane carriageway levels, would considerably improve the traffic capacity.

The Orlovski Tunnel project is a pioneering German-Russian project, setting new engineering and constructional standards in large diameter tunneling. ■

Robbins TBM begins work in Azerbaijan

On Aug. 22, 2011, construction of Baku, Azerbaijan's third metro line got a jump start with the launch of a Robbins earth pressure balance (EPB). The 6.3-m (20.7-ft) diameter tunnel boring machine (TBM) for contractor Azerkorpu is one of two EPB machines excavating parallel 3.5 km (2.2 mile) tunnels approximately 15 m (50 ft) apart.

The capital city Baku is home to 1.7 million people and is known for its chronically clogged city streets. Improved transportation infrastructure is a country-wide initiative in Azerbaijan, where the economy is rapidly growing due to substantial oil reserves. "Azerbaijan is poised to become one of the richest countries in the world. There is no doubt, that with the increase in economic interest, the population will soon outgrow the already outdated and undersized transportation infrastructure," said Evan Brinkerhoff, Robbins field service superintendent.

So far, the ground has consisted of full-face clay, similar to London blue clay, with no appreciable ground water, pebbles or soil. "The material is sticky, and our initial advance was limited because the pit size was only long enough to muck out with one car. Our machine performance has since improved," said Brinkerhoff.

The Robbins EPB is custom-designed for the ground conditions with independent foam injection on the cutterhead, resulting in less abrasive wear and smooth muck flow.

As the TBM mines, it is placing 5+1 universal concrete segments using Robbins-supplied segment plant. Muck is being stored in separate storage stations for each TBM, and is then trucked away during the day.

The Robbins machine features a mixed ground cutterhead with carbide bits that are interchangeable with disc cutters, depending on the geology. Four independent foam injection points in the cutterhead evenly consolidate the face in the ground conditions. The design results in decreased cutterhead wear and a smooth flow of muck into the mixing chamber.

The new metro Line 3, for owner Metrostroy Azerbaijan, will connect to the existing Line 1 as well as a new bus station. The EPBs are excavating two sections connecting Cavadxan Station and Avtovağzal station sites. Upon completion of the first leg, the machines will continue on to excavate between the Memar Ajami-2 station and an as-yet-named station located near the Azerbaijani Defense Ministry's hospital. The stations are expected to open in 2013. ■

DC Water: Clean Rivers project is under way

(Continued from page 3)

March 2018, providing relief to the Anacostia first. The remainder of the tunnel north of RFK Stadium is required to be completed by 2025.

Since the early 1900s, only sewer systems with separate pipes for sewage and stormwater have been installed in the district.

The Clean Rivers Project is the result of a 2005 federal consent decree. DC Water is beginning discussions with the parties on reopening the agreement. The goal would be to explore green-development technologies that could reduce or eliminate future pieces of the project, create jobs, green the district and reduce rate increases for customers. Other cities, notably Philadelphia, PA, have proposed CSO solutions that rely heavily on green techniques instead of tunnels.

"We are looking at other ways to manage combined sewage in the Rock Creek and Potomac River sections," DC Water general manager George S. Hawkins said. "No city or utility has ever done a sustained and large-scale pilot study of green roofs, trees and porous pavement to help in those areas. We hope to do just that." ■

CH2M Hill to acquire British engineering firm Halcrow

CH2M Hill recently announced that it has agreed to acquire the share capital of Halcrow for approximately £124 million (US$358 million). The acquisition is subject to the approval of Halcrow shareholders and the U.K. High Court, which is investigating whether the Halcrow pension obligations are fully funded. *The Denver Post* reported that CH2M Hill agreed to honor to the pensions.

CH2M Hill is a global engineering firm with expertise in consulting, design, operations and program management. It will acquire a company steeped in tradition. Halcrow is a U.K.-based engineering, planning, design, and management services firm that was founded in 1868. The company specializes in transport, environmental and other infrastructure projects. The firm has 6,000 employees and is known for signature projects, such as High Speed 1 in the United Kingdom (also known as the Channel Tunnel Rail Link), the Chongzun Expressway in China and Yas Island in the United Arab Emirates.

CH2M Hill's signature projects include the London 2012 Olympic and Paralympic Games Program, the Panama Canal expansion program, the sustainable Masdar City in the United Arab Emirates, the Singapore Deep Tunnel Wastewater Program, and the Management of The Rocky Flats Environmental Technology Site in the United States, one of the most complex nuclear decommissioning and environmental cleanup programs in the world.

"This acquisition is a game changer for our clients. Our global footprint will be deeper and our bench strength will be even more robust. By combining our resources and leveraging our collective technical know-how, we will set a new standard for the marketplace," CH2M Hill chairman and chief executive officer Lee McIntire said. "Best of all, our two firms are ideally suited in terms of cultures, markets, geographies, and we have a shared long-term vision for the future."

The combination of the two firms will help CH2M Hill advance its leadership in water, environmental, transportation and other markets. With the addition of Halcrow's operations in Europe, the Middle East, Asia Pacific and South America, CH2M Hill will more than double its international presence to almost 30,000 employees globally including more than 11,000 outside of the United States. ■

Tunnelling and Underground Construction Academy opens

The Tunnelling and Underground Construction Academy (TUCA), a new academy in Aldersbrook in East London, England opened its doors for its first class in October.

The academy will begin by offering vocational courses such as training for the Tunnel Safety Card, prerequisite for anyone who will work below ground on Crossrail, and a construction skills certification scheme health and safety card training.

Vocational courses initially on offer are precast concrete manufacture and tunnel operations training.

The academy aims to train people in an effort to address the shortage of people with the necessary skills to work on large underground construction projects such as the Crossrail project.

By the end of the year, a variety of other vocational training courses will begin to be offered, increasing the number of students attending the new campus, *Rail News* reported.

Work to install tunneling plant and machinery in the major vocational training areas, including a static tunnel boring machine and a simulated tunnel environment, will be complete by the end of the year, allowing students to gain experience in the practical skills required for underground construction.

By early 2012, the academy will be fully open for business with the full curriculum in delivery and the vocational training areas operational. Up to 150 students will be attending courses offered through the academy at any one time.

The Tunnelling and Underground Construction Academy will offer training to at least 3,500 people over the lifetime of the Crossrail project alone. The only other dedicated tunneling training facility in Europe is located in Switzerland.

Rail Minister Theresa Villiers said: "Investing in this academy further emphasizes government's commitment to rebalancing our economy and promoting the skills our young people need to help Britain compete in the world.■

Clarification

It has been brought to our attention that in the article titled "Versatility of Roadheaders in Tunnel Construction," which appeared in the June 2011 issue of *T&UC* magazine, page 17, we listed Alpine as a "distributer and manufacture of excavation attachments." Wilheim Kogelman, President of Alpine Sales and Rental/ Alpine Equipment CO., LLC of State College, PA. has informed us the Alpine also manufactures roadheaders.

Kogelman founded Alpine in 1968. Also Kogelman was issued a U.S. Patent No. 4,133,582 for roadheader with interchangeable transverse and longitudinal (axial) cutterheads. ■

Preliminary engineering for Ottawa Light Rail Transit project nears completion

Capital Transit Partners (CTP), a joint venture of Morrison Hershfield Ltd., STV Canada Consulting Inc., URS Canada Inc., and Jacobs Associates Canada Corp., is currently completing the preliminary engineering phase for the $2.1-billion Ottawa Light Rail Transit (OLRT) project.

The project, which is the first stage in Ottawa's planned 40 km (25 mile) light rail network, will see the construction of a 12.5-km (7.7-mile) LRT system, including 3 km (1.8 miles) of tunnel under the downtown and 13 stations, three of which will be in the tunnel portion. Implementation of the new system will include converting portions of the existing Bus Rapid Transit to light rail (one of the first such undertakings in North America), Jacobs and Associates said in a press release.

The preliminary engineering assignment, awarded to CTP in September 2010 and now nearing completion, required CTP in advancing the OLRT design to reduce capital and operating costs, improve operating characteristics, reduce future maintenance requirements, minimize construction related impacts and minimize impacts to adjacent properties. CTP also developed the request for qualifications and contributed to the related request for proposal documents for what will be a design, build, finance and maintain project.

During the assignment, the city of Ottawa made the decision to accelerate the overall project schedule by one year, moving the proposed opening date from the spring of 2019 to the spring of 2018. This decision to advance the overall schedule resulted in the CTP assignment being accelerated by six months to allow the construction of the system to begin in early 2013, approximately six months earlier than had been planned. CTP, due to its extensive experience in planning, design and procurement of LRT projects, was able to meet this new deadline.

In addition to the city of Ottawa's own financial contribution, the OLRT project is supported by both the federal and provincial governments, who are providing up to $1.2 billion of the project costs. The city will require the winning proponent to finance up to $400 million of the construction cost. All three levels of government are committed to working with the successful proponent in delivering an innovative, world class transit solution. ■

Panama Metro 1 project TBMs delivered

A pair of Herrenknecht tunnel boring machines (TBM) that will be used to build Line 1 of the Panama Metro were delivered to FCC Construction S.A. at a ceremony in the southwestern German town of Schwanau.

The two 10-m- (32-ft-) diameter TBMs will arrive in Panama separately, in October and November. The machines will be used to bore a 6.4-km- (4-mile-) long tunnel to complete Panama Metro's Line 1. The project, which was awarded to a consortium comprising FCC and Brazilian company Odebrecht, has a budget of more than $1.4 billion.

The TBMs are equipped with cutting-edge technology and include complementary equipment such as locomotives, conveyor belts, rails, spares, maintenance equipment, cabling and cutting tools. The agreement includes transport to Panama and assembly of the TBMs.

At the delivery ceremony, held at Herrenknecht AG's hangars, Martinelli announced the tender for Line 2 of Panama Metro: "We are going to transform the former transport chaos in Panama into a safe, reliable system for all citizens."

The Panama Metro Line 1 contract adds to FCC's experience in subway building worldwide. FCC Construction has participated in the construction of the Lisbon Metro (Alameda-Expo section) and in the extension of Line 2 of Athens Metro, as well as the construction of new stations there (Periteri and Anthoupoli).

Through Alpine, its Austrian subsidiary, FCC is currently building the metro line between New Delhi and Indira Gandhi International Airport and two new sections of the Singapore Metro.

The company was recently awarded the contract to build the Toronto-York Spadina Subway Extension (TYSSE) in Canada, which includes construction of the North tunnels and the Highway 407 Station and is worth $440 million, and Section 1 of Bucharest Metro's Line 5 in Romania for $385 million.

FCC also built extensions to Madrid Metro, including Line 10, Line 8 (Barajas-T4), and Line 3 (from Legazpi to Villaverde), as well as sections I and III of Metrosur. In Barcelona, the company built several sections of metro Lines 2, 5 and 9. It is currently building the metro in Málaga and Section 1 of Barcelona Metro's Line 9. ■

BUSINESS PROFILES

A special advertiser sponsored advertorial section

DECEMBER 2011

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Messinger Bearings – A Kingsbury Brand

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

TBM Bearing Customers Have an Option

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

New or Rebuild? Your Choice

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

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

TBM Bearings and More, Planning for the Future

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

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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 break-ins, 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.

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Jet Grout Secant Pile Wall – South River Tunnel Project, Atlanta, GA

Jet Grouting – Brightwater Conveyance System, Seattle, WA

Compaction Grouting – Highway 85 Sinkhole above Utility Tunnel, Brighton, CO

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 near breakthrough, tunneling under cover as shallow as 7.5 m (24.5 ft) with minimal settlement, and 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 129m (423 ft) per week—rates higher than the majority of 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 nine other machines working on the project.

In 2011, Robbins also launched the first of 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 EPB was fast-tracked to prevent potential flooding of downtown Mexico City due to deteriorating sewer lines.

Robbins innovations will continue to advance into 2012, with more major EPB projects planned in Singapore, Russia, and India. For more information on recent tunneling and groundbreaking R&D, visit www.TheRobbinsCompany.com or call +1 440 248 3303.

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

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.

Mining Equipment builds new Jetair Axiflow Fans up to 500 horsepower and 84-inch diameter. They developed a line of Super-Silenced™ Fans that run quieter and take up less space than other integrated fan and silencers. They also roll steel ventilation ducting on-site. Ducting as small as 12-inch and as large as 84-inch can be rolled.

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.

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

Antraquip Corporation

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

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

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

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

JENNMAR™ – World Class in Ground Control Technology

We're JENNMAR, a multi-national, family-owned company that is leading the way in ground control technology for the mining, tunneling and civil construction industries. For nearly 40 years, our singular focus has been on manufacturing products and creating strata control solutions that help keep those who work underground safe and more productive. And with manufacturing plants and distribution networks around the world, we are uniquely positioned to react to ground control needs anywhere, anytime.

Our manufacturing plants and distribution networks are located around the world. These facilities exist for one reason, to respond to our customer's needs, wherever they are, on time and on budget. JENNMAR is just a few hours from most of our customers, so we can ensure superior customer service and product availability. We now operate eleven manufacturing plants throughout the United States. Of these eleven facilities, ten are related to manufacturing ground control products, and the eleventh is a steel service center that supplies a steady flow of flat steel products. Globally, we operate six manufacturing facilities with three located in Australia, and three more in China, Chile and Canada. We've also just acquired a facility in Poland to better serve our European customers.

JENNMAR continues to grow, but our focus will always be on the customer. We will always provide exceptional, on-going service that is second to none. We feel it is essential to develop a close working relationship with every customer so we can understand the unique challenges they face. Our commitment to the customer is guided by three words; Safety, Innovation and Service. It's these words that form the foundation of our business. It's who we are.

JENNMAR
258 Kappa Drive
Pittsburgh, PA 15238 USA
Telephone: +1-412-963-9071
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www.jennmar.com

Pacific Boring Inc.

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.

When your project needs to be done right, on time, and safely, partner with Pacific Boring.

Pacific Boring Inc.
Telephone: +1-559-864-9444
www.pacificboring.com

AECOM

Second Avenue Subway Project, New York, New York

AECOM is a global provider of professional technical and management support services to a broad range of markets, including transportation, facilities, environmental, energy, water and government. With approximately 45,000 employees around the world, we are a leader in all of our key markets, including our specialized services of designing and developing tunnels. We offer clients extensive knowledge in such niche areas as hard and soft ground large diameter tunneling, micro-tunneling, geology, systems design and explosive environmental modeling and all aspects in between.

Our tunneling specialists provide the technical expertise our clients rely on to meet the challenges of even the most demanding tunneling project. Our expert team has a wealth of experience in such key facets as tunnel and cavern design, station design, tunnel ventilation and system safety, seismic using the latest state-of the-art analysis and design programs. Across the country and around the globe AECOM's tunneling experts have the global resources and local knowledge to deliver advanced solutions to complex challenges.

From the North Shore Tunnel Connector project in Pittsburgh, Pennsylvania, to the Second Avenue Subway in New York City, our knowledgeable experts can complete even the most complex tunnel projects. AECOM provides a blend of global reach, local knowledge, innovation, and technical excellence in delivering solutions that create, enhance and sustain the world's built, natural, and social environments.

AECOM
www.aecom.com

Homestead Avenue Interceptor Extension, Hartford, Connecticut

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 experienced employees, many of whom have been with the company for over 25 years. Geokon, Inc. has emerged as *The World Leader in Vibrating Wire Technology*™ and one of the major global instrumentation companies due to our high-quality products, responsive customer service and industry-leading designs.

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

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

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

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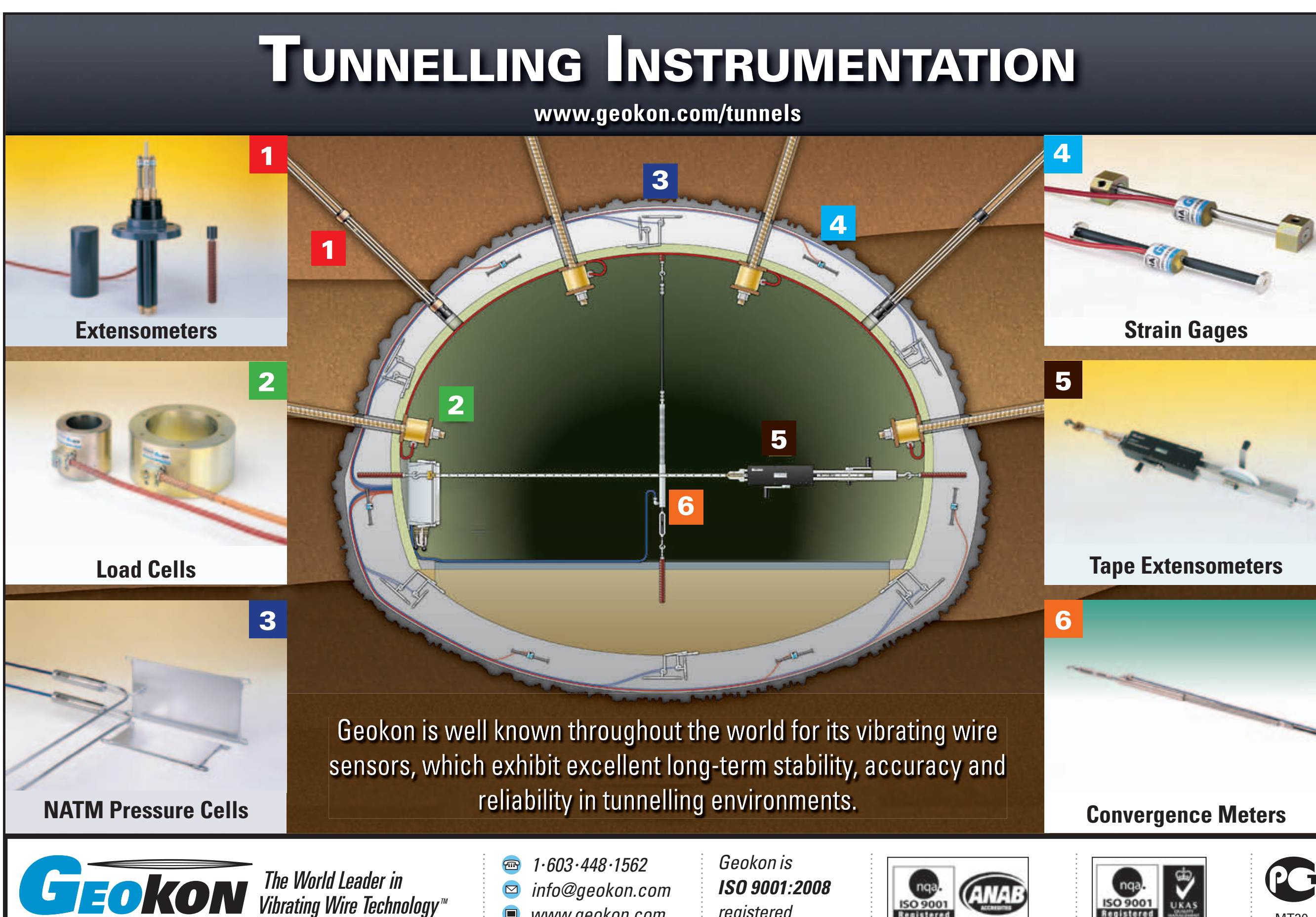

Normet in North America - Equipment and Construction Chemicals for Tunneling and Mining

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
PO Box 64, 19116 Spring St.
Union Grove, WI 53183 USA
Telephone: +1-262-878-5760
Email: info@normet.fi
www.normet.fi

Rapid Set® Cement Products for Tunneling and Mining

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

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

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

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

Rapid Set®
Construction Cement Products

There's More to Moretrench

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

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

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

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

Stirling Lloyd - Worldwide Leader in Waterproofing

Stirling Lloyd is a world leader in the manufacture of specialist waterproofing systems for the civil engineering industry. For over 40 years, Stirling Lloyd has used innovative MMA technology to produce safe, effective, seamless spray applied waterproofing systems. Recognized by owners, civil engineering consultants and general contractors, Stirling Lloyd's seamless, spray applied approach to waterproofing addresses the problems inherent in pre-formed sheet waterproofing.

Integritank HF is Stirling Lloyd's solution to waterproofing SEM concrete lined tunnels. Integritank HF is a seamless, spray applied two-coat waterproofing system that remains fully bonded to the primary lining and is specifically designed to accept a sprayed concrete secondary lining. The membrane also exhibits excellent crack-bridging capabilities. The membrane accommodates the most complex geometry and is ideal for use in station boxes, cross-passages and SEM tunnels. Integritank HF can also be non-destructively tested once installed to demonstrate its waterproofing characteristics.

With high production rates, simplified detailing and excellent crack-bridging capability, Integritank HF can greatly reduce SEM tunnel build times and costs, while providing the long term performance characteristics for which Stirling Lloyd's innovative products are recognized worldwide.

For more information visit:
www.tunnelwaterproofing.com, or
www.stirlinglloyd.com/tunnels

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152 Rockwell Road, Building A
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Telephone: +1-860-666-5008
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David R. Klug & Associates, Inc.

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

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Email: dklug@drklug.com

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:

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

CDM
www.cdm.com

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.

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

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175 West Liberty Road
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www.bradshawcc.com

Brookville Equipment Corporation

Brookville Equipment Corp. continues to be the leading manufacturer of rail support equipment for tunneling projects. BROOKVILLE's products are custom designed to the highest engineering standards for quality, safety, and environmental responsibility in both diesel and battery-powered designs.

BROOKVILLE's mine-duty units feature a planetary final drive gear and liquid-cooled internal wet disc brakes, crucial components that result in longer service life and maximum efficiency for demanding tunneling projects. BEC also builds rubber-tired equipment, which is suited for steep tunnel grades, tunnel inspection or maintenance with non-tracked projects. BROOKVILLE also offers multiple opportunities for after-sales services from our dedicated service organization, Brookville Services LLC.

Your company will see that with each custom piece of equipment BROOKVILLE builds, there it's an investment with added value. "You can believe in a BROOKVILLE."

Visit our new website at www.BrookvilleCorp.com.

Brookville Equipment Corp.
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Brookville, PA 15825 USA
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ABC Industries

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

ABC Industries, Inc.
P.O. Box 77
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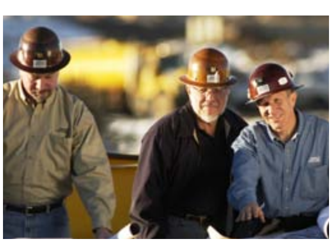
Underground Intelligence with Brierley Associates



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

Brierley Associates
2329 West Main Street, Suite 201
Littleton, CO 80120 USA
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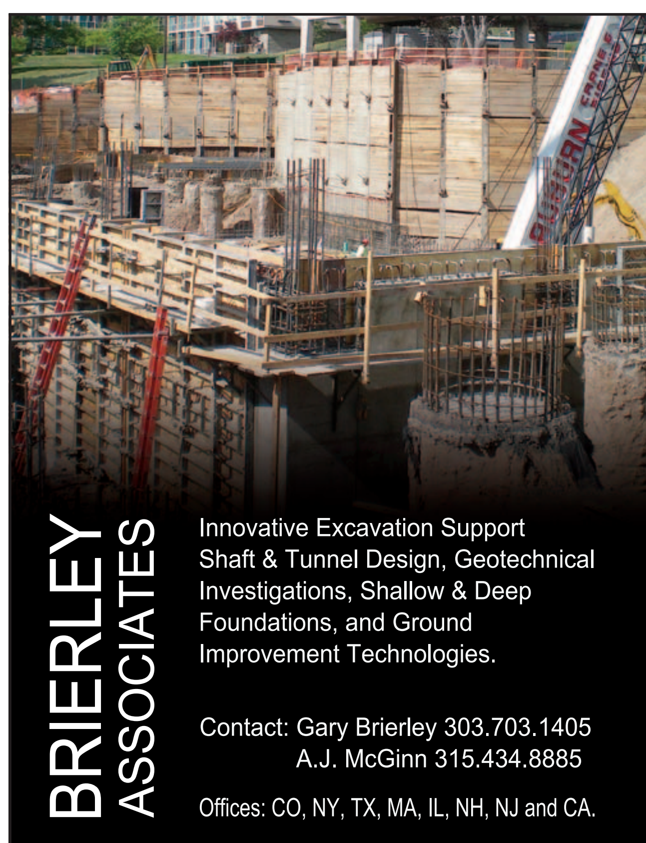

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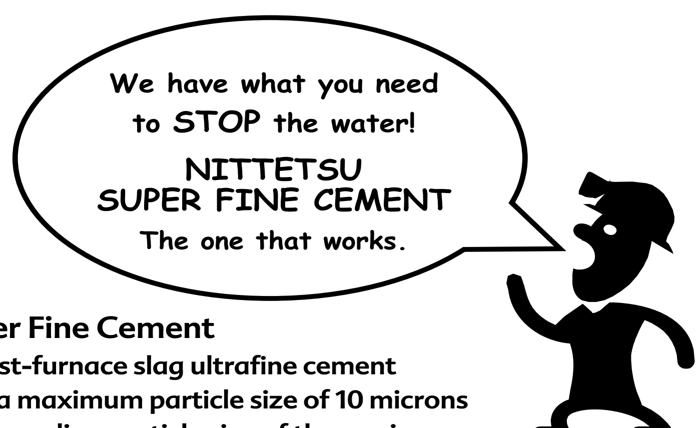
Telephone 206.523.1233 • FAX 206.524.6972
info@surecrete.com • www.surecrete.com

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

Concrete materials for Chester Creek Dam, Metlakatla, AK



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- MWD Arrowhead Tunnels, San Bernardino, CA
- SNWA Lake Mead No.3 Pumping Station, Henderson, NV
- Amtrak Thames River Bridge Replacement, New London, CT

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The McDowell Group of Companies

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.

Recent developments have further enhanced the growth of the company. In 2007, a new complex was opened which houses all of offices and a 15,000 sq/ft. shop with 15 bays. In 2006, McDowell acquired Driftech Inc. and Webcon Equipment, solidifying itself as the biggest provider of used mining equipment worldwide.

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

A new exchange parts program offers clients the flexibility of exchanging core parts for rebuilt ones immediately, thus saving down time or inventory expenses. McDowell's parts department is sure to have the part you need, or it will be sourced locally or through its worldwide locator.

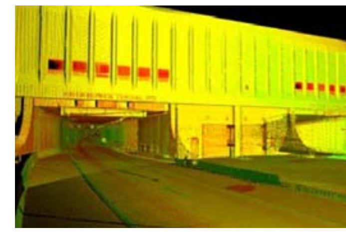
Auditing, commissioning and consignment are also offered by McDowell for clients' surplus equipment. McDowell's search to acquire additional late model equipment is ongoing.

McDowell buys good used equipment.

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

Atkins North America

The National Geomatics Division of Atkins North America, Inc. has provided a wide range of surveying and mapping services to designers, construction managers and contractors in the tunneling industry a specialized approach to surveying and geodesy for over twenty years.



Atkins incorporates the latest surveying technology as well as providing high-order survey control for tunneling and construction operations. Atkins' success has been based on incorporating new technologies and innovative techniques that are to the client's advantage and having a staff of trained and motivated personnel willing to perform the required survey at any time.

Atkins has invested heavily in ensuring that we have the proper equipment for each specific task as well as reliable equipment to perform any form of surveying required by our client. Atkins' specialized equipment includes the DMT Gyromat 2000 gyro-theodolite which has proven its success over the years and terrestrial scanning for as-builts' using the Leica ScanStation 2.

Atkins North America, Inc.
Telephone: +1-719-213-4130
www.atkinsglobal.com/northamerica

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

Daigh Company is the supplier of Dā-mite Rock Splitting Mortar. Dā-mite is used to fracture rock and concrete in "no-blast" conditions. Dā-mite is an ideal and effective tool for fracturing mass rock, boulders, trench rock, dimensional stone, concrete and reinforced concrete. Dā-mite is mixed with water and placed in predrilled holes, where it sets and expands with a compressive strength of over 18,000 PSI, Dā-mite has more than enough force to get the job done. No license or permits are required. There are four grades of Dā-mite, providing enough versatility to be utilized in drilled hole diameters from 1" to 2 3/4". www.da-mite.com

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Cumming, GA 30040
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Fax: +1-770-887-3783
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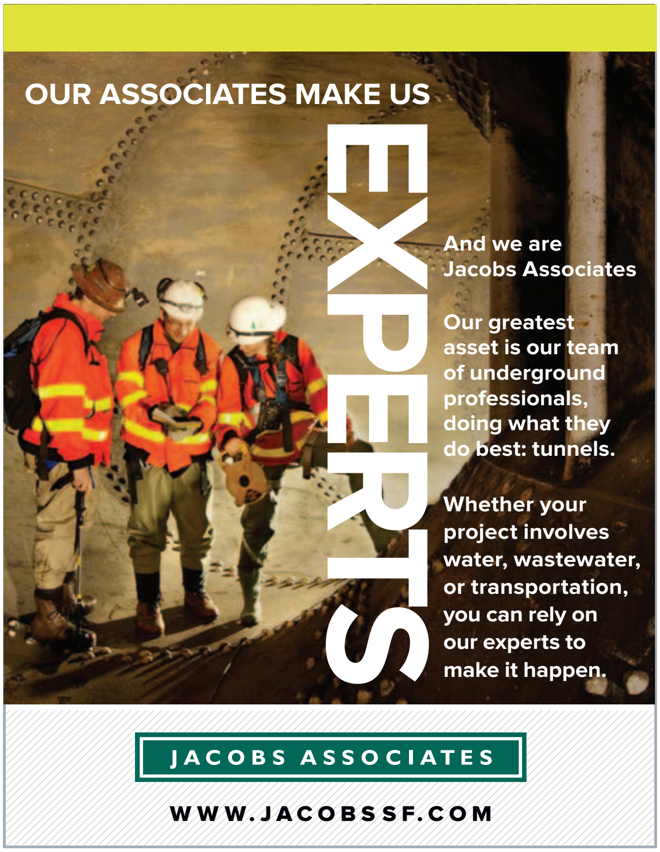
www.daighcompany.com

Dā-mite®
Rock Splitting Mortar

Bay Tunnel TBM is Launched

As the prime consultant, Jacobs Associates led the tunnel design on the Bay Tunnel project and is currently providing construction support services. The project achieved a major milestone on August 16, 2011, when the tunnel boring machine (TBM) was launched to begin excavation of the first bored tunnel under the San Francisco Bay. The 15-foot-diameter TBM is being used to excavate the sandy and silty clays under high groundwater pressures of up to 3.5 bar. The 5-mile-long Bay Tunnel is part of the San Francisco Public Utilities Commission's $4.6 billion capital improvement program to upgrade the Hetch Hetchy Water System, which brings water through gravity-fed pipes from Yosemite National Park to the San Francisco Bay Area.

Jacobs Associates
Telephone: +1-800-842-3794
www.jacobssf.com



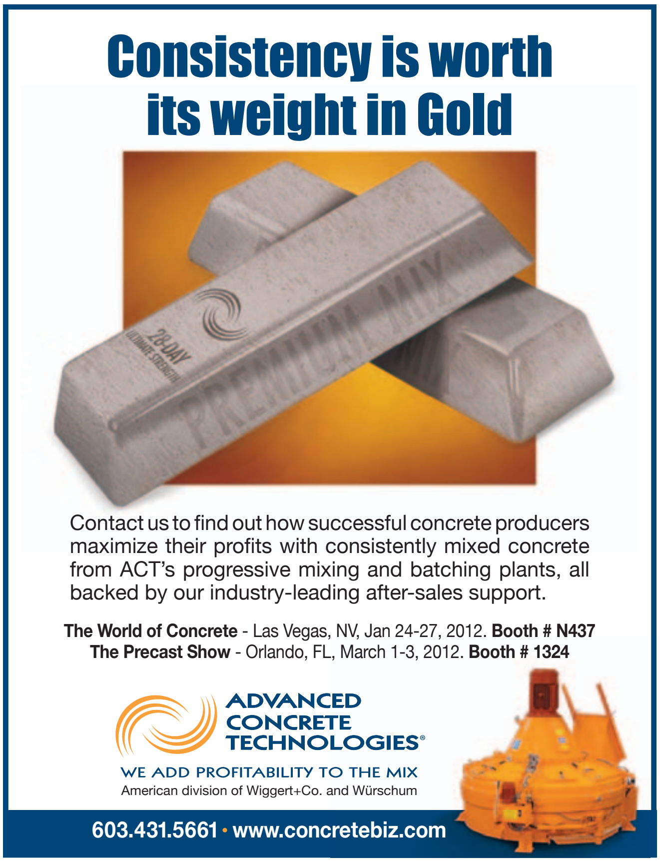
Advanced Concrete Technologies, Inc. - We Add Profitability to the Mix

Advanced Concrete Technologies, Inc. (ACT) is a single source supplier of turnkey concrete batching and mixing plant solutions that draws on over 45 years of experience and more than 4,000 concrete plant installations worldwide. ACT provides the industries most flexible and proven solution for producing highest-quality,

central mixed concrete and backfill grout for on-site construction, tunneling and mining projects. ACT's MobilMat batch plants, come in ten different sizes, ranging from 30 up to 240 cubic yards per hour concrete output. We offer high intensity HPGM counter-current mixers and DWM twin-shaft mixers, advanced PCS control automation, commissioning services as well as an industry leading training & support program.

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

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



The Heintzmann Group

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

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

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

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.

Alpine Equipment, LLC
Telephone: +1-814-466-7134
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www.alpinecutters.com

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FEATURE ARTICLE

Challenges and triumphs of a large-diameter microtunnel relief interceptor sewer in Indianapolis

The city of Indianapolis has more than 25,000 homes currently on septic systems. Many of these systems do not function well because of their age and surrounding soil conditions. As Indianapolis has worked to eliminate septic systems and install sanitary sewers in large unsewered areas on the northwest side, capacity of the existing Belmont North Interceptor (BNI) became a concern. The BNI system currently services an area of approximately 80 km^2 (31 sq miles) located within the northwest quadrant of the city (Fig. 1).

Monitoring of the existing interceptor indicated portions of the system flowing half- to two-thirds full during dry weather conditions and surcharging during some wet weather conditions. Further analysis of the BNI based on growth projections coupled with increased sewershed yield resulting from the city's septic tank elimination program (STEP) indicated dry-weather flows could potentially triple over the next 20 years. Based on these modeling results and current wet weather capacity issues, the city determined further STEP projects could not be performed within the BNI service area until additional capacity within the interceptor was achieved.

In addition to BNI improvements being critical to the STEP program, the city and U.S. Environmental Protection Agency (EPA) included a BNI relief sewer project in the federally mandated city-wide consent decree to increase sewer capacity, reduce combined sewer overflows (CSO) and eliminate wet weather sanitary sewer overflows (SSO). Indianapolis' consent decree currently consists of 31 consent decree control measures totaling

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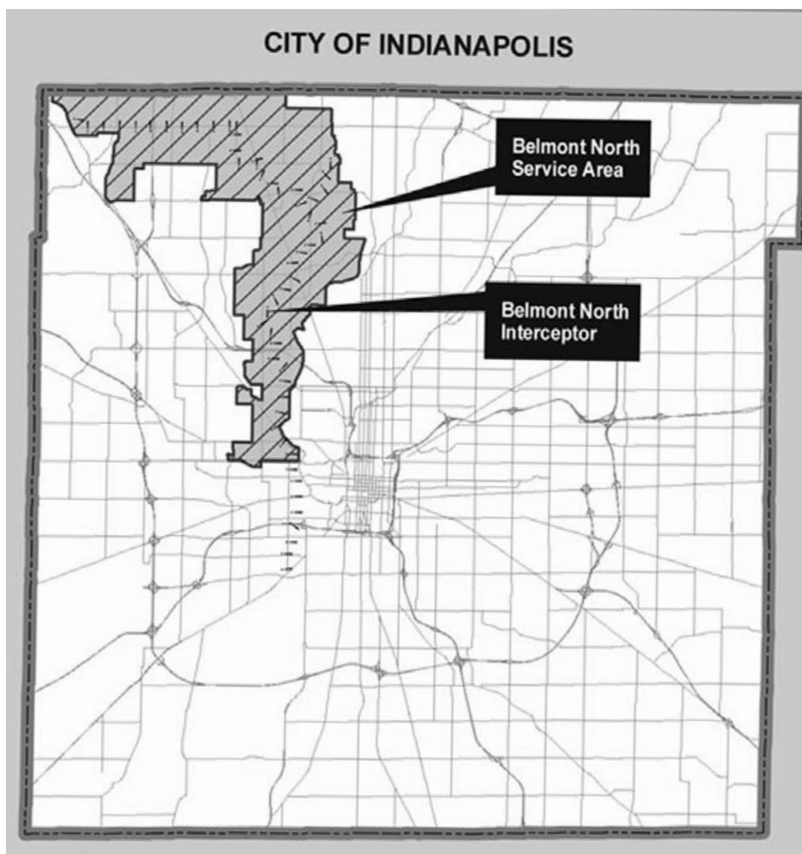
FIG. 1

Belmont North Interceptor service area.



$1.3 billion in 2004 dollars. These CSO program projects are being completed per specified consent decree milestone schedule dates with the entire CSO requiring to be completed and in full operation by 2025 or the city could receive significant fines.

The Belmont North Relief Sewer Project is one of the first projects and, at the time, was the largest single project, to be constructed in terms of the city's consent decree.

Detailed engineering feasibility studies and preliminary engineering reports ultimately resulted in the design of a multi-phased relief sewer project to eliminate the BNI capacity issues. The Belmont North Relief Interceptor (BNRI) Project consists of four sections (Fig. 2):

BNRI Section 1 — Project includes construction of approximately 1,600 m (5,250 ft) of 1,800 mm (72 in.) diameter gravity relief sewer, 1,219 m (4,000 ft) using trenchless methods and the remaining 381 m (1,250 ft) using traditional opencut methods. The project also includes construction of nine significant cast-in-place sanitary sewer structures, two of which require construction while maintaining flow in active large diameter connection sewers.

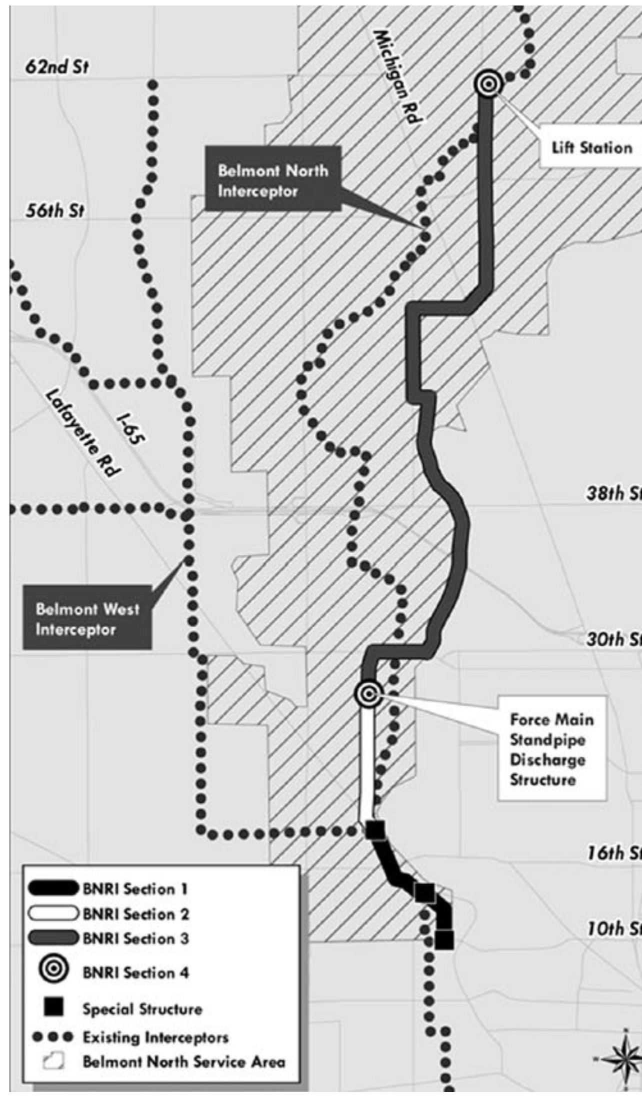
BNRI Section 2 — Project includes construction of approximately 1,525 m (5,000 ft) of 1,200-mm- (48-in.-) diameter gravity sewer installed using opencut excavation and limited trenchless installation. Project includes crossing and supporting/protecting critical water and gas utility transmission lines.

BNRI Section 3 — Project is comprised of approximately 8,534 m (28,000 ft) of 1,000-mm- (42-in.-) diameter sanitary force main installed using opencut excavation and limited trenchless installation. The project also includes approximately 1,980 m (6,500 ft) of 200-mm (8-in.) gravity sanitary sewer installation as part of the septic tank elimination program (STEP). The project starts at the Section 4 Standpipe and stretches north to Juan Solomon Park where it ends at the Section 4 lift station.

BNRI Section 4 — Project consists of the 144,000 m^3/d (38 million gal/day) Belmont North Lift Station (BNLS) and Belmont North Standpipe (BNS) discharge structure. The lift station design includes a wet well and dry well approximately 12 m (40 ft) deep, with a large control building for power, pump control and odor control equipment situated over the dry well. The lift station uses four high-horsepower, dry-pit submersible pumps to send waste water to the 1,000 mm (42 in.) Section 3 force main, which eventually discharges into the BNS at Coffin golf course. The Section 4 BNS accepts waste water flow from the Section 3 force main and transfers it into the Section 2, 1,200-mm- (48-in.-)

FIG. 2

Belmont North Relief Interceptor project sections.



diameter gravity sewer immediately downstream to the south.

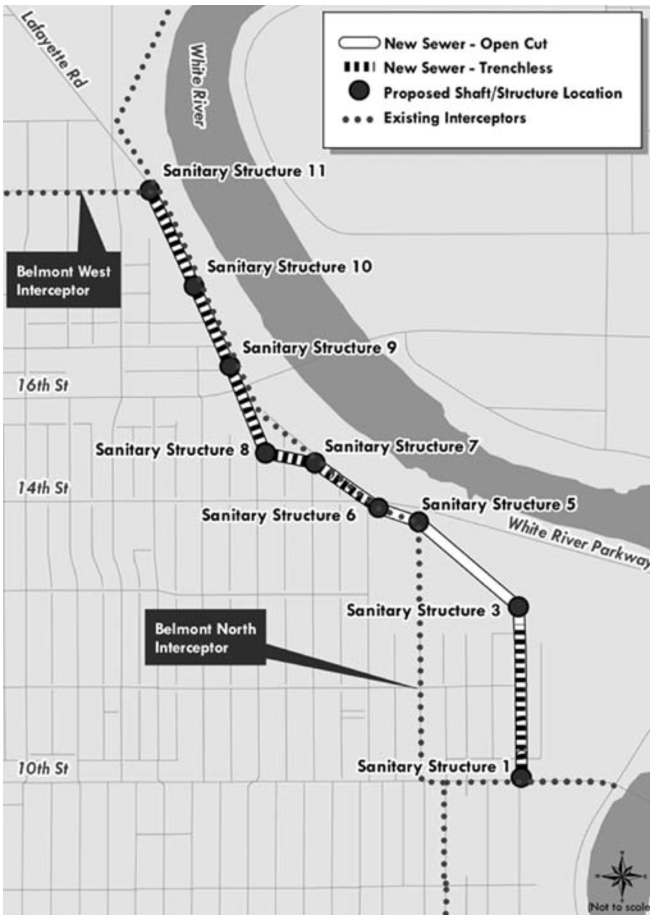
The remainder of this article focuses on the challenges and successes of the BNRI Section 1 project, the large diameter microtunnel relief sewer.

Planning and execution constraints

The Belmont North Relief Interceptor (BNRI) Section 1 project is the southern downstream end of the relief sewer system and consists of approximately 1,600 m (5,250 ft) of 1,800-mm- (72-in.-) diameter gravity sewer installed primarily using microtunneling methods. Right-of-way and city-owned property, coupled with feasible jacking and receiving shaft locations, resulted

FIG. 3

Belmont North Relief Interceptor Section 1 project alignment.



in six microtunnel boring machine (MTBM) drives and one traditional opencut section (Fig. 3).

BNRI Section 1 — project phasing

Arguably the most difficult challenge realized during design of the Section 1 project was critical project shafts and associated sewer connection structures could potentially result in the simultaneous closures of multiple major roadways within the same general vicinity of the city. City representatives determined traffic restrictions or closures of 10th St. and White River Parkway West Drive (WRPWD), two thoroughfares within the project limits, could not be permitted during the following three critical yearly community events as a matter of public safety:

- Indianapolis Mini-Marathon—May 2, 2009 and May 1, 2010;
- Indianapolis 500—Weekends of May 24, 2009 and May 30, 2010 (to include Friday, Saturday, Sunday and any additional rain days);
- Brickyard 400—Weekends of July 26, 2009 and July 25, 2010 (to include Friday, Saturday, Sunday and any additional rain days).

In addition, the city decided traffic restrictions at 10th St. could not be permitted to occur simultaneously with restrictions on WRPWD.

In order to effectively manage these significant traffic related construction restraints and ensure completion of the Section 1 project within the required time, the project was divided into four phases (Fig. 4). Each phase was assigned a substantial completion and final completion period (calendar days), each including liquidated damages, in an effort to ensure work would be prosecuted regularly and diligently, while still achieving the city's traffic control requirements. The following summarizes the contract specified project phasing, timeframes, liquidated damages and key work elements within each phase:

Phase 1: Overall project includes all other project phase and limits.

- 550 Calendar days to achieve substantial completion.
- Final completion of all work 90 days following substantial completion.
- \$750/calendar day liquidated damages for delay in achieving substantial completion.
- \$400/calendar day liquidated damages for delay in achieving final completion.

Phase 2: Work at the 10th St. and Miley Ave. intersection, including the shaft and structure for connection to the existing BNI, several other smaller sewer relocations/connections and all associated restoration work.

- 150 calendar days to achieve substantial completion.
- Substantial completion cannot extend beyond Phase 1 substantial completion.
- \$500/calendar day liquidated damages for delay in achieving substantial completion.

Phase 3: Work in the vicinity of 19th St. and Lafayette Rd., including the shaft and structure for connection of the 1,000-mm (42-in.) Belmont West Interceptor, several other smaller sewer relocations/connections, and all associated restoration work.

- 180 calendar days to achieve substantial completion.
- Substantial completion cannot extend beyond Phase 1 substantial completion.
- \$500/calendar day liquidated damages for delay in achieving substantial completion.

Phase 4: Work within White River Parkway West

Dr., including multiple shafts and connection structures for relief interceptor bends and all associated restoration work.

- 270 calendar days to achieve substantial completion.
- Substantial completion cannot extend beyond Phase 1 substantial completion.
- $500/calendar day liquidated damages for delay in achieving substantial completion.

Bidding approach

In the initial pre-bid assessment of any tunnel project, the first step taken by bidders is to compare the geotechnical reports provided and the engineer's specified means-and-methods with their company's equipment fleet and availability. In the case of BNRI Section 1, the geotechnical baseline report (GBR) demonstrated a complex variable geology containing soils from loose, wet sands to dense glacial till, all of which contained high concentrations of cobble and boulders; including one drive were all of the different conditions were expected to be encountered (Fig. 5).

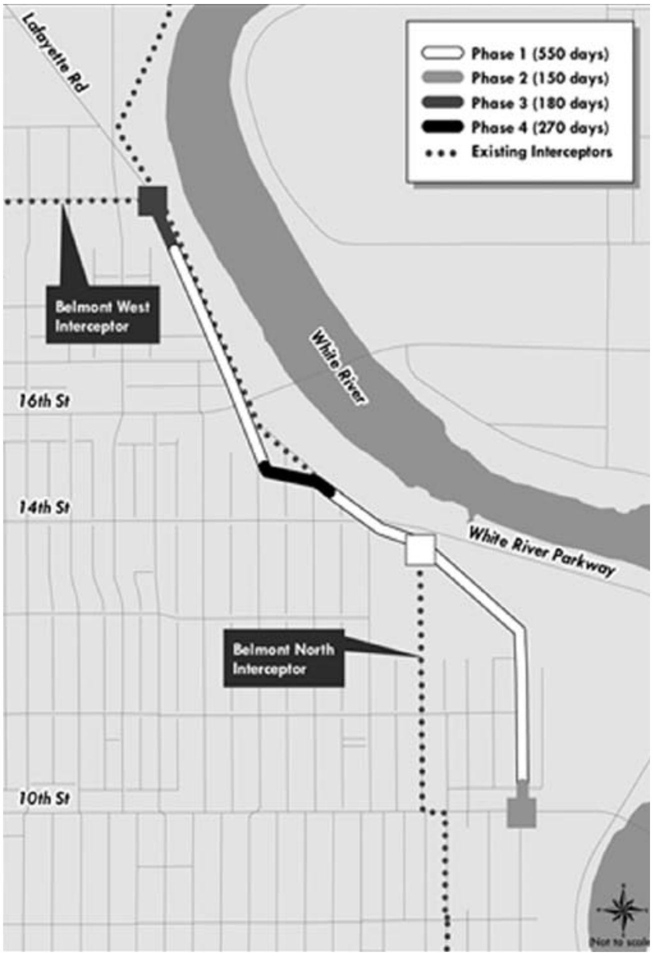
The Rasa DH-1900 MTBM owned by Bradshaw Construction Corp. was selected for use in this application because its size was a reasonable fit with the product pipe, and because of its power and weight. The 1,800-mm (72 -in.) interior diameter pipe size, on the larger end of the microtunnel pipe jacking spectrum, allowed the MTBM to have enough power and thrust to effectively cut the cobbles and boulders to a manageable size and to have room enough for an opening allowing manned access to the tunnel face that could be used in investigating and/or removing a boulder that was blocking the cutter head. Having successfully used the MTBM on previous projects, Bradshaw Construction was comfortable with the Rasa machine's ability to perform on the project. However, the specification that the project mobilization would serve as full payment for the MTBM rental added significant bidding risk if it did not perform, regardless of the cause. The potential boulder encounters made this risk a significant consideration.

Pipe selection was a less complicated operation, as to win a job, contractors typically have to use the least expensive product allowed by the specifications. And while both ASCE Type B and Type C joints were allowed for use, the only quotation available at bid time was the Type B. The quote from a local manufacturer, Independent Concrete Products, would allow Bradshaw Construction ready access to the construction process and availability of their engineers and technicians if the project required it.

Another bidding consideration was the restraints to the schedule due to the project's proximity to the Indianapolis Motor Speedway and the restrictions during events to be held there. As an 11-m- (35-ft-) deep tunnel access shaft cannot simply be "plated over" to allow safe access to traffic, the tunneling operation had to be condensed into phases within the total project duration. The potential of not meeting the phase durations also added bidding risk to the project.

FIG. 4

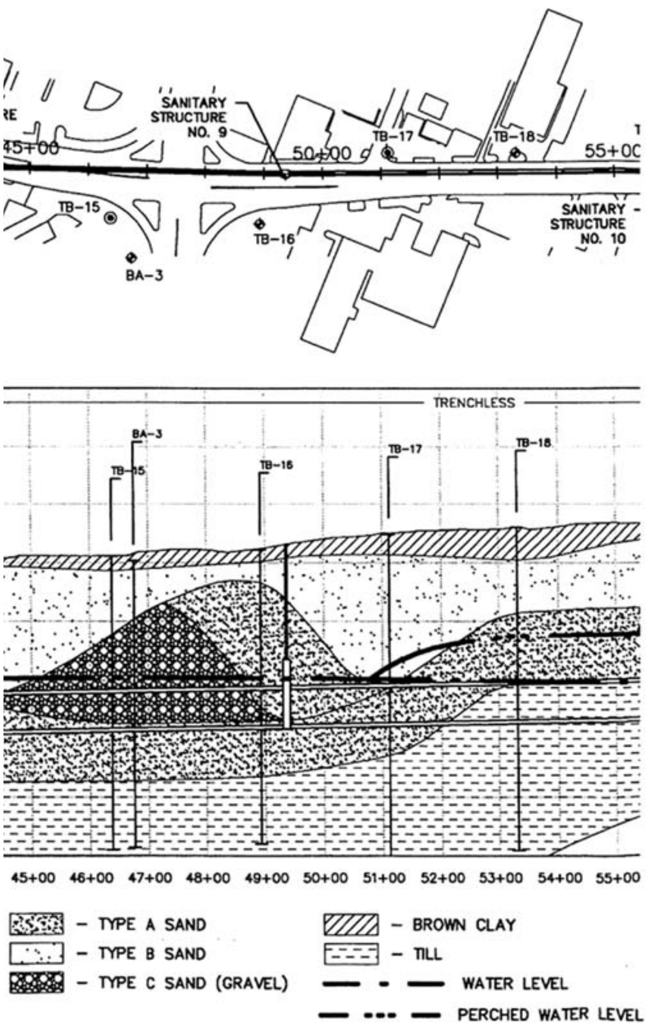
Belmont North Relief Interceptor Section 1 project phases.



Bid Alternates 1 and 2, as defined by the city, also had to be considered. Bid alternate No. 1, which eliminated Structure No. 2 and lengthened the tunnel north from Structure No. 1 by 76 m (250 ft) to Structure No. 3 was selected to bid by Bradshaw Construction. Not only would this change present a cost-savings to both the city of Indianapolis and Bradshaw Construction Corp., the pipe size and soil conditions would allow for the additional length to the tunnel drive with minimal additional risk. Bradshaw Construction did not elect to pursue bid alternate 2 as it would require the mobilization of a second TBM. The company did not feel that elimination of one of the three shafts on Lafayette Road would present savings in either cost to the city or gains to the overall project schedule.

FIG. 5

Belmont North Relief Interceptor Section 1 typical geotechnical profile.



Construction

Shaft sinking. The selection of support of excavation materials for shaft sinking was made considering the geotechnical information, cost effectiveness and versatility of the system. Steel sheeting was eliminated from consideration, as the boulder content in the soils from the GBR made driving sheeting very risky, if not impossible. A large boulder could stop the sheet from being driven to its correct depth, and even boulders that did not cause refusal of the sheet, would slow productions, and would have made sheeting an expensive option. The location of the ground water table also had to be considered in shaft support material selection. The typical ground water table throughout the project was located 3 m (10 ft) above the bottom of excavation and could be dewatered, but the sandy soil conditions required that the supports be installed in such a way that only small surface areas be exposed at any given time to limit soil raveling. Also, in many instances, the proximity of the shaft perimeter to existing overhead power lines would have either required the electric line to be de-energized (which the utility was unable to do) or the shafts to be moved. Relocating shafts was not an acceptable option because it would not maintain traffic lanes while keeping all work within the defined construction easements.

Gasketed liner plate and steel rib shaft supports solved these issues. Individual plates installed in a dewatered condition minimized ground loss and, in areas where boulders conflicted with the shaft perimeter, they were removed as needed with their voids filled during the grouting process. The segmental nature of liner plate shaft construction allowed the shaft supports to be assembled by hand in areas where a crane could not reach such as directly below power lines, eliminating the overhead conflict. Additionally, since the plates are individually installed when the soil is exposed, shaft penetrations can be made with only minor gaps between the shaft support and the existing utility, such as the existing 1,400 mm (54 in.) and 2,000 mm (78 in.) sewer at Structures No. 5 and No. 1, respectively. Also, in dealing with the installation of the shafts that contained existing sewers, there was no guessing game when it came to the exact location of the sewers. Once they were physically located within the shaft excavations, the penetration was constructed tightly around the sewer. The alternative of driving sheeting would have required the assumption of a location and, if that information was wrong, a sheet could be driven through the existing pipeline on one side while the gap on the other side is so large that stopping the soil from raveling into the shaft would be a challenge. In total, nine liner plate shafts were installed on the project with diameters ranging from 7.3 m (24 ft) to 12 m (40 ft) to an average depth of 10.3 m (34 ft) (Figs. 6 and 7).

The shaft for Structure No. 1 is a good example of the advantages of liner plate construction. Structure No. 1 was the connection point between the new 1,800 mm (72 in.) Belmont Relief Interceptor and the existing 2,000 mm (78 in.) Belmont Interceptor. On the south and west sides of the structure location were active overhead power lines. The line on the west side was a large transmission line that served as a one-way feed to a mill that could not be de-energized for any reason. The selection of a liner plate shaft was made to avoid this power line during construction. The shaft was designed with 10.7-m- (35-ft-) diameter inside clearance to allow the recovery of the MTBM, while the existing interceptor remained in service and to allow CIP structure construction to occur per plan giving the sewer location a ±1 m (±3 ft) tolerance. Bradshaw Construction felt that this tolerance was necessary because the existing sewer had been installed by tunnel more than 50 years ago and the nearest manhole in which the alignment could be verified was more than 150 m (500 ft) away.

As shaft excavation progressed, the existing sewer was encountered near its plan location. However, it was determined to be a 2,750-mm (108-in.) liner plate horseshoe tunnel with a cast-in-place concrete tunnel liner instead of the 2,000-mm (78-in.) reinforced concrete carrier pipe (RCP) expected. Only minor alteration to the shaft supports were required to complete the excavation, but the support of the sewer itself did require redesign. The initial intention was to remove the existing tunnel supports from the sewer and hang the 2,000-mm (78-in.) RCP from the surface using steel beams and cables. The cast-in-place liner did not allow for this support system, as its weight was estimated at more than twice that of the RCP. In order to make use of the same support materials that had already been purchased and was onsite, the pipe support was revised by pouring a concrete cradle under half of the exposed span. This cradle reduced the unsupported tunnel span enough that the current support beams could handle the weight. Since the shaft supports were one-time use liner plates, the delays associated with the change did not result in additional support of excavation costs to the city.

Microtunneling

The 1,193-m (3,913-ft) of microtunneling on the project was accomplished in six drives ranging in distance from 107 m (351 ft) to 346 m (1,136 ft) and was completed by pipe jacking of 1,800 mm (72 in.) RCP with an ASCE Type B joint behind a Rasa DH-1,900 MTBM. One of the most challenging aspects of the project's tunneling was the use of the same machine for different soil conditions. The southern three-quarters of the tunneling occurred in glacial sands below the ground water table with the north one-quarter in glacial till, all of which had the potential for cobbles and boulders. The transition between the two major soil types even occurred in the middle of the tunnel drive between structures No. 9 and No. 10. The Rasa MTBM owned by Bradshaw Construction had to be modified to handle all of these conditions. In conjunction with the engineers at Rasa, a mixed-face cutter wheel, equipped with nine disc cutters, was determined to be the appropriate cutter head for the job. Its tooling could be arranged to excavate both the sand and till, while the cutters would be able to crush boulders as they presented themselves. Equipping the cutter wheel in this manner was more than required for excavation of most soils, but it significantly reduced the risk that the MTBM would be required for its rescue should it encounter a boulder it could not cut with a lesser cutter wheel. A BNRI microtunneling summary is included in Table 1.

The MTBM and cutter wheel proved effective throughout the project, with average 12-hour shift advances of approximately 6 m (20 ft) in the glacial till and 14 m (46 ft) in the sands. Additionally, the authors believe that is was effective in crushing boulders. Many boulders ranging up to 1.8-m- (6-ft-) long were encountered in the shaft excavation at the level the MTBM mined through, and all six tunnels were completed without rescue and without finding a boulder being pushed ahead of the MTBM upon recovery. Large spikes in cutter head torque were seen in all drives during the course of the mining operations, some that even rolled the machine 10°- to 15°. The authors assume that these occurrences were boulder caused, and assume that they were crushed as they did not cause a stop to the tunnels. With microtunneling, there is no physical way of viewing the actual soil at the cutting face dur-

FIG. 6

Typical project shaft.

FIG. 7

Shaft with typical launch/receiving portal.

Table 1

Belmont North Relief Interceptor microtunneling summary.

Drive number	Drive length (M)	MTBM launch/ recovery date	Shifts per day	Maximum pipe in-stalled per shift	Maxium jacking forces (tonnes)	Number of IJS	Alignment tolerance achieved (mm)
No. 1	176	11/05/09-11/18/09	1	8	390	1	±33 V / ±48 H
No. 2	107	12/03/09-12/09/09	1	10	360	0	±46 V / ± 41 H
No. 3	198	12/29/09-01/14/10	1	8	740	1	± 43 V / ± 50 H
No. 4	195	02/04/10-02/22/10	1	9	320	1	± 25 V / ± 56 H
No. 5	171	03/09/10-04/02/10	1	4	360	1	± 38 V / ±15 H
No. 6	346	09/14/10-09/29/10	2	9	625	3	± 43 V / ±53 H

ing excavation because it is a closed machine and the spoils are recovered by a slurry separation system. The mining anomalies of torque spikes and sudden MTBM roll are the only direct evidence of the boulder presence (Figs. 8 and 9).

The mining, despite consistent production, was not without its own issues. One of the first challenges occurred in the first tunnel drive from Structure No. 6 to Structure No. 7, where shortly after the launch, the pipe spigot directly behind the MTBM was found to have broken. In this case, a steering correction less than 15 m (50 ft) from the launch shaft probably caused the damage, but broken pipe spigots are not uncommon in pipe jacking of RCP with Type B bell-and-spigot joints. In order to meet rebar cover requirements, the rebar cage cannot be extended through the entire pipe spigot making it the weakest point on the pipe. A steering correction or boulders in the soil wedging against the pipe, among other things, can cause a point load which can cause such a break. In this case, as the jacking forces were transmitted in the pipe bell only, the structural integrity of the pipe was still intact allowing mining to continue. Working together with the pipe manufacturer, an internal steel brace was installed to prevent further damage and limit ground water infiltration. Upon recovery, the broken joint was cut off of the pipe at its connection to the cast-in-place structure wall. To limit the potential for further spigot breaks, Bradshaw Construction design and constructed an additional steel trailing section to follow the MTBM through the ground. It was made 3-m- (10-ft-) long and at the same diam¬eter as the MTBM, which is larger than the 2.4-m- (8-ft-) long RCP pipes with a slightly smaller diameter. The theory is that the larger trailing section will better distribute any point loads and the pipes themselves can pass through its path with less resistance. Of the approximately 500 pipe joints installed less than 1 percent required repair, of which most were hairline cracks that passed a joint test prior to repair. All repairs were performed and guaranteed by the pipe manufacturer.

Another issue occurred in the tunnel drive from Structure No. 8 to Structure No. 9. With 95 percent of the mining complete, the MTBM ceased being able to return excavated materials to the surface. Typically, this would indicate that the slurry circuit was blocked. Under that assumption, Bradshaw Construction Corp. proceeded to test all of the valves in circuit and inspect the lines for blockages, but could not find the problem. While testing the circuit, a sinkhole developed above the MTBM. This occurrence was especially perplexing in that it developed while no spoils had been excavated. What Bradshaw Construction found was that the blade of the valve used to bypass the slurry circuit behind the MTBM cutting face had sheared off. Externally, the valve looked like it was opening and closing normally

FIG. 8

Rasa DH-1900 MTBM.

and was indicating such to the MTBM operator in the surface control container. In reality the only thing rotating was the automated stem while slurry pressures left the bypass valve in a constant open position. The problem this posed was that when attempting to excavate material, the path of least resistance for the slurry was through the "closed" bypass valve and not through the cutting face, thus no excavation. We could only assume that the sinkhole developed through head vibration when the MTBM could not excavate and slurry pressure while trying to clear a non-existent blockage, consolidated the fines in the soil into the sands below causing the sinkhole. Luckily, all of this occurred once the MTBM had exited the lanes containing active traffic and beneath a concrete pavement layer nearly 300-mm- (12-in.-) thick. The nearly 30-m^3 (40-cu yd) void was filled using a low strength, cement-fly ash slurry material that, because it is self-leveling and highly flowable, was able to fill the void through a 300-mm- (12-in.-) diameter hole cored in the pavement.

As replacement parts for this type of machine are not typically off-the-shelf items, and this valve failure had never before occurred during Bradshaw Construction's microtunneling history, a direct part replacement was not an option. While a new valve was ordered and expedited for delivery, the tunnel drive still needed to be resumed faster than the part could be delivered. The farther out a pipe jacking tunnel has progressed, the higher the risk of the pipe freezing in place due to friction if it is not moved. And, in this case the MTBM was less than 7.5 m (25 ft) from the recovery shaft. The temporary fix was to install a standard 150-mm (6-in.) butterfly valve in place of the broken one. The challenge with this solution was that the valve stem did not match the machines automated system and had to be operated manually. The tunnel was completed with one operator driving the machine in the control container and another opening and closing the bypass valve by hand inside the MTBM. The replacement valve was installed prior to the MTBM's next launch (Fig. 10).

Active flow sewer tie-ins

Completion of the project required the tie-in of the relief sewer to the existing system at three locations: 2,000 mm (78 in.) at Structure No. 1, 1,400 mm (54 in.) at Structure No. 5 and 1,000 mm (42 in.) at Structure No. 11. While the 1,000 mm (42 in.) tie-in required the diversion of an existing sewer into the new interceptor and abandonment of its previous connection, the other two larger tie-ins were at junctions structures were the new and existing lines remained active. The connection points also occurred away from the existing manhole structures on straight sections of the existing pipelines. Bradshaw Construction Corp.'s initial assessment of the tie ins was to perform them with temporary flumes. A typical bypass pumping system was not seen as feasible in these locations because depth of the existing sewers,

FIG. 9

Cutter head tooling.

7.5 - 9 m (25 - 30 ft) below ground surface, would be at the extreme end of efficient suction pump capabili¬ties, meaning more pumps would be required to move the same amount of flow in a shallower pipe line. Secondarily, the access allowed by the contract staging areas did not provide the required room for pump setup upstream of the tie-in, easement for discharge piping, or a discharge location.

Once presented with the flume option reducing the 2,000 mm (78 in.) sewer at Structure No. 1 to a 1,500 mm (60 in.) flume and reducing the 1,400 mm (54 in.) at Structure No. 5 to 1,000 mm (42 in.), the city of Indianapolis's design engineer, Clark Dietz Engineers, verified that the diameter reduction would present a minimal increase to the system's hydraulic grade line in high flow conditions and approved using a flume.

The next hurdle was to design a flume system that would allow efficient, safe installation and removal while providing working access. This all had to occur within inside diameter of the existing sewer so the flow channels could be installed. The solution to this problem was presented by MacAllister Machinery and Plug-it Products. Their system was a hydraulically powered, telescoping flow-diverter equipped with inflatable

FIG. 10

MTBM breakthrough.

plugs on either end to match the existing pipelines, and flow-through openings to match the designed flume diameter.

Installation of the flumes was found to be less complicated than a bypass pumping setup. The walls of each structure were cast around the existing sewers while they were still active (Fig. 11). Once ready to install the flow channel, the existing pipe was saw-cut near the face of the walls and removed, leaving the interior of the structures to serve as a retention pool for the sewer flow until the flume could be installed (Fig. 12). At that point, the collapsed flume was lowered into the structure and extended so that the plugs on either end entered the existing sewer (Fig. 12). The plugs on either end were then inflated, returning all flow from the sewer into the flume. Lastly, the structure's interior was pumped out and the sewage washed away from the working area for construction of the flow channel and benchwalls (Fig. 13). After the channel was poured, removal simply consisted of deflating the plugs, collapsing the flume's hydraulic jacks and hoisting it out of the channel, activating the structure. The entire operation was confined to the shaft's staging area and structure's footprint as a working zone.

Schedule

Bradshaw Construction's preliminary construction schedule delivered within two days of the notice to proceed (NTP) elicited some discussion between the CM and contractor. While it accurately reflected the overall and specific execution constraints described, the main causes for concern were multiple critical paths and the proposal to complete Phase 4 followed by Phase 2 before the Indianapolis Mini Marathon on May 1, 2010. This was partly because the longest MTBM drive of 346 m (1,136 ft) was included in Phase 2. Consequently any delay to the scheduled completion of both of these phases would violate the contractual requirement that Phase 2 work could not be carried out during several iconic Indianapolis events, including the annual mini marathon, the Indianapolis 500 and the Brickyard 400 races.

Bradshaw Construction felt that this aggressive schedule was necessary to meet the project phase milestones. The period between the mini marathon and the Brickyard 400 (May 3 to July 26, 2010) was not enough time to complete the Phase 2 work, which included excavation of shaft, MTBM recovery, tie-in to the existing 2,000 mm (78 in.) interceptor and construction of Structure No. 1. Therefore the work would either have to be done before the 2010 Mini Marathon or after the 2010 Brickyard 400 race. Phase 3 schedule limitations at the staging area No. 9 at the furthest upstream end of the project could not be completed until after the downstream end of the sewer was activated. Performing the Phase 2 work after the shutdown period would have led to an incredible amount of work to be done in the last third of the contract duration while having virtually no critical path work completed during the preceding spring and summer.

During several rounds of reviews and discussions when the Primavera P3 cost loaded schedule was produced, Bradshaw Construction conceded that any delays would compromise timely completion of Phase 2 and assured the city and the CM that a contingency plan was put in place in the event that a late start on the drive from Sanitary Structure No. 3 to Sanitary Structure No. 1 would jeopardize completing Sanitary Structure No. 1 and therefore opening 10th St. before the mini marathon.

By the end of November 2009, it became clear that Phase 2 could not be completed before the mini marathon and a change in approach was needed. Bradshaw Construction submitted a revised construction schedule that postponed Phase 2 to the end of July 2010, after the Brickyard 400. Essentially, this involved microtunneling from Sanitary Structure No. 10 to Sanitary Structure No. 9 directly following the Phase 4 work that required the closure of White River Parkway West Dr. This would all be completed before the longest drive (Sanitary Structure No. 3 to Sanitary Structure No. 1) terminating at Miley Ave. and 10th St. Figure 3 illustrates the layout reflecting the drives and sanitary structures.

To increase the efficiency of this alternate schedule, Bradshaw Construction Corp. proposed to move Structure No. 11 south along the alignment. This change would allow the shaft to be installed and the tunnel from Structure No. 10 to No. 11 completed without closing the intersection of 19th St. and Lafayette Road which is what the Phase 3 work constraint detailed. As the upstream tie ins to Structure No. 11 had always occured outside the structure walls themselves, shortening the tunnel distance and lengthening the tie-ins presented a situation that would alleviate much of the post-Brickyard scope and allow the final tie-ins to be completed independently of the structure at the end of the project.

Disputes review board

Officials from the city of Indianapolis Department of Public Works were aware that they were embarking on a $1.3 billion CSO program that included approximately 40 km (25 miles) of tunnels as well as associated working and retrieval shafts, 30 drop shafts and several miles of large diameter consolidation and relief sewers to comply with their consent decree. Large tunnel contracts were new to the city, so managing these contracts had been foremost in the minds of the department, and strategies included appointing the Clean Stream Team as program managers and ensuring that consultants appointed for the underground design contracts were experienced in this field. Another strategy that was under consideration was the use of a dispute review board (DRB), particularly for underground construction elements of the program. While the Belmont North Relief Interceptor – Section 1 is a relatively small part of the overall program, it provided an ideal opportunity for the department to evaluate the benefits of a DRB without the added pressure of managing the main tunnel contracts, scheduled to be the largest construction contract in the history of the city, all at the same time.

The DRB was set up contractually with a conventional DRB three-party agreement, with the city and Bradshaw Construction each nominating a DRB member with the concurrence of the other party and these two members selected the DRB chairman. The DRB members were, respectively, Ed Cording, Don Hill and Dan Meyer, and the first DRB meeting was held on site five months after the notice to proceed was issued to Bradshaw Construction.

This meeting was clearly an information gathering exercise for all involved. As is usual, the DRB chairman posted a detailed agenda so that the DRB members could be swiftly and efficiently brought up to speed and to supplement the contract documents and documentation they had already received such as pre¬construction and progress meeting notes. Many city staff representatives were eager to learn about DRBs, and their numbers from the Department of Public Works and the Clean Stream Team surprised the DRB Members. Of course Bradshaw Construction Corp., Christopher B. Burke Engineering, Ltd., Clark Dietz Engineers, and Black & Veatch Corp. were also in attendance.

The main outcome of the meeting, in addition to routinely setting up a schedule for quarterly DRB meetings and site visits as well as outlining the procedures should a dispute arise were as follows:

- The informal nature of the regular meetings was emphasized; notes were not to be kept of these meetings.
- Dan Meyer made it clear that any DRB procedures required the agreement of both parties to the contract.
- The DRB strongly suggested that an agreed, contractual schedule be finalized as soon as possible to replace the working schedule that was being used to monitor the work.
- All DRB recommendations to try and resolve a dispute would be based strictly on the contract terms and conditions. In other words, the DRB were not going to try and broker an extra-contractual deal.

Notwithstanding the success of the initial DRB

FIG. 11

Structure walls cast around.

FIG. 12

Removal of existing sewer.

FIG. 13

Flowline and benchwall construction.

meeting, a certain amount of reluctance to accept the benefits of a DRB was still noticeable. This was not confined to Bradshaw Construction. The city, Clean Stream and Christopher B. Burke Engineering staff all jokingly discussed with Bradshaw Construction how removing the DRB would result in an immediate cost reduction of $50,000 (the allowance item for the DRB) on the project.

What must be recorded is that the DRB recommendation to finalize the contractual construction schedule did provide the impetus needed to get that task done. As time passed and the regular quarterly meetings and site inspections became routine, the benefits of having the DRB review notes of progress meetings and ask detailed questions about proposed changes to the construction schedule for Sanitary Structure No. 11, which ensured thoughtful implementation became evident to all concerned. It is pleasing to report that at the last DRB meeting, when there were still no unresolved disputes or expectations of any, the city representative and Bradshaw Construction site staff noted that they were pleased that the DRB was in place and that simply having a DRB on the project had caused them to be extra vigilant in correctly handling the contractual issues that did arise on the project. Indeed, at the "Better Specifications for Underground Projects Workshop" held at the North American Tunneling Conference, June 20, 2010, Les Bradshaw (A principle of Bradshaw Construction Corp.) was quoted as saying "In the meantime, I strongly recommend the use of disputes review boards (DRB)s for mechanized tunneling projects as small as $5 million. A DRB cost of $50,000 to $100,000 is insignificant when you realize that daily crew cost for even a small 1,500-mm- (60-in) diameter microtunnel is rapidly approaching $20,000 per 10-hour shift. Minimizing just a few days of delay alone can easily pay for a DRB's time."

Certainly, based on the Belmont North Relief Interceptor–Section 1 experience, all of the role players on this project would endorse the recommendation made by Bradshaw.

Conclusion

The BNRI project is acknowledged by all concerned parties to be a successful project. True to form with underground structures, it was not without challenges. Even with the benefit of hindsight, preventing settlement above the MTBM near Structure No. 9 would be nearly impossible to prevent. The paper also outlined issues faced and overcome with steering forces causing Type B bell-and-spigot joint failures, difficult staging constraints that required rescheduling to overcome, revising Structure No.11 to minimize the contract duration and ingenuity required to use previously planned steel support for the 2,750 mm (108 in.) horseshoe tunnel instead of a 2,000 mm (78 in.) RCP existing sewer within structure No. 1.

Dealing with all of these issues required a dedicated, suitably experienced and professional team that included the city, contractor, design engineer and third-party construction inspector to work together. Perhaps the most important aspect was continuing dialogue, which is not to say that there were no differences of opinion.

In addition, Bradshaw brought technically superior solutions to the project. This started with carefully considered bidding strategies and continued with the liner plate and steel rib initial support for shaft excavations, aggressively pursuing schedule goals and rapid responses to the unexpected. Perhaps the most impressive aspect was their use of hydraulically powered, telescoping flow-diverters equipped with inflatable plugs on either end instead of expensive bypass pumping where active flow sewer tie-ins were required.

We should record that the use of a DRB on a relatively small project has proven to be successful and is endorsed for future use on underground projects. (References are available from the authors.) ■

Acknowledgments

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FEATURE ARTICLE

Small tunnel, big solution: The Pearl River CSO storage and conveyance tunnel project

Gui DeReamer, Philip Kassouf, Brad Talley and Dan Dobbles

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Located on the Wabash River in the central portion of the state, the city of Lafayette, IN is relatively small compared to most cities that incorporate tunnels into their combined sewer overflow (CSO) systems. The original CSO plan for the city was to replace two aging lift stations that were built in the 1950s. The original concept was to build a new sewer using conventional cut-and-cover construction to eliminate one of the lift stations — the Parking Lot Lift Station — and build a new regionalized one at the location of the Pearl River Lift Station. The initial sewer design was sized just to handle the flow that would eliminate the Parking Lot Lift Station. The planning for this project was being developed as part of the city's CSO long-term control plan (LTCP) that focused on reducing the overflows from the city's 14 overflow points. However, during the development of the CSO LTCP, a major industrial user indicated it would be increasing its flows to the system, which required additional conveyance capacity to meet the city's CSO LTCP.

FIG. 1

Downtown Second St. in Lafayette, IN.

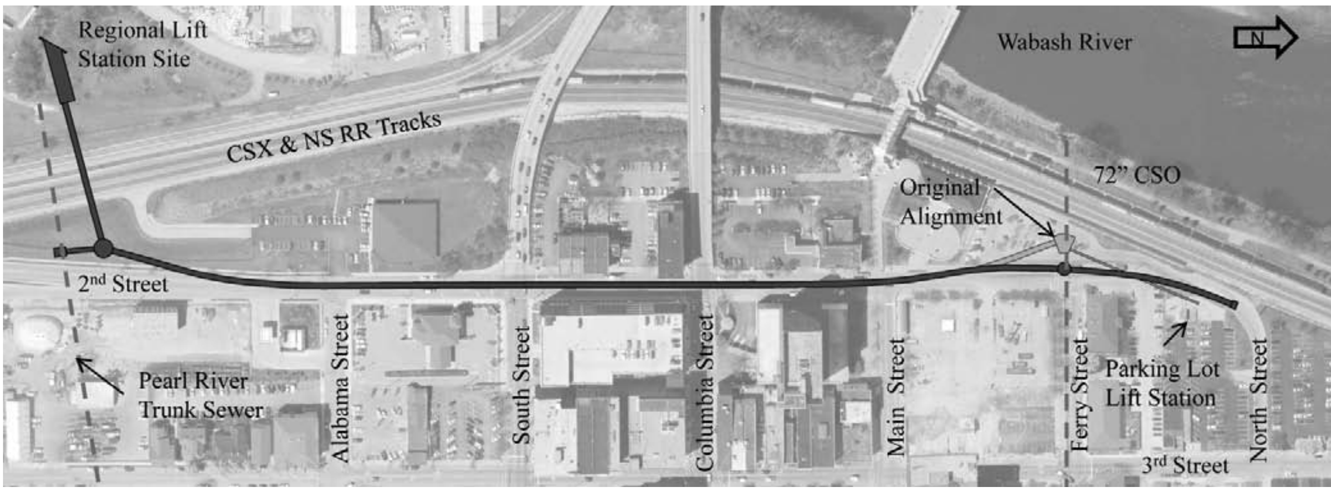
After reviewing the design concepts with city representatives during the planning phase of the project, the mayor indicated that he wanted to minimize impacts to downtown businesses; therefore, trenchless alternatives were considered. The last piece of the puzzle that drove the project away from a small diameter pipeline was discovered during a flow monitoring program to collect flow data for the CSO LTCP project. This study revealed a major restriction in the 100-year-old Pearl River Trunk Sewer, located beneath four active railroad tracks. To eliminate this flow restriction, provide more overflow storage and reduce the impact to local businesses, a new 2.7- to 3.6-m- (9- to 12-ft-) diameter tunnel sewer became the most viable solution.

Tunnel designs that combined the conveyance sewer to eliminate the Parking Lot Lift Station and storage volume to eliminate the need for a larger storage facility planned in the CSO LTCP were evaluated. The alternatives evaluated had to address the following major challenges to build the proposed storage and conveyance tunnel:

- Four main line railroad tracks.
- Major thoroughfare across the Wabash River (state highway).
- Need to divert flows from three sources (Parking Lot Lift Station, 1,829-mm [72-in.] CSO along Ferry St, and the Pearl River Trunk Sewer) to the tunnel.
- Varying soil types along alignment.
- A high ground water table and an alignment close to the Wabash River.
- Historical buildings along alignment.
- Conveyance and pumping needs that resulted in shallow depth of cover.
- Buried old canal in alignment (unknown

FIG. 2

Tunnel alignment.



if it would be an obstacle).

- Existing sewers (utilities) near alignment.
- Curves, which were required to meet alignment needs.

Some of these challenges are illustrated in Fig. 1, which shows the tunnel alignment along downtown Second St. The final alternative selected by the city eliminated the Parking Lot Lift Station by building a 3-m (10-ft) minimum diameter tunnel that was approximately 610 m (2,000 ft) long under downtown Second St., shown in Fig. 2. This alternative also allowed the city to completely eliminate a 1,829-mm- (72-in.-) diameter CSO at the upstream end of the tunnel alignment and make a significant reduction in combined sewage flowing to the Wabash River.

Design considerations

Ground conditions. The city of Lafayette is located in Tippecanoe County, on the southeast side of the Wabash River, within the Tipton Till Plain physiographic province. This till plain comprises the central portion of Indiana, and includes relatively flat to rolling topography, except where rivers have incised the surface. The thickness of the glacial soils beneath the till plain is generally less than 61 m (200 ft) except in a few locations of buried bedrock valleys, where the thickness of the glacial soils is greater than 91 m (300 ft). Based on desktop studies conducted early in the planning phase of the project, the till plain in the general site vicinity was expected to consist primarily of a lodgment glacial till (i.e., material deposited beneath a glacier) composed of sand, silt and clay that locally contains small- to medium-sized boulders and is interbedded with glaciofluvial deposits (glaciofluvial deposits are the product of glacial stream/river deposition during periods of glacial retreat) of sand and gravel. The glaciofluvial deposits were anticipated to range from small, discontinuous pods, to continuous layers up to at least 61 m (200 ft) thick. These deposits are the chief ground water aquifers in the Tippecanoe County. Topographical low areas within the Wabash River Valley were anticipated to be overlain by postglacial alluvial deposits, which could include inorganic silt, sand and gravel, reflecting channel and overbank deposition, as well as organic silt and peat produced in adjacent wetlands.

A detailed geotechnical field investigation program was undertaken to provide information necessary for design and construction of the project. The field work was undertaken in two phases, an initial phase during preliminary engineering and design and a final phase during final design. In total, 20 test borings were taken along the tunnel alignment, typically to depths of approximately 3 to 9 m (10 to 30 ft) below tunnel invert. The majority of the borings were conventional hollow stem auger borings with standard split spoon sampling; however, four rotosonic borings were conducted to provide continuous sampling of the glacial till soils. A total of three ground water observation wells were installed in completed test borings to assist in determining ground water conditions along the tunnel alignment.

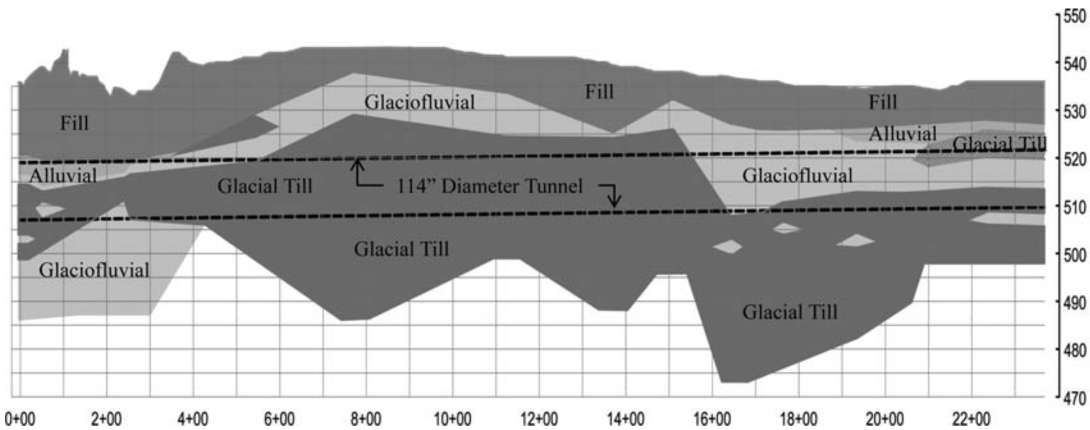
The geotechnical field investigation program revealed the following general soil units in the project area:

Fill. Encountered along the entire tunnel alignment, the fill consisted of a heterogeneous mix of both granular and cohesive materials. The fill also contained trace amounts of miscellaneous debris, including brick, coal, concrete, cinders, wood and slag.

Alluvial deposits. Encountered at both the northern and southern ends of the proposed tunnel alignment, these postglacial materials were recently deposited on or adjacent to the Wabash River floodplain and within its tributary channels, which included the Pearl River at the south end of the alignment and the former Wabash and Erie Canal at the north end of the alignment. The alluvial deposits were variable in nature, and included both cohesive and granular soils, which were anticipated to occur in alternating layers. Materials encountered included very soft to medium stiff silt, organic soils, clay, and sandy clay with occasional organic particles and shells and loose to medium dense, silty sand with clay and gravel.

FIG. 3

Geotechnical profile.



Glaciofluvial deposits. Encountered below glacial till at the south end of the alignment, above the glacial till at the north end of the alignment and as discontinuous layers, lenses and pods within the glacial till, these deposits generally consisted of medium dense to very dense, well-graded sand with and without gravel, poorly graded sand with and without gravel, silty sand and silty gravel. Although not specifically mentioned on the exploration logs, the glaciofluvial deposits were expected to contain cobbles and boulders.

Glacial till. Encountered along the entire tunnel alignment, the glacial gill generally consisted of sandy and clayey silt with gravel, sandy and silty clay with gravel and sandy silt. Although not indicated on the exploration logs, cobbles and boulders have been encountered in the glacial gill deposits in local excavations and typically consist of medium hard to hard, sedimentary, igneous and metamorphic rock types, including granite.

These soil units were generally as anticipated based on the desktop studies conducted prior to the field investigations. The anticipated distribution of the various soils units along the tunnel alignment is indicated on Fig. 3.

Ground water was determined to be approximately 3 to 4.6 m (10 to 15 ft) below ground surface, which corresponds to 0.6 to 1.5 m (2 to 5 ft) above tunnel crown.

As illustrated in Fig. 3, the predominant soil unit along the tunnel alignment is glacial till. The glacial till was expected to exhibit slow raveling to firm behavior, except in areas with higher sand or silt content, where it was anticipated to exhibit fast raveling behavior. The glacial till was also expected to be relatively impervious. The glacial till is hard in consistency, as indicated by the high SPT N-values and relatively high undrained shear strength. Cobbles and boulders were anticipated in the glacial till, and it was anticipated that the matrix of material encountered would have sufficient strength to allow cobbles and boulders to be fragmented by rolling type cutting tools (i.e., "disk" or "strawberry" cutters) on the cutterhead of the tunnel boring machine (TBM).

The next most common soil unit to be encountered along the tunnel alignment was the glaciofluvial deposits. Owing to their generally medium dense to dense granular nature, the glaciofluvial deposits were anticipated to exhibit slow to fast raveling behavior above the ground water table and fast raveling to flowing behavior below the ground water table, depending on the hydraulic gradient and in situ density. The glaciofluvial deposits were expected to be highly pervious. As with the glacial till, cobbles and boulders were anticipated to be present in the glaciofluvial deposits, and it was anticipated that the matrix of material encountered would have sufficient density to allow cobbles and boulders to be fragmented by rolling type cutting tools.

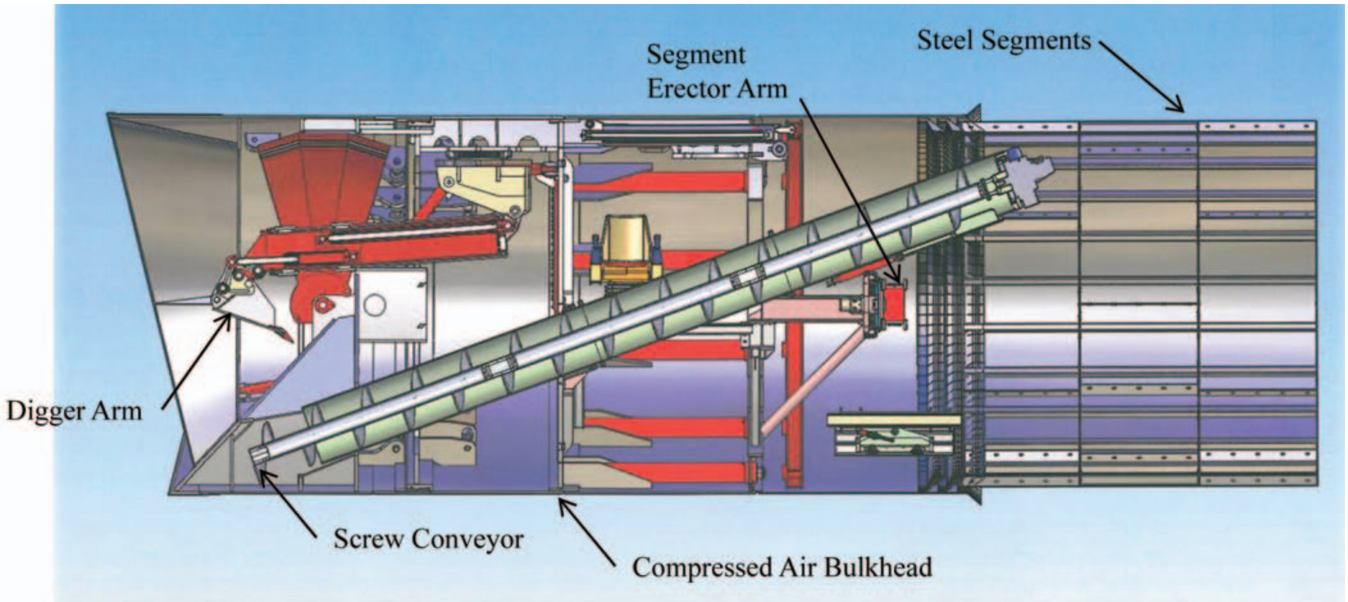
The remaining soil units, fill and alluvial deposits, were grouped together for purposes of discussion of ground behavior. These soil units were anticipated to be highly variable in nature, ranging from soft to stiff cohesive soils to loose to dense granular soils. As such, it is difficult to predict their behavior and so a conservative approach was taken whereby it was assumed that the fill and alluvial deposits would exhibit fast raveling to running behavior above the ground water table and fast raveling to flowing behavior below the ground water table. Unlike the glacial till and glaciofluvial deposits, the alluvial deposits and the fill were not anticipated to have sufficient strength to allow cobbles and boulders to be fragmented by rolling type cutting tools.

Overview of the design process

Prior to getting into design details, a somewhat unique aspect of the design process relative to reducing risks and opening up the project to a larger pool of interested contractors would be discussed. Initially, an aggressive

FIG. 4

Compressed air tunnel digger shield.



design was developed that, at the time, was intended to keep construction costs down. The project was put out to bid, and the bid results were not as expected. Despite what seemed to be reasonable interest in the project by tunnel contractors, only one bid was received with a bid price well over the engineer's estimate. The bid was rejected. At that point, the project team, led by Greeley and Hansen, took a step back and interviewed contractors that had received bidding documents as to why they did not bid the project. The responses from the contractors can be summarized as follows: the market at the time of bidding was very "hot," and the perceived risks on the project were relatively high compared to other projects being bid at the time. To put it another way, the scope and size of the project was in a gray area between being too small and not worth the risk for large, national tunneling contractors and too large with too high a risk for smaller, regional tunneling contractors.

To resolve these issues, the design team went back and modified the design to make it more amenable for a larger pool of contractors. Steps taken to modify the design were again based on discussions with the contracting community. From a broad perspective, these steps included providing for options for alternative, less aggressive (i.e., less risk) design elements; options for alternative tunnel excavation methods; and allowing a range in tunnel diameters. The design modifications were successful, as demonstrated by the fact that five bids were received and the low bid was very close to the engineer's estimate. Moreover, all bids were within 30 percent of each other.

A detailed discussion of major design issues and modifications to the initial design is provided in the following sections.

Horizontal alignment

The horizontal alignment of the tunnel was constrained by several factors. Probably the most significant of these constraints was the location of the upstream and downstream ends of the tunnel. The downstream end of the tunnel had to be located as close as possible to the new regional lift station (Fig. 2), since the lift station would be used to lift dry weather flow for gravity conveyance to the treatment plant as well as to dewater the tunnel after storm events. The upstream end of the tunnel had to be located as close as possible to the Parking Lot Lift Station since the tunnel would be receiving dry weather flow after this lift station is abandoned. In addition to these constraints, it was also considered highly desirable to minimize the length of the required connections between the tunnel and the diversion structures located on the CSO's on Ferry St. and the Pearl River Trunk Sewer. The final constraint was that the tunnel had to be located on city-controlled property wherever possible to avoid the need for taking private land.

The initial design for the horizontal alignment included a tight curve at the downstream end of the tunnel, under the railroad tracks, to allow for the tunnel to be constructed in a single 610-m- (2,000-ft-) long drive. At the time, it was believed that this layout would result in lower construction costs. However, the results of interviews with prospective contractors after rejecting the initial bid indicated that the perceived risks with tunneling on a curve under the railroad tracks in the beginning of the tunnel drive were quite high for some contractors. In response to these perceived risks, an alternative layout was developed that included a "dog-legged" alignment that allowed the

FIG. 5

Horizontal "S" curve with 3.75-m- (12.25-ft-) diameter steel segment liner and 3-m- (10-ft-) diameter final concrete liner.

tunnel to be constructed in two drives, a 533-m- (1,750-ft-) long drive along Second St. and a 76-m- (250-ft-) long drive under the railroad tracks. Contractors were allowed to bid on either the single or multiple drive alternatives when the project was bid for the second time. The low bidder, a joint venture of Triad Engineering Contracting Inc. and Frontier Kemper (TFKJV), selected the multiple drive alternate (Fig. 2).

Vertical alignment

The vertical alignment of the tunnel was controlled by the criteria to minimize long-term pumping costs, both in terms of dry weather flow and dewatering after storm events, a maximum slope of 0.1 percent, and to allow for future upstream extensions of the tunnel system beyond the downtown area. These criteria led to a fairly shallow tunnel with cover over the crown ranging from 6 to 9 m (20 to 30 ft). Early in the design process, an alternate lower vertical alignment was evaluated to provide for increased cover, but it was concluded that the long-term operating cost of the downstream lift station and the increase risks associated with mining a tunnel in lower glaciofluvial deposits outweighed the benefits of increased cover.

Tunnel excavation

Two general approaches for tunnel excavation were evaluated for the project: nonpressure-balanced TBMs, including conventional digger shields and an open face TBM with wheeled excavators; and pressure-balanced TBMs, including earth pressure balance and slurry pressure balance TBMs. Based on these evaluations, it was concluded that nonpressure-balanced TBMs would be too risky, given the potential for flowing behavior of the glaciofluvial sand layers in glacial till and low cover in potentially flowing glaciofluvial sand at the upstream end of alignment. It was also concluded that the ground was amenable to earth-pressure-balanced TBMs.

When the project was initially bid, an earth pressure balance TBM was required. However, the results of interviews with prospective contractors after rejecting the initial bid indicated that at least two prospective contractors had the qualifications and equipment to construct the tunnel under compressed air, therefore, a compressed air tunnel excavation alternative was added when the project was bid for the second time. The low bidder (TFKJV) opted to construct the tunnel using a unique compressed air shield as described hereinafter.

Tunnel lining

Multiple tunnel lining systems were evaluated during design with three systems being determined to be technically feasible:

- A two-pass system with initial support consisting of steel liner plate and final lining consisting of rein forced concrete pipe (RCP), pipe grouted in place.
- A two-pass system with initial support consisting of steel liner plate and final lining consisting of cast-in-place concrete.
- A one-pass system consisting of bolted, gasketed, precast concrete segments.

Cost evaluations conducted during design indicated that there was no clear economic advantage for any one of these technically feasible alternatives. Accordingly, it was decided to include all three lining system alternatives in the bidding documents to allow for increased competition. To further increase competition when the project was

FIG. 6

The 1,829-mm (72-in.) inverted siphon is lowered into a 7.3-m- (24-ft-) diameter shaft.

bid for the second time, it was decided to allow a range in final tunnel diameter of 2.7 to 3.7 m (9 to 12 ft). The low bidder (TFKJV) selected a two-pass system with initial support consisting of unique fabricated steel segments and a final lining consisting of cast-in-place concrete, 3 m (10 ft) in diameter.

Impacts to adjacent structures

Estimates of settlement were made based on empirical methods originally presented by Peck (1969) and updated by various authors since that time. The estimates assumed a maximum of 1 percent ground loss due to tunneling, a settlement trough approximating a normal statistical distribution curve, and the volume of the settlement trough equal to the ground loss due to tunnel construction. The results of these settlement analyses yielded an estimated settlement along the centerline of the tunnel along Second St. on the order of 12.7 to 25.4 mm (0.5 to 1 in.), with an associated settlement trough width of about 15 to 18 m (50 to 60 ft). The existing above-grade structures along the Second St. tunnel alignment lie outside the estimated settlement trough and, as such, were not anticipated to be impacted by tunneling activities, provided that ground loss ws kept at or below 1 percent.

Value engineering

Immediately following the issuance of the notice to proceed, the city and the design consultants indicated a willingness to discuss value engineering ideas that could enhance the value, operation and storage capacity of the tunnel for the city. TFKJV presented a value engineering concept that was further enhanced through collaboration with the city and design consultants, which included a final proposal to extend the tunnel 122 m (400 ft) further north than the designed termination point.

The benefit to the city would be elimination of a proposed 1,067-mm- (42-in.-) diameter connector sewer and provision of a longer tunnel for more CSO storage. The proposal required relocation of existing utilities and the tunnel alignment to change from a simple horizontal curve to a more complicated "S" curve. TFKJV also desired to change the multisided concrete junction chambers to a circular geometry, which would be more compatible with the circular mining shafts preferred by the contractor. The benefits to the city greatly outweighed the cost of the utility relocations, which entailed the removal of an existing 1,829-mm (72-in.) CSO outlet, abandonment of a 457-mm (18-in.) sanitary sewer and relocation of a 508-mm (20-in.) water main.

Value engineering allowed the city of Lafayette to reduce the overall cost of the originally proposed tunnel project by allowing the contractor and consultants to collectively discuss ideas that ultimately changed the original project design. The value engineering process facilitated keeping the communication channels open between the owner, designers, inspectors and the contractor and proved to be a valuable cost savings tool for the owner.

Construction issues

Selection of tunnel excavation and lining methods. When bidding, tunnel contractors always try to match available TBMs to the owner's limitations on means and methods and desired final lining. The team that can find the optimum pairing often will be the lowest bidder. In an effort to increase competition among bidders for the project, the owner allowed contractors to choose from several alternative tunnel layouts, excavation and lining methods, and tunnel diameters for the bid submission. TFKJV investigated various options before making a decision.

The two-drive alignment was chosen over the single curved drive to keep the tunnel isolated from the Wabash River and to address the potential for seasonal flooding. The two-drive alignment was also more desirable because the TBM would not be starting in its initial project launch in a horizontal curve in the most difficult area of the tunnel, which was under the railroad.

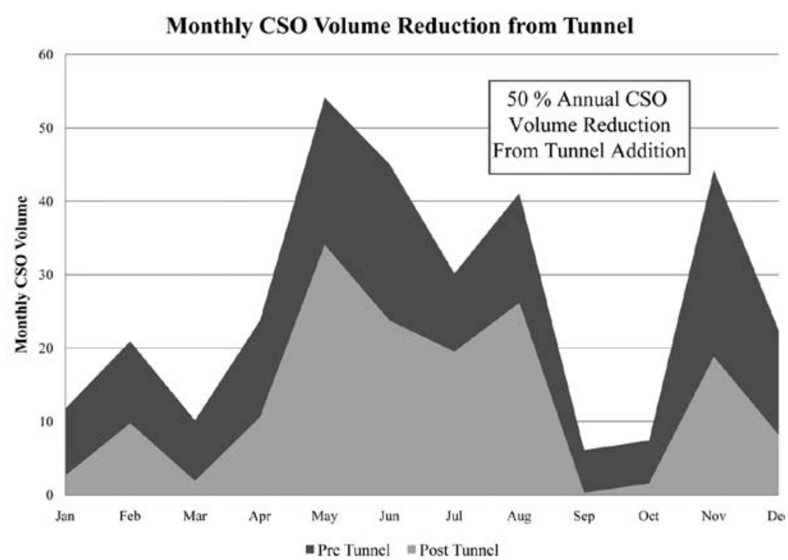
Furthermore, the initial investigation concluded that the costs associated with the precast molds and segments would not be competitive because of the relatively short length of proposed tunnel, thus eliminating the one-pass tunnel lining option. The specifications dictated that the two-pass option be steel liner plates with gaskets designed by the contractor. TFKJV believed that use of the two-pass method could be competitive if the initial liner was the same length as the TBM's cylinder push length. With those requirements in mind, TFKJV sought out an initial steel liner that could closely resemble the push length of the TBM. TFKJV collaborated with Technicore Underground Solutions, which provided the tunnel digger shield (TDS) (Fig. 4) and ultimately manufactured the steel segment plates to form a complete package. Standard liner plates are either 406 or 610 mm (16 or 24 in.) in width and approximately 0.9 m (3 ft) in length. In order to decrease the amount of time the crew spent bolting the segment plates together, TFKJV sought out a steel liner segment that would be 1.2 m (4 ft) in width. Although steel liners have been in the tunnel industry for a long time, the steel segment plates made for the Pearl River CSO Tunnel project were unique. Each steel segment plate was reinforced with 76 × 102 mm (3 in. × 4 in.) square tubing to channel the 1.5 million lbs. of thrust generated by the push cylinders, along with 101 mm (4 in.) radial flanges that surrounded each plate's perimeter. The 3.2-mm- (0.125-in.-) thick steel skin bound all those elements together to form a very stiff steel segment plate able to resist loading from the existing soil and the thrust of the push cylinders. Each segment plate weighed 208 kg (450 lb), which is considerably heavier than a conventional steel liner plate. Five full-sized steel segment plates, as previously described, and two smaller steel segment plates made a complete ring, which was assembled inside the tail can. The weight of the steel segment plates necessitated placement by an erector arm similar to a precast segment installation.

The rectangular tube stiffeners were spaced at 15° intervals, which allowed the erector arm to mechanically fasten on for hoisting.

The five full-sized plates were installed first, followed by the two smaller steel closure plates, which wedged together to complete a full circle. Figure 5 shows the assembled rings and the final concrete liner. Once the circle or ring was completely bolted together, the TDS would thrust forward to begin another cycle.

FIG. 7

CSO overflow reduction from tunnel.



Operation of the compressed air tunnel digger shield

The various layers of glacial soils overlain by softer alluvial and fill deposits mixed in with boulders and a variable water table guided TFKJV's team to choose a tunnel digger shield (TDS) manufactured by Technicore. Tunneling through the previously described soil matrix proved to be quite a challenge. The TDS had to be designed to retrieve boulders, maintain a positive face pressure and prevent over-excavation of the softer soils during mixed face mining. In order to achieve this, the TDS head consisted of two critical components, a mechanical digging bucket and a compressed air bulkhead.

The open face of the TDS allowed the operator to remove the mixed face material in a uniform manner because the digging bucket could be directed to a specific area at the tunnel face. Therefore, more attention could be devoted to the removal of the hard glacial till than the softer gravel/sand layers, which greatly reduced the chance for the softer soils to flow or slough into the TDS. Another important advantage of the TDS was its ability to remove large boulders, up to 1,016 mm (40 in.) long, without having crew members exposed to the tunnel face. The TDS operator could manipulate the digger bucket to pry the boulder from the face and place it in a safe area inside the TDS head. The boulder could then be broken up into smaller pieces through the use of jackhammers during the maintenance shift.

The digging compartment and exposed tunnel face were isolated from the rest of the tunnel crew through the use of a steel bulkhead to maintain positive air pressure at the tunnel face. The purpose of the compressed air is to drain the soil matrix in front of, and above, the face of the progressing tunnel machine to provide soil stability. The low air pressure effectively drives water from the soil, stabilizing it long enough for the TDS operator to excavate and install the initial steel liner. When sizing the compressed air system, two critical elements had to be considered, pressure and volume. The required pressure necessary to dry the tunnel face might appear as a relatively straightforward computation; however, the designer must balance the required air pressure neces¬sary to force the free pore water out of the soil without causing the air pressure to leak explosively to the surface. When a leak expands to a blow, the face can quickly become unstable, because of the loss of air pressure, and collapse. The depth from ground surface to invert of tunnel (H) averaged approximately 9 m (30 ft). Since it is desirable to form an air bubble in front of the tunnel machine and not blow air to the surface, the value H was reduced by 3 to 4.6 m (10 to 15 ft) when computing the required pressure. Given the unit weight of water (w) as 999.6 kg/m^3 (62.4 lb/cu ft), the maximum pressure required to drive the water up and away from the tunnel face would be $p = w \times H - 15$, or 0.45

bar (6.5 psi). This will provide a close approximation to the required pressure, but will have to be adjusted for the type of soil encountered in the field. For the Pearl River CSO Tunnel project, maintaining approximately 0.34 bar (5 psi) at the tunnel face proved optimum for the sandy/gravel soil matrix.

Maintaining the necessary pressure was paramount, but equally important was being able to maintain a sufficient volume of air to the face. The general rule of thumb is 20 cfm per square foot of tunnel face. In other words, a large volume, low-pressure blower is required to maintain a stable tunnel face. The minimum cfm calculated was 2,520, but after considering efficiencies and losses, TFKJV chose a Gardner Denver 9CDL18 as the primary blower and a Gardner Denver 11CDL23 as a backup blower. Each one of the blowers was capable of 3,000 cfm at 0.83 bar (12 psi). Transfer of the compressed air from the surface to the heading was done through 203-mm-diameter (8-in.) high-density polyethylene (HDPE). As the tunnel progressed, the crew would add lengths of 203 mm (8 in.) HDPE to the blower line, in a similar manner used by other utilities, as necessary to maintain the tunnel operation. Unfortunately, this method proved detrimental when the crew had difficulty adding to the blower line in a reasonable amount of time, causing the head to depressurize over a two-hour time period. This resulted in the sand/gravel soil matrix in the upper half of the tunnel face to become saturated and start to flow. To prevent this from happening in the future, a redundant line was installed that ensured the tunnel face would always be pressurized.

Challenges at the Ferry St. junction chamber

To facilitate the relocation of the 1,829-mm- (72-in.-) diameter CSO at Ferry St., the proposed junction chamber was shifted and centered over the existing 1,829-mm (72-in.-) diameter CSO sewer outfall and proposed tunnel. The first phase of construction was to install a 7.3-m- (24-ft-) diameter liner plate and rib shaft 0.9 m (3 ft) below the invert of the existing 1,829-mm (72-in.) CSO sewer in order for the crew to remove a section of the existing sewer and install a fabricated steel inverted siphon (Fig. 6). Vertical and horizontal placement of the inverted siphon was critical because the TDS would be at the end of the 91-m- (300-ft-) long reverse curve and the 1,829-mm (72-in.) sewer relocation would provide only 152 mm (6 in.) of clearance between the sides and top of the tunnel.

The 7.3-m- (24-ft-) diameter shaft was then backfilled with control density fill to provide a medium in which the TDS excavated through without losing alignment control.

Relocation of the 457-mm (18-in.) sanitary sewer was facilitated by the close proximity to an existing 457-mm (18-in.) force main. The force main was tapped and an existing CSO junction chamber was modified to accept 152-mm (6-in.) grinder pumps. When the downstream end of the junction chamber was bulkheaded, the chamber became a mini wet well. The sewage was then pumped out of the mini wet well to the existing 457-mm (18-in.) force main, eliminating the need for the remaining portion of gravity sewer. As the TDS advanced and encountered the existing sanitary sewer, it quickly became apparent that the size of the sewer was not 457 mm (18 in.). The original sewer was 0.9 m (3 ft) in diameter and had been slip lined with 457 mm (18-in.) reinforced concrete pipe (RCP). The large void left after its removal destabilized the face, requiring the crew to suspend tunneling until a solution could be determined. It was soon agreed by the city of Lafayette and TFKJV that the existing sewer should be removed by conventional opencut methods and the void filled with control density fill.

The proposed tunnel passed successfully underneath the relocated 1,829-mm (72-in.) CSO sewer and through the existing 457-mm (18-in.) sewer, providing the city of Lafayette with more CSO storage than originally designed. The benefit of increasing the storage capacity greatly outweighed the cost of dealing with existing utility relocations, mainly because of innovative thinking by the contractor and city representatives.

Conclusion

The planning, designing and construction of a tunnel can be intimidating to owners who have never had a tunnel built in their community. The ability to have the owner, designers, inspectors and contractors keep an open line of communication has proven to be a benefit to all parties. Educating the city of Lafayette during the design process and keeping an open mind to value engineering greatly contributed to the project's success. Through the effort of the entire team, the Pearl River CSO Tunnel Project achieved the projected environmental goals and remained a positive project in the eyes of the city officials and the citizens of Lafayette. As illustrated in Fig. 7, the CSOs directly affected by the tunnel project have seen a 50-percent reduction over a typical one-year period. Since the tunnel was placed in operation, it is estimated that approximately 83 million L (220 million gal) of raw sewage have been prevented from being discharged into the Wabash River. (References are available from the authors.) ■

Acknowledgments

The authors gratefully acknowledge the contributions of the following individuals, groups and firms for the successful completion of the Pearl River CSO Storage and Conveyance Tunnel Project: Tony Roswarski, Mayor of the City of Lafayette; Jennifer Miller, Public Works Director for the City of Lafayette; the Board of Public Works for the City of Lafayette; Cliff Kassouf, Managing Partner for TFKJV, Haley & Aldrich, Inc., which provided tunnel engineering services for the project: ATC, Inc., which provided geotechnical site investigation services for the project; Fink, Roberts and Petrie, which provided structural engineering services for the project; and Christopher B. Burke Engineering, Ltd., which provided resident inspection services during construction.

FEATURE ARTICLE

2011 permeation test results for grouts made with ultrafine cement

The 32nd annual short course "Grouting Fundamentals and Current Practice" was held at the Colorado School of Mines, June 13-17, 2011. The field demonstration portion of the course was conducted June 16 at Baski Inc.'s yard in Denver, CO.

The full-scale field demonstration presents many types of drilling and grouting equipment in operation as well as numerous grouting methods performed under various field conditions.

As part of the field demonstration, the class was shown the proportioning, mixing, testing and injection of various cement grout mixes into sand columns under controlled and recorded conditions. These sand column demonstrations have been conducted under controlled and measured conditions each year since 1999 as part of the short course. The sand column demonstrations were conducted prior to 1999, but with less quality control and minimal record keeping of the proportioning, mixing, testing, injection pressures and the final permeation results.

FIG. 1

Atlas Copco grout plant.

The goal of the sand column demonstration is to show the students the effect of the water:cement ratio and the use of admixtures as well as the fineness of the cement (portland versus ultrafine) used have on the engineering properties of the grout and the grout's vertical permeation height through the sand.

Test results for the demonstrations conducted in 1999 and for two separate demonstrations conducted in 2000, one at the grout course and one at Geo Denver, were published in the 2001 Proceedings of the Rapid Excavation and Tunneling Conference (RETC) (Henn et al., 2001). The test results for the 2002 and the 2003 demonstrations were published in the 2005 Proceedings of the RETC (Henn et al., 2005).

Test results for the demonstration conducted in 2009 and 2010 were published in the December 2009 and December 2010 issues of *Tunneling & Underground Construction* (*T&UC*) magazine (Henn et al., 2009 and Henn et al., 2010).

Past demonstrations

The demonstrations over the years have included cement grouts made with various brands of Type I-II portland cements and various brands of ultrafine (microfine) cements. The grouts have been batched with and without admixtures, and the water cement ratios have ranged from approximately 0.7:1 to 4:1.

Beginning in 2000, the injection pressure was set at a maximum of 10 psi (0.7 bar) and held constant during the entire injection period. Previously, the injection pressures ranged from 5 psi (0.3 bar) to 10 psi (0.7 bar). The maximum injection time was, and remains, 20 minutes per column. The sand columns have always been 191 mm (7.5 in.) inside diameter and 1,524 mm (60 in.) tall and are made of a clear plastic. Several different manufacturers and designs of grout plants have been used.

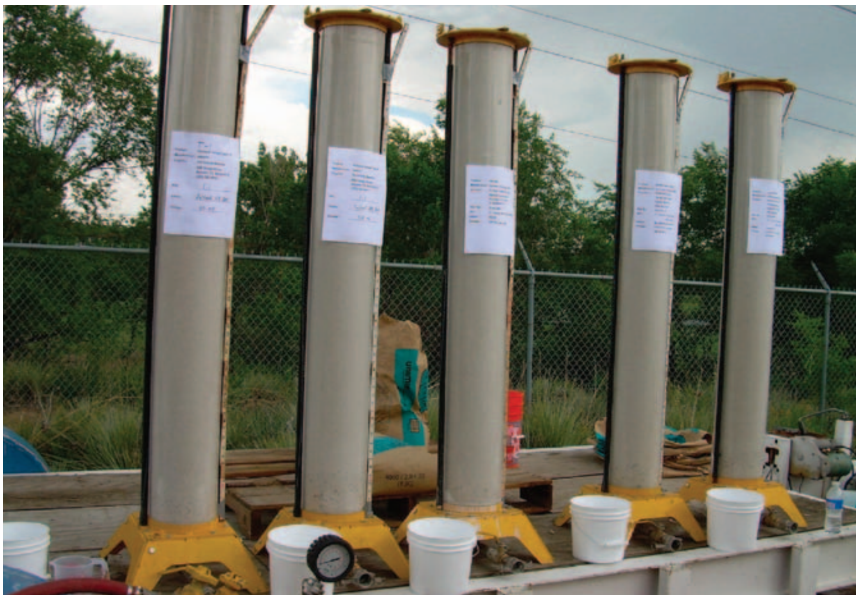
Basic field-testing has always included the grout mix temperatures, specific gravity

Raymond W. Henn and Jacob Prezkuta

Raymond W. Henn and **Jacob Prezkuta**, members UCA of SME, are senior consultant and engineer, respectively, Brierley Associates, LLC, in Denver, CO. rhenn@brierleyassociates.com or jprezkuta@brierleyassociates.com.

FIG. 2

Sand columns (2011) prior to grout injection.



and marsh funnel viscosity. Several additional field and laboratory test procedures including cohesion testing, flow cone tests and unconfined compressive strength testing of the cured grouted sand samples have been performed during several of the previous demonstrations.

More detailed information for a better understanding of the data available and how it compares with the 2011 results is available in the two papers published in *RETC Proceedings* (Henn et al., 2001 and Henn et al., 2005), in T&UC (Dec. 2009, pp. 28) and (Dec. 2010, pp. 42).

2011 demonstration

The 2011 demonstration consisted of five grout mixes (batches) and five sand columns labeled #1 through #5. There was one mix (#1) of Type I-II portland cement, one mix (#2) of Type III portland cement, and three mixes made using ultrafine (microfine) cements. All five mixes were mixed using an Atlas Copco high-speed, high-shear (colloidal) mixer.

Each grout batch was injected into the sand column immediately after mixing and QC testing at the maximum injection pressure of 10 psi (0.7 bar) and the maximum injection time of 20 minutes per column, which remained unchanged from previous demonstrations.

Supervision of the demonstration, as well as quality control, testing and record keeping, were performed by personnel from Brierley Associates LLC of Denver, CO.

Equipment

A model Unigrout Smart-A45D Atlas Copco grout plant was used for the 2011 demonstration. The plant consists of standard components: Cemix 403 HWB mixer with a mixing capacity of 0-4 m^3/hr (0-5.2 cu ydf) CEMAG 803 HWB agitator with a volume of 800 L (212 gal), Pumpac grout piston pump with a grout flow of 0-220 L/min (0-58 gpm) and a pressure output range from 2 bar (30 psi) to 55 bar (800 psi), PUMPAC progressing cavity pump with a grout flow of 190 L/min (up to 50 gpm) and a pressure output of up to 12 bar (174 psi). Figure 1 shows the Atlas Copco plant.

The sand columns were 191 mm (7.5 in.) inside diameter and 1,524 mm (60 in.) tall. These are the same, redesigned and newly fabricated, columns used for the first time during the 2009 and 2010 demonstrations. Figure 2 shows the five sand columns during the 2011 demonstration just prior to the start of the grout injection.

Inspection, record keeping and testing

Inspection was performed and the results recorded on each batch of grout. The recorded data included the quantities of cement and water added to the mixer, the quantities and types of admixtures used, the mixing times, injection pressures and the vertical travel distance of the grout in the sand column versus time. In addition to the inspection, three field tests were performed on each batch of grout. These tests were grout temperature, specific gravity and marsh funnel viscosity.

Discussion of test results

A total of five mixes were batched:

- Portland cement type I-II.
- Portland cement type III.
- DeNeef MC500.
- Nittetsu super fine cement.
- TamCrete UFC.

Shortly after field-testing and grout injection into the sand columns had started, the test results and grout flow in the sand columns appeared somewhat erratic, based on experience gained over many years of performing the grout demonstrations. Therefore, in fairness to all the cement suppliers to the 2011 sand column demonstration, none of the test results, nor the grout injection heights in the columns are reported in this paper.

At the conclusion of the demonstration, some inspection was performed on the various equipment used for the demonstration. Using this information, coupled with historical data, it was concluded that two possible factors may have contributed to the somewhat erratic results. One was the use of a high production capacity grout plant to mix minimum size batches. In the past, small capacity grout plants have been utilized. Based on these smaller plants being used over the years, the cement suppliers have provided only enough cement to match the grout plant's capacity. The relatively small batch sizes may have affected the mixing cycle of the much larger Atlas Copco grout plant.

In addition, it was discovered that, unknown to the sand column demonstration crew, a filter fabric was installed at the base of the sand columns during the filling of the columns with sand. These filters were installed with the intention to help prevent sand in the column from fouling the grout delivery line.

An additional grout permeation demonstration conducted by BASF was a separate sand column permeation test of two of their products:

- Rheocem 900 microcement.
- MEYCO MP 325 colloidal silica.

The demonstration consisted of a 1-m- (3-ft-) long clear plastic, 5-cm (2-in.) inside diameter PVC tube. The ends of the tube were reduced, and fine screening with fine steel wool were placed in the reducers so no sand could be lost when pressure was applied. Three sands were used to fill the tube, one-third each with a coarse, medium and fine sand. The finest sand was similar to the sand used in the large columns that were part of the larger grouting demonstration outlined previously. The sands were compacted with vibration in the tube prior to the test. Ball valves were on each end of the sand column to stop the grout at the completion of the test. Water was pumped through the sand column prior to the grouting test.

The pump was a small hand grout pump from Kenrich Products, Inc. Model GP 2HD.

Two different grouts were placed. The first was a grout made using Rheocem 900 microcement from BASF. The grout was a 1:1 water cement ratio with 2 percent Rheobuild 1000 for dispersion. The grout was able to penetrate all of the different sand sizes. The penetration took a longer time than the next grout and required more pressure (based on force applied to the grout pump handle). The second grout was a mineral grout (colloidal silica) MEYCO MP 325. The grout was accelerated using a 10-percent sodium chloride solution at about 15 percent (by volume) addition to the MP 325. This gave about 20 minutes of pot life for the injection before it gelled. It pumped easily through the sands and with much less pressure than the previous grout. Figure 3 shows the set up of the BASF test. ■

FIG. 3

BASF sand column demonstration.

Inspection was performed and the results recorded on each batch of grout. The recorded data included the quantities of cement and water added to the mixer, the quantities and types of admixtures used, the mixing times, injection pressures and the vertical travel distance of the grout in the sand column versus time.

Acknowledgments

The authors thank Hank Baski of Baski, Inc for the use of his yard and other facilities. Thank you to Joe Schatz of ChemGrout for providing the sand columns, grout header and supervising the batching of the grouts. Thanks to Fred Sherrell of Surecrete for supplying the Nittetsu SuperFine cement, to Brian Iske of DeNeef for supplying the MC500 microfine cement, and to Chris Gause of Normet for supplying the Tam Crete UFC. Thank you Bill Warfield of Atlas Copco for providing the Unigrout Smart-A45D grout plant. Thank you Jeffrey Champa of BASF for providing the test equipment and results of the BASF products. And as always, a big thank you to Don Hegebarth, independent grouting consultant, for doing all the pre-planning and organizing the overall demonstration.

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Gateway Tunnel project	Amtrak	Newark	NJ	Subway	8,000 x 2	24.5	2014	Under study
2nd Ave. Phase 2-4	NYC-MTA	New York	NY	Subway	105,600	20	2012-20	Under design
Water Tunnel #3 bypass 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	2016	Under design
Cross Sound Link Highway Tunnels	Sound Link	Long Island	NY	Highway	190,000	55	2014	Under design
Silver Line Extension	Boston Transit Authority	Boston	MA	Subway	8,400	22	2013	Under design
Hartford CSO program	MDC	Hartford	CT	CSO	32,000	20	2013	Under design
East-West Subway Extension	Baltimore MTA	Baltimore	MD	Subway	32,000	18	2012	Under design
WASA CSO Program								
Anacostia River Tunnel	DC Water and Sewer Authority	Washington	DC	CSO	12,500	23	2013	Under design
Northeast Branch Tunnel				CSO	11,300	15	2018	Under design
Northeast Boundry Tunnel				CSO	17,500	23	2021	Under design
Virginia Ave. Tunnel Expan.	CSX Railroad			Rail	4,000	40	2012	Under design
Dulles Silver Line Phase 2	WMATA			Subway	Various	20	2014	Under study
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
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
Dugway Storage Tunnel	NEORSD	Cleveland	OH	CSO	16,000	24	2014	Under design
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	Advertise Oct. 2011
Water Treatment Plant #4	City of Austin	Austin	TX	Water intake	45,000	7 to 9	2010	Obayashi/ Manson
St. Louis CSO Expansion	St. Louis MSD	St. Louis	MO	CSO	47,500	30	2014	Under design

FORECAST T&UC

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Deep Rock Connector Tunnel	City of Indianapolis DPW	Indianapolis	IN	CSO	40,000	18	2011	Shea-Kiewit JV low bidder
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 design
North Link Light Rail Extension	Sound Transit	Seattle	WA	Transit	34,000	21	2013	Under design
East Link Light Rail Extension	Sound Transit	Seattle	WA	Transit	12,000	21	2015	Under design
China NATM Station	San Fran. Muni Tansit Authority	San Francisco	CA	Subway	340	60	2012	Under design
Central Subway Tunnel	S.F. Municipal Trans. Authority	San Francisco	CA	Subway	16,600	20	2011	Barnard/ Impregilo/Healy
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
LA Metro LAX to Crenshaw	Los Angeles MTA	Los Angeles	CA	Subway	12,200	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
Eglinton West Tunnel	Toronto Transit Commission	Toronto	ON	Subway	10 km	6 m	2011	Under design
Yonge Street Extension	Toronto Transit Commission	Toronto	ON	Subway	15,000	18	2013	Under design
Downtown LRT Tunnel	City of Ottawa	Ottawa	ON	Transit	10,000	20	2013	Prequalified JV's announced
Evergreen Line Project	Trans Link	Vancouver	BC	Subway	10,000	18	2012	Prequalified JV's announced
UBC Line Project	Trans Link	Vancouver	BC	Subway	12,000	18	2014	Under design
Kicking Horse Canyon	BC Dept.of Trans.	Golden	BC	Highway	4,800 m 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 08/26/11

CSM TUNNELING PROGRAM

CSM launches tunneling center

by Mike Mooney, Center of Excellence in Underground Construction director

Underground construction and tunneling (UC&T) depends on a highly skilled engineering workforce and technical innovation made possible through interdisciplinary research. To address these needs, the Colorado School of Mines (CSM) is launching the Center of Excellence in Underground Construction and Tunneling. The university is leveraging private funding to develop the first center of this kind in the United States, designed to build a pipeline of graduates who are well-prepared to address the increasingly complex challenges faced in UC&T today.

The center will be interdisciplinary to reflect the UC&T community. Faculty and students from CSM's departments of civil and environmental engineering, geology and geological engineering and mining engineering will comprise the heart of the center. The center is being developed collaboratively by professors Mike Mooney and Marte Gutierrez (civil/geotechnical engineering), Christian Frenzel (mining engineering) and Paul Santi (geological engineering). They will be joined by peers from mechanical and electrical engineering, as well as geophysics and economics and business, The center builds upon the rich tradition of UC&T education and research at CSM.

The focus of the center will be to forge technical solutions and game-changing breakthroughs and address complex challenges in UC&T by:

- Training highly skilled and sought-after engineers.
- Mobilizing comprehensive research expertise to develop short- and long-term technical innovation.
- Offering specialized services such as professional training and specialty testing.

The Center of Excellence in UC&T will provide a platform for undergraduate- and graduate-level education. CSM undergraduates will be able to gain UC&T training by earning a minor degree (eight courses) or as an area of specialization (four courses). They can also conduct a year-long senior design project directly tied to UC&T, partner with faculty to conduct applied research or complete a professional internship with a UC&T partner. Graduate students at CSM will be able to pursue a five-course graduate certificate, a 10-course nonthesis master's degree, an eight-course and research-based thesis master's degree or a 16-course doctoral dissertation.

The center will pursue research to promote short-, medium- and long-term innovation for the UC&T industry. Students will participate in site visits, field trips and technical conferences, and the entire campus community will be invited to attend presentations as part of the ongoing UC&T seminar series. Finally, CSM is home to the first student chapter of the UCA, which offers further opportunities for connecting students with their future industry pursuits.

As the program grows, top-quality CSM students, faculty and industry partners will collaborate on new specialized training and emerging research initiatives.

For more information, please contact acting center director Mike Mooney at 303-384-2498 or mooney@mines.edu. ■

PERSONAL NEWS

Two recognized tunneling experts have joined HNTB Corp. to lead and enhance its tunnel practice. **NASRI MUNFAH** (SME) P.E. has become senior vice president and chair of tunnel services. Munfah, who also is an adjunct professor in Columbia University's civil engineering department, has 30 years of experience in all phases of international transportation, transit and underground engineering projects. His work includes the East Side Access Project in New York, the Windsor GreenLink in Ontario, Canada and the Istanbul Strait Road Crossing tunnel in Turkey. **SANJA ZLATANIC** (SME) P.E. has become vice president and chief tunneling engineer. With more than 20 years of experience, she was the project manager and the chief structural engineer on the No. 7 Subway Line Extension, the East Side Access project, the Trans Hudson Express (ARC) project and the Hudson-Bergen Light Rail Transit project's Weehawken Tunnel and Bergenline Avenue Station in New York. Munfah and Zlatanic will be located in HNTB's New York City office.

WILLIAM C.B. GATES (SME) P.E., P.G., has joined Jacobs Associates as a senior associate in its Seattle office. Gates is a retired U.S. Army Special Forces officer and specializes in geotechnical and rock engineering, blasting and hydrogeology. He has a Ph.D. and 44 years of experience dealing with engineering geology and geotechnical problems worldwide. Gates is currently the lead rock engineer on Seattle City Light's (SCL) Boundary Dam Rockfall Mitigation in Metaline, WA. There, he conducted a detailed geologic investigation of the engineering characteristics and rockfall problems of the rock mass that houses the turbines and transformer bays. His expertise includes interrelated geological and geotechnical disciplines attendant to rock mechanics, rock slope engineering, construction blasting, hydrogeology, fracture trace analysis, fracture flow and fracture mechanics. ■


GATES

OBITUARIES

DONALD R. ZENI
An appreciation by Toby Wightman

Donald R. Zeni died Oct. 13, 2011 at his home in Las Vegas, NV. He was 68.

Zeni earned a bachelor of science degree from West Virginia University then served in the U.S. Navy Seabees mobile construction battalion 7 for two tours in Vietnam. He was decorated with two bronze stars. In 1971, he founded Zeni Drilling with his father Angelo. Prior to 1971, he worked for Dravo and Zeni McKinney Williams Corp. on shaft and tunnel projects, including a state-of-the-art, mechanical drilling machine prototype. This was the forerunner of many developments in the mechanical sinking of vertical shafts. Zeni Drilling pioneered a myriad of mechanical drilling equipment and processes under Zeni's guidance.

Zeni Drilling was a dynamic organization and grew into an international presence known around the world. He was never reticent about taking on large and risky projects that kept the company stretching its human and financial resources to the limit. As a result, the company gained a reputation for never walking away from a challenge and completing all work satisfactorily and with integrity, regardless of the financial consequences. He committed all of his personal resources without reservation to the success of Zeni Drilling, carrying it through some very tough years, many times with little more than determination and mettle.


ZENI

As an astute businessman, Zeni worked hard to keep the company on track and always provided the best benefits that the company could afford, even benefits it could not afford. He was never hesitant to get his hands dirty. During the early years, he did physical labor during the day and administrative work at night.

Zeni was instrumental in advancing the technology of shaft drilling by helping to inspire and establish the Institute of Shaft Drilling Technology (ISDT). The institute promoted the technology of shaft drilling by bringing together all of the brightest lights from the government, universities, private industry and mining to share their knowledge with future generations and to provide scholarships to students entering the field. He was responsible for membership and increased the organization's membership to more than 1,000. He also served for several years as president of the ISDT. The ISDT later merged with the American Underground Space Association and is now a part of the Underground Construction Association (UCA) division of SME. Zeni was a member of the Executive Committee of the UCA when it merged with SME in 2007 and remained a member until September 2011, just before his death.

Zeni was known and respected around the world and made great friends everywhere, from Europe to the Ukraine, China, Australia, South Africa, Canada, Morocco, India and South America. Thanks in large part to Don Zeni, the name Zeni is almost synonymous with large diameter drilling knowledge and experience. He was instrumental in carrying the Zeni name throughout the mining world, not only by good business practices but by his friendship with respected and admired people in the industry. He is counted prominently among the rare luminaries in the mechanical excavation world.

In his relationships with people, Zeni was nothing less than extraordinary. When he was in a room, a restaurant or a meeting venue, there was never any doubt that he was there. His voice was well known and impossible to miss. Everything he did was done in a big way. Even his e-mails were written in large print and boldface type. In a conversation or presiding over a meeting, one would never know what he would say next and at full volume. Political correctness was not a consideration. Many times he was asked to be a master of ceremonies or preside over a meeting just because people loved to hear him talk.

Zeni loved his children and grandchildren unconditionally. Anyone who was privileged to have known Don Zeni will not soon forget him. Those of us fortunate enough to be a part of his family will always have a plus size space in our lives filled with memories and laughter. ■

DAVE FISHER
In memoriam by The Robbins Co.

Dave Fisher, a world-class field service superintendent with The Robbins Co. since 1991, died on Sept. 21, 2011 in Everett, WA. He was 65. Fisher was well-known in the industry for his expertise and dedication at projects such as the Yellow River Diversion Tunnels in Shanxi Province, China and the Parramatta Rail Link in Sydney, Australia, among many others. A native of Spokane, WA, his professional experience prior to Robbins

(Continued on page 71)

OBITUARIES

WILHELM JOHANN KOGELMANN III

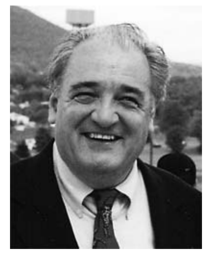
An appreciation by his son, Wilhelm (Chip) Kogelmann

Wilhelm Johann Kogelmann III, 72, of Boalsburg, PA died at his home at the base of Nittany Mountain on Oct. 24, 2011. Son of Wilhelm and Maria Kogelmann, he was born and raised in the town of Fürstenfeld in the Steiermark region of Austria. He earned a degree in mining engineering from the University of Leoben, Austria.

In 1963, Kogelmann earned a master of science degree in mineral processing from The Pennsylvania State University. He went on to found the Alpine Equipment Corp. in 1968, and he remained active in the business until just a few weeks before his death. His oldest son, Chip, continues to operate the business.

Kogelmann was an inventive engineer who held multiple patents and authored many publications in the fields of tunneling and mining. These include the U.S., Canadian and Australian patents for the field-interchangeable, transverse ripper and inline axial milling cutter heads for roadheaders. This combined the advantages of the Austrian/Hungarian and British/Russian cutter heads in one machine.

Kogelmann introduced roadheaders (boom miners, boom-type continuous miners) to North America in 1968. This was at a time when roadheaders were still in their infancy in Europe where they originated.



KOGELMANN

Among the many special machines he designed was the excavator-mounted Alpine Cutter Loader. In 1969, he supplied a roadheader for its first North American application at the construction of a sewer tunnel in Charleston, SC. In 1969, he introduced the first roadheader to Mexico, in 1971 to Canada and in 1972 to Australia — the first roadheader installations in these countries.

In the late 1980s, Kogelmann's company entered the rapidly growing market for rehabilitation of the crumbling infrastructure by applying its rock cutting know-how to the removal of deteriorated concrete at locks, dams, tunnels, bridges and other concrete mass structures. Excavator-mounted Alpine grinders were more productive and cost effective than hydraulic hammers. In 1995, Kogelmann designed and built the first no gap, transverse cutter head, a major improvement in cutting technology. Alpine then entered the rapidly growing market of environmental clean-up by applying its rock cutting expertise to in situ remediation of contaminated soil and hazardous waste dumps.

Kogelmann traveled worldwide, was a student of history and had a voracious appetite for books. Although a resident of central Pennsylvania for more than 40 years, his strong Austrian accent and grit never faded, much to the enjoyment of his friends and family. He celebrated his Austrian heritage and maintained its traditions, such as his well known Osterfeuer — Easter bonfire. He was a member of SME since 1969.

Kogelmann loved hunting and never missed a year of skiing. He is survived by his sons Wilhelm and Mark, daughters Karin Brown and Heather Fernsler, and six grandchildren. In addition, he leaves a sister, Lisl Maravic, in Austria. He was so grateful for the support he received from friends and family prior to his death and will be dearly missed by many. ■

Fischer

(Continued from page 70)

included work as an electronics technician in the Air National Guard and a degree in the fluid power program at Spokane Community College in 1979.

FISCHER

"Dave was one of those rare people you find in life. He was very experienced in field service. He was worldly and well-read. He took the time and care to learn the history and culture of every area that he worked in," said Lok Home, Robbins president.

Throughout his 20 years with Robbins, Fisher showed dedication to his work and skill in meeting customer requirements. "When he was at a tunnel, you didn't ever get a phone call. He was just that good. He was the type of guy you wished you could send to every complex jobsite," said Home.

Fisher was also well-known for his photography at jobsites, and many of his photos have appeared in Robbins press releases and stories. "In our off time we always spent time together taking in the sights. Dave was really fond of taking photos of the jobsites and local cultures," said Mike Burngasser, field service training specialist, who worked with Fisher on many projects around the world.

Fisher is survived by his brothers, Douglas, Steven and Patrick, as well as numerous nieces and nephews. ■

February 2012

7, Colorado Shool of Mines - Pilot Tube Short Course.

8-10, Colorado School of Mines - Microtunneling Short Course. Colorado School of Mines, Golden, CO. Contact: Microtunneling, Inc. P.O. Box 7367, Boulder, CO 80306, e-mail timcross@microtunneling.com, website www.microtunneling.com.

19-22, SME Annual Meeting, Seattle, WA. Contact: Meetings Department, SME, 12999 E. Adam Aircraft Circle, Englewood, CO 80112 USA, phone 800-763-3132 or 303-979-3461, e-mail sme@smenet.org, website www.smenet.org.

March 2012

27-29, INTERtunnel 2012, Lingotto Fiere, Turin, Italy. Contact: Romeland House, Romeland Hill, St Albans, AL3 4ET, Great Britain, phone 440-1727-814-400, fax 440-1727-814401.

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

14-16, International Symposium on Tunnel Safety and Security 2012, Roosevelt Hotel, New York, NY. Contact: SP Technical Research Institute of Sweden, Box 857, SE-501 15 Borås, phone +46 10-516 50 00, e-mail info@sp.se, website www.istss.se/en/Sidor/default.aspx.

27-31, NASTT's 2012 No-Dig Show, Gaylord Opryland Resort and Convention Center, Nashville, TN. 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 2012

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

June 2012

24-27, North American Tunneling Conference, JW Marriott Indianapolis, Indianapolis, IN. Contact: Meetings Department, SME, 12999 E. Adam Aircraft Circle, Englewood, CO 80112 USA, phone 800-763-3132 or 303-979-3461, e-mail sme@smenet.org, website www.smenet.org.

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George A. Fox Conference
Jan. 24, 2012

Graduate Center, City University of New York
New York, NY USA

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T&UC

2012 EDITORIAL CALENDAR

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Northeast United States	Tunnel Demand Forecast
Drilling / Blasting	

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SME Minnesota Conference	Apr. 17 - 18, 2012	Duluth, MN, USA
Coal Prep	Apr. 30 - May 3, 2012	Lexington, KY, USA
Offshore Technology Conference	Apr. 30 - May 3, 2012	Houston, TX, USA
CIM Annual Conference & Exhibit	May 3 - 9, 2012	Edmonton, AB, Canada
ITA World Tunnelling Congress	May 18 - 23, 2012	Bangkok, Thailand

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Sales Close: Tuesday, Feb. 7 — Material Close: Friday, Feb. 10

June

EDITORIAL FEATURES

Midwest United States	Tunnel Demand Forecast
Managing Project Risk	NAT Preshow and Official Showguides, Pocket Program

BONUS DISTRIBUTION

North American Mine Ventilation Conference	Jun. 17 - 20, 2012	Salt Lake City, UT, USA
NAT - North American Tunneling Conference	Jun. 24 - 27, 2012	Indianapolis, IN, USA

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NAT PreShowGuide section /	*Ad discount: 25% exhibitors*
Official ShowGuide	*Free polybag insert offer with any full page ad purchase*
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CLOSES

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September

EDITORIAL FEATURES

MINExpo	Tunnel Demand Forecast
Mining / Tunneling Equipment	Western United States

BONUS DISTRIBUTION

MINExpo	Sep. 24 - 26, 2012	Las Vegas, NV, USA

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December

EDITORIAL FEATURES

International Tunneling Projects	Tunnel Demand Forecast
Tunnel Design / Planning	

BONUS DISTRIBUTION

George A. Fox Conference	Jan., 2013	New York, NY, USA
UCT Annual Conference	Jan. 10, 2013	San Antonio, TX, USA
SME Annual Meeting & Exhibit	Feb. 24 - 27, 2013	Denver, CO, USA
PDAC Convention	To be determined	

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March, June, September, December 2011
Feature Articles, Industry Newswatch,
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* Denotes feature article

WTC 2012
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THAILAND

ITA AITES

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This is the first time that Thailand will host the ITA-AITES World Tunnel Congress and 38th General Assembly, one of the most privileged congresses in the construction industry. The host city, Bangkok, is one of the world's favorite tourist destinations. In addition to its unique culture and exquisite architecture, the capital of Thailand has much to offer to the Congress delegates.

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