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TUNNELING & UNDERGROUND CONSTRUCTION

THE OFFICIAL PUBLICATION OF UCA OF SME   WWW.TUCMAGAZINE.COM   VOLUME 6 NO 1   MARCH 2012

Blasting impacts on Grand Central Terminal

South Toulon Tunnel project

2012 Fox Conference highlights

Special Editorial Section from the publisher of *Mining Engineering*

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COVER STORY

COVER — The use of drill-and-blast techniques on New York's East Side Access Project faced two major issues: Impact to structures due to the close proximity of blasting, and impacts of perceptibility to passengers and other members of the public who would be in the vicinity of the blasting operations. A.J. Thompson and Doug Anderson explain beginning on page 46.

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CHAIRMAN'S COLUMN

Fox Conference one of many events that gets the year started well

January has always been an exciting time in the tunneling and underground construction industry. Besides being refreshed from the holiday break that many of us attempt to have, we also have the Beavers Dinner, the Moles Dinner and the annual George A. Fox Conference put on by the UCA of SME in New York City.

These are great events in our industry. Not only for the awards given to recognize those providing exceptional contributions to our industries, but also for us to be able to connect with many colleagues face-to-face in a world of phones, e-mails and text messages. These events give us a chance to meet up with partners, visit with lifelong friends and also develop new friends and partnerships.

And this year was no exception, with record attendance at all three events.

Personally, I think this year's George A. Fox conference was the best one yet. A record crowd of 377 people attended the conference. And this year the format was changed to include a one-half day agenda on international tunneling. The second half of the conference was focused on the many projects taking place in the Eastern Region of the United States.

A majority of the presentations at the conference were case studies and they covered everything from projects in Korea, Switzerland and Canada to the some of the largest and most dynamic projects in New York and the rest of the region (see page 57).

The international format for the conference provided a perfect venue for us to host our guests this year — the Executive Committee from the International Tunnelling Association (ITA). Having the ITA guests in the United States for a few days provided an excellent opportunity to spend some time with them, both in formal and casual meeting environments. For me, it was great to be able to meet and spend more time with many of them whom I have not had a chance to get to know better, especially In-Mo Lee, the current president of the ITA.

Spending time with the Executive Committee of the ITA allowed us, among other things, to discuss two specific initiatives that the UCA is working on — our goal to develop a better working partnership between the UCA and ITA and also to emphasize our goal to host the 2016 World Tunnel Conference in San Francisco, CA. We still have a lot of work to do on both of these goals, but it certainly was a good opportunity for positive discussion. Stay tuned for details on updates as we make progress on both of these fronts.

One final note — please take some time to check out the details on the Pressurized Tunneling Seminar scheduled for April 23-24 in Miami, FL. The UCA has partnered with *NAT Journal* to put on what will be a great seminar and field trip to the Port of Miami Tunnel site.

This seminar will be full of presentations from experts from around the world, panel debates and forum sessions as well as a tailored exhibit.

You can get more details in this issue or online at www.smenet.org or by e-mailing the SME meetings department at meetings@smenet.org.

See you in Miami. Be Safe.

Jeffrey Petersen,
UCA of SME Chairman

MTA moves to speed up progress on East Side Access project

In an effort to shave off as much as two years' worth of excavation work on the East Side Access project in New York City, the Metropolitan Transportation Authority (MTA) has reshuffled the work load and relieved the project's largest contractor of some its responsibility.

The excavation work beneath Grand Central Terminal is a key element of the largest infrastructure project in MTA history. It was once slated to be finished by the summer of 2012. However, in the fall of 2011, contractor Dragados told the MTA it did not expect substantial completion of work until as late as 2015.

Changing the terms of the contract with Dragados will help reduce — but not erase — the extensive delays in the Manhattan section that have placed "incredible pressure" on the project, Michael Horodniceanu, president of MTA Capital Construction, told *The Wall Street Journal*.

Because of the holdups under Grand Central Terminal, other contractors were not able to begin their work.

Dragados, an international construction firm, will give up some of its work responsibilities in the "caverns" it is digging to house train platforms.

The company will finish excavating the caverns, but turn over responsibility for installing concrete linings in them to a new contractor. That contract was put out to bid.

The MTA will receive a credit on its agreement with Dragados of roughly $17 million, officials said. Its contract was valued at $1.2 billion.

In addition, Dragados, which operated the tunnel boring machine responsible for the tunnels already bored under the East River in Queens, will construct a new tunnel for a ventilation system at 55th Street.

The excavation work will still wrap up one year later than advertised, Horodniceanu said, "but I saved another two years and change."

The MTA is still developing an estimate of the completion date of the entire project, *The Wall Street Journal* reported.

The trade-off also includes a newly restructured system of incentives and penalties for Dragados. The company could now be docked for as much as $49.5 million for future delays on its outstanding work, but could reap as much as $16 million in incentives if it finishes before its new projected completion date of August 2013.

The MTA did not go out to bid for Dragados's new assignment, building a tunnel to a planned ventilation facility under 55th Street, but Horodniceanu said the company's involvement would streamline that part of the construction.

Instead of building the ventilation system from "top down" and trucking away rock and debris, he said, the debris from the ventilation tunnel will be removed through the East Side Access tunnels to Queens, lessening the inconvenience to drivers and pedestrians at street level.

The changes may not speed up the entire project, Horodniceanu warned. Work is also proceeding slowly at the Harold Interlocking in Queens, which the MTA calls the busiest railroad interchange in the country. Renovations of Amtrak's East River Tunnel have also contributed to project delays. ■

Robbins opens new office in South America

A new Robbins office is now operating in Santiago, Chile to support the local tunneling market and grow Robbins' business in the region. Robbins South America is led by managing director Rolando Justa with support from project coordinator Esther Zerrer.

"South America is one of the most promising future markets with many upcoming projects, strong competition and potential for manufacturing opportunities. Setting up an office in this region was important to us because a close and constant approach with our clients is essential in the Latin American market," said Justa.

The subsidiary was established to augment the growing regional market and provide project management services, tunnel boring machine (TBM) field service, sales functions and technical support to clients. The office will work closely with the Robbins main offices in the United States as well as offices in Spain and Latin America.

Robbins has 14 offices worldwide with more growth planned for the future, each providing support for local projects and growing markets. "The benefit of having local support is immeasurable – customers will have an immediate response to field service issues, a conduit for our worldwide resources, and Robbins employees with whom they can communicate directly in their native language," said Doug Harding, Robbins vice president of sales-Solon, OH. ■

Federal study finds US water and sewer systems in need of $300 billion worth of work

A report focused on the nation's water and sewer systems found that municipalities nationwide will need more than $300 billion worth of essential upgrades to the systems over the next 20 years.

In light of this report, U.S. Sen. Charles Schumer (D-NY), is pushing a bill that would counter planned funding cuts in the federal transportation bill now being negotiated in Washington, the *Associated Press* reported.

The National Association of Counties' 2008 report found that the need for these upgrades is greatest in northeastern states with older systems like New York, which needs $29.7 billion worth of improvements. Schumer said that price is a "just a drop in the bucket" compared to the higher cost of continuing to upgrade parts of sewer and water systems when emergencies strike.

"EPA found that the nation's 53,000 community water systems and 21,400 not-for-profit, non community water systems will need to invest an estimated $334.8 billion between 2007 and 2027," stated the federal Drinking Water Infrastructure Needs Survey and Assessment, which is updated every four years.

The report estimated the need for water and sewer upgrades at $300 billion to $450 billion nationwide and the federal stimulus project provided just a fraction of that as the recession reduced local governments' revenues.

"This is a very serious concern," said Carolyn Berndt of the National League of Cities. "Many communities have a long-term plan to replace all their underground water infrastructure, but even if they do a couple percentages of pipes a year, it's still going to take over 100 years for some of them to replace it all."

She said local governments have been paying more than 95 percent of the cost of water and sewer upgrades since the 1990s as federal aid has declined. Schumer said federal aid covered 75 percent of local costs in the 1980s and 1970s.

"It's a huge undertaking," Berndt said. "Some of these pipes are 100 years old. That's why they continue to see water main breaks." ■

Correction

In the December issue of *T&UC*, Todd Brown's name was listed as an author of the feature article "Challenges and triumphs of the large-diameter microtunnel relief interceptor sewer in Indianapolis" on page 44 but it was not highlighted in bold letters. His name was also omitted from the contents page of that issue. The editors of *T&UC* regret the error. ■

Sany Heavy Equipment acquires Putzmeister

Sany Heavy Industries Co., along with a partner, acquired Putzmeister Holding GmbH in January, expanding its brand with the purchase of the concrete pump maker.

Sany, a Chinese construction-equipment maker, will buy 90 percent of Putzmeister for 324 million euros and Citic PE Advisors (Hong Kong) Ltd. will purchase the balance, it said in a Shanghai stock exchange statement. The deal may be completed by March 1, pending regulatory approvals, *Bloomberg* reported.

Putzmeister develops, produces and sells construction machinery worldwide, especially concrete pumps, for the building and mining industries, as well as for tunnel construction and large-scale industrial projects. Sany, based in Changsha, China, is a large Chinese producer of construction machinery and market leader for concrete pumps in China, which is the largest and fastest-growing market for concrete pumps and other industrial equipment worldwide. The business activities of Putzmeister and Sany are highly complementary geographically. The merger of the Chinese market leader in concrete pumps with the leading provider in most markets outside of China thus follows a clear strategic and industrial rationale: the creation of the global market leader for concrete pumps.

Both partners benefit substantially from the combination. Sany's financial strength secures Putzmeister's growth prospects and provides a significant competitive advantage. Sany adds to its portfolio technologically cutting-edge products and innovations "Made in Germany" and acquires a strong distribution and service network outside of China.

This transaction marks the first time that a large and well-known German company decided to merge with a Chinese partner. Karl Schlecht, founder of Putzmeister, said: "This merger is a global showcase transaction. Sany is one of the few large Chinese conglomerates that is personally operated by the founder, who is also the majority shareholder. In fact, Liang Wengen is one of China's most successful entrepreneurs. He not only shares our entrepreneurial spirit, but also Putzmeister's visions and corporate values."

Aichtal, Germany, will become Sany's new headquarter for concrete machinery in the world outside of China. Putzmeister will continue to operate with a high degree of independence in day-to-day management. Sany will focus on operations in China where Putzmeister will continue to be the premium brand. Norbert Scheuch will remain in his position as chief executive officer of Putzmeister within Sany and will join the Sany executive board.

Liang Wengen, chairman and founder of Sany, said, "With this merger, Putzmeister and Sany will create a new and global market leader for concrete pumps. Putzmeister will remain as an independent brand with its own management within the Sany group. We are looking forward to working with the Putzmeister management, which made this business so successful."

Putzmeister is the parent company of Putzmeister America, which operates in the tunneling and mining sector in North America through the Putzmeister and Allentown brands. ■

London's Thames tunnel to be ready in 10 years

A new road tunnel under the River Thames in east London will be ready within a decade, London Mayor Boris Johnson announced.

With a capacity of 2,400 vehicles an hour in each direction, the link will relieve pressure on existing tunnels at Blackwall and Rotherhithe to the west.

The tunnel, to be built between Greenwich Peninsula and Silvertown in the historic Royal Docks near City Airport, will support regeneration, and the area could benefit with up to 13,000 new jobs and 24,500 new homes, Johnson said.

Transport for London began preliminary consultation work on the Silvertown Tunnel in February.

East London has historically been one of the most deprived areas of the capital and a lack of river crossings has hurt businesses in the area.

Successive Labor and Conservative governments have made regenerating East London a priority and it is now expected to accommodate 40 percent of London's population growth until 2031, equating to 400,000 people.

The 2012 London Olympic Games will also be hosted predominantly in East London.

Johnson, who faces a mayoral re-election contest in May against his Labour adversary Ken Livingstone, stressed how public sector investment can be successfully achieved through partnership with private sector funding.

London has already used public-private partnerships to improve transport links, including Barclays bank sponsorship for a large cycle hire scheme and a contribution by the Emirates airline toward a cable car crossing over the Thames. ■

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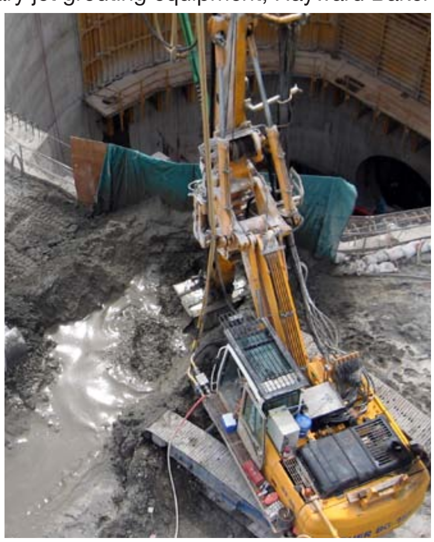
Seattle, WA
Brightwater Conveyance System

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 of 94 feet compose the soilcrete blocks.



Brightwater Conveyance System

Los Angeles, CA
Lower North Outfall Sewer Rehabilitation Project

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

Lower North Outfall Sewer

River Supply Conduit Unit 4
Los Angeles, CA

Ground subsidence above a 108-inch-diameter tunnel for a water supply line required compaction grouting (low-mobility) to densify disturbed soil and control settlement. Hayward Baker drilled over 180 grout holes between 10 and 23 ft deep, and pumped over 350 cy of low-mobility grout over a 600-ft length of the tunnel. All work was completed safely even though a portion was within a major city intersection.

River Supply Conduit Unit 4

Los Angeles, CA
Metro Gold Line C800

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

St. Louis, MO
Baumgartner Tunnel Alignment

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

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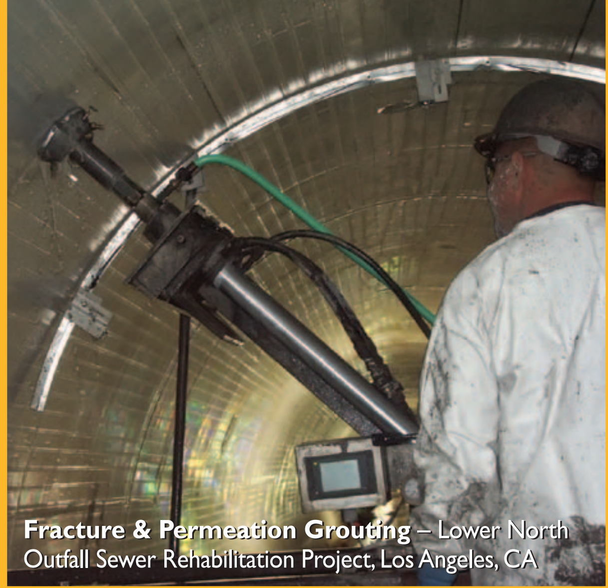
Fracture & Permeation Grouting – Lower North Outfall Sewer Rehabilitation Project, Los Angeles, CA


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

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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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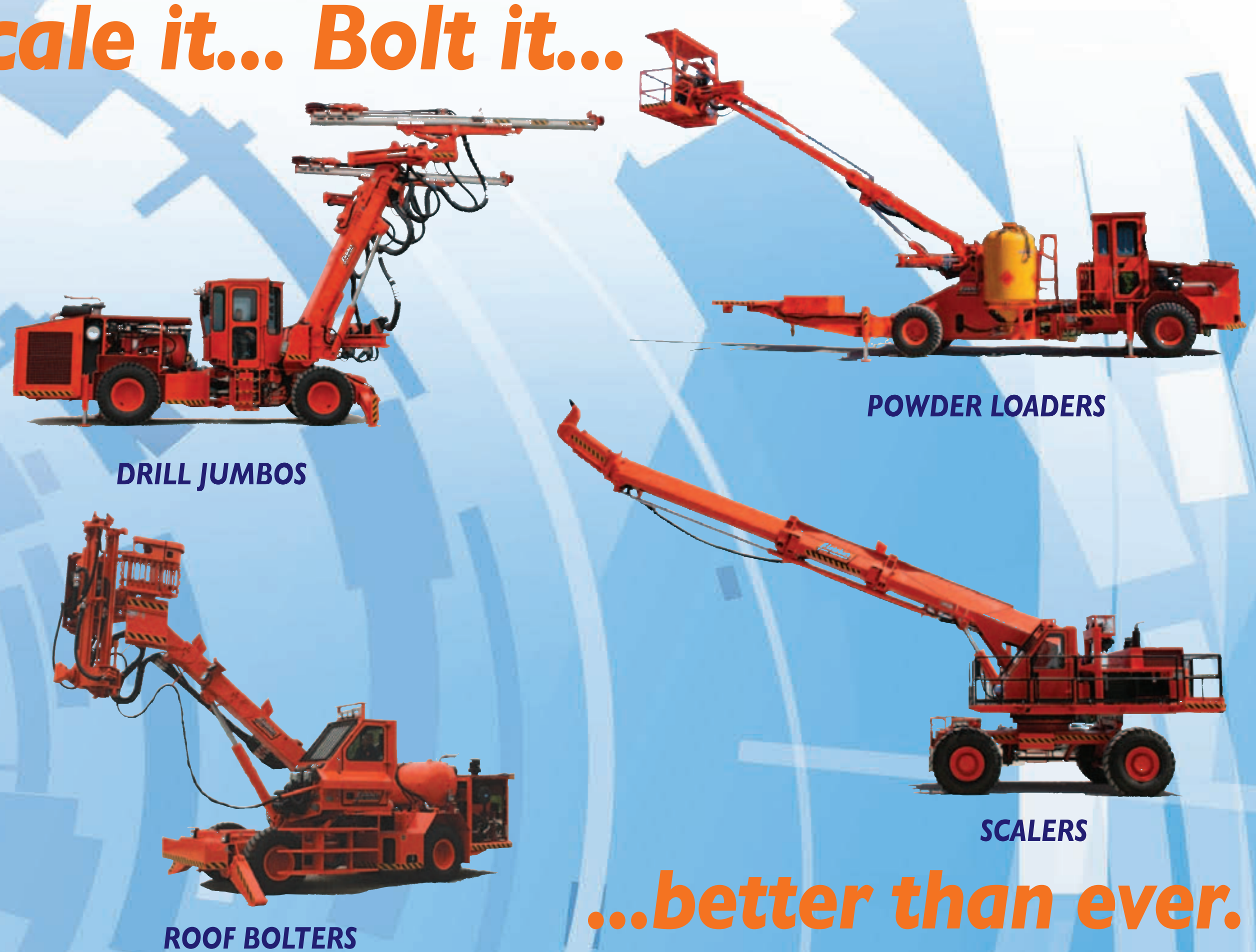

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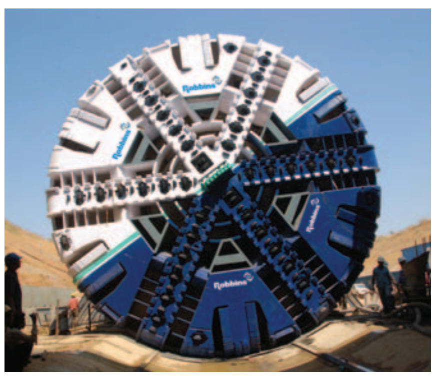

Robbins is a total supply company, offering everything from cutters and stacker conveyors to knowledgeable field personnel and technical support. Robbins' time-saving Onsite First Time Assembly (OFTA) method was first used at Canada's Niagara Tunnel Project in 2006 and continues to be successfully carried out on multiple projects and with all types of TBMs. The method results in significant time savings and cost reductions for the contractor, all by initially assembling the TBM at the jobsite rather than in a manufacturing facility. The method has been used most recently for the Kargi Hydroelectric Project, where a 10.0 m (32.8 ft) Double Shield TBM will bore an 11.6 km (7.2 mi) headrace tunnel through a mountainside in Corum Province, Turkey.

Robbins' field service personnel bring years of engineering experience to each project. On the Olmos Trans-Andean Tunnel project, Robbins engineers coped with undue wear on the cutterhead from fractured and broken rock by adding wear plates and square bars in front of each cutter to protect the hubs from bursting at the face. On December 20, 2011, the 5.3 m (17.4 ft) Robbins Main Beam TBM working on the project triumphantly achieved breakthrough with record advance rates as high as 674 m (2,211 ft) per month.

Continued Success in Hard Rock and Soft Ground

Robbins EPBs continue to achieve remarkable advance rates in soft ground, taking the industry standard from 400 m (1,312 ft) to 700 m (2,297 ft) a month. The 10.0 m (33 ft) Robbins EPB boring Mexico City's new Metro Line 12 enjoyed advance rates up to 133 m (443 ft) per week, achieving breakthrough in early February. Also in Mexico City, one 8.93 m (29.3 ft) Robbins EPB machine is boring the Emisor Oriente wastewater line, soon to be joined by two more machines of the same diameter.

In India a 6.25 m (20.5 ft) Robbins Main Beam TBM will begin boring 8.3 km (5.2 mi) of the new Mumbai Water Supply Tunnel the first half of 2012 to help prevent leakages and ensure drinking water is not contaminated during monsoon season. Also in India, a new 6.65 m (21.8 ft) Robbins EPB will excavate two 1 km (0.6 mi) tunnel sections for Line 1 of the Chennai Metro, which is expected to help relieve traffic congestion.

Robbins innovations continue to advance in 2012, with major hard rock and soft ground projects planned in such regions as Singapore, Russia, India, Latin America and more. For further 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

Underground Intelligence with Brierley Associates

Brierley Associates partners with clients and peers to produce underground facilities that are cost effective and timely, and employ the best that tunneling technology has to offer. A vibrant and growing national firm with 60 employees in nine states and counting; Brierley Associates offers a full range of underground design, geotechnical, and construction consulting and management services. With extensive experience in design and design-build, 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 that is conducive to cooperation, motivation, innovation, and accomplishment.

Brierley Associates
2329 West Main Street, Suite 201
Littleton, CO 80120 USA
Telephone: +1-303-703-1405
Fax: +1-303-703-1404
www.brierleyassociates.com

Xylem Dewatering Solutions

Xylem brings you dewatering solutions through Flygt and Godwin products and services. Flygt's history of innovative product engineering, coupled with Godwin's reputation for superior products and services presents you with the most comprehensive dewatering product and service solution for your construction dewatering challenges.

With more than 30 years as the industry leader in pump manufacturing, Godwin is an immediately recognizable name in the international portable pump industry by way of its innovative approach to pump manufacturing, rental, sales, and service. Godwin sets the pace for the range and versatility of pumping solutions available worldwide because it designs, manufactures, services, sells and rents products that are economical, reliable and targeted to the specific needs of its clients.

State-of-the-art technology and durable construction materials ensure that Flygt dewatering pumps deliver highly reliable performance at the lowest possible total cost of ownership. You have the possibility of choosing from a wide range of Flygt pumps that are built to handle the toughest dewatering jobs, because they are truly sturdy and reliable under all conditions.

With a broad network of locations to serve you throughout the United States, you can now satisfy your surface-mounted and submersible pumping needs from one, comprehensive dewatering solution provider – Xylem's Dewatering Solutions business. Visit our website at godwinpumps.com for the Godwin location nearest you.

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www.godwinpumps.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

Brokk AB – Underground Expertise

No matter the tunneling challenge, whether refurbishment or enlargement, safety niches or cross-passages, there's nothing a Brokk can't handle. Brokk's zero-emissions, compact powerhouses go anywhere and stand up to the most demanding environments. Complete the package with a rock drill, shotcrete gun or other specialty attachment, and it's the perfect combination to take on any application.

Your toughest tunneling challenge? Bring It. Brokk has the machine to tackle it.

Brokk 100

Featuring a more compact design, yet 35-percent greater breaking power, the all-new Brokk 100 is the ideal replacement to the popular Brokk 90 model.

Brokk 160

The Brokk 160 combines powerful performance and a lightweight design to offer the capabilities and flexibility for challenging applications.

Brokk 260

Our most popular model, equipped with a hydraulic rock drilling attachment, is perfect for drilling spiles, anchors or blast holes.

Brokk 400

The Brokk 400 is the second-largest machine in the Brokk range and features unsurpassed capacity.

Brokk 800S

The 12-ton Brokk 800S is breaking way for a whole new field of application when it comes to tunneling projects.

For more than 30 years, Brokk has been focused on developing remote controlled machines for use in the underground and tunneling industries. Today there are more than 5,000 Brokk machines in use all over the world. From safety and productivity, to power and profitability, Brokk machines provide cost-effective, efficient solutions.

For more information, contact Brokk's North American headquarters at 800-621-7856, email info@brokkinc.com, or visit the website at www.brokk.com.

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BROKK®

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

Mining Equipment Ltd.

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

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

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

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

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

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

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

CDM Smith

CDM Smith provides lasting and integrated solutions in water, environment, transportation, energy and facilities to public and private clients worldwide. As a full-service consulting, engineering, construction and operations firm, we deliver exceptional client service, quality results and enduring value across the entire project life-cycle.

CDM Smith's underground construction staff includes geotechnical, structural, and civil engineers and geologists located worldwide. Our staff has extensive experience in providing the full range of tunnel and geotechnical related services. Our tunnel related work includes planning, feasibility and design, including both 2D and 3D FEM analyses. We offer construction services including construction and program management, inspection and geotechnical instrumentation monitoring and interpretation for soft ground and rock tunnels. Design and construction includes all types of ground modifications including ground freezing, grouting, and dewatering.

Our field equipment includes geotechnical instrumentation and construction data acquisition equipment. Our field personnel are NICET, OSHA and NRC certified. CDM Smith's tunnel services include:

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

CDM Smith
www.cdmsmith.com

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Paul C. Rizzo Associates Inc.

Paul C. Rizzo Associates, Inc. (RIZZO) provides world-class technical expertise and innovative solutions for tunneling projects. Working in the water resources, mining, transportation, and nuclear markets, we encounter traditional and ground breaking projects around the world. The breadth of our services allows us to add value to a project at any stage: from conception to completion.

RIZZO's in-house services include design for tunnels and shafts; geotechnical engineering; seismic engineering; hydraulic engineering; construction management; environmental engineering; and developing tunnel rehabilitation programs.

Our recent projects include final design and comprehensive services for the Margarita Export Line Tunnel in Bolivia, design and geotechnical oversight for the Gualcamayo Mine Tunnels in Argentina, geotechnical engineering support for the Second Avenue Subway in New York City, and seismic engineering for upgrades to the BART Transbay Tube under the San Francisco Bay.

Paul C. Rizzo Associates Inc.
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Fax: +1-412-856-9749
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Premier Pipe Systems Manufacturer Since 1925

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

Naylor Spiralweld is available in diameters from 4” through 96” and wall thickness from 14 Ga. through ½” wall. The Spiralweld pipe is complemented with all types of fittings, fabrications to specification, and joint connections, including the exclusive Naylor Wedgelock Coupling, to complete your pipe system.

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

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

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

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

Quotations are immediately available on inquiry.

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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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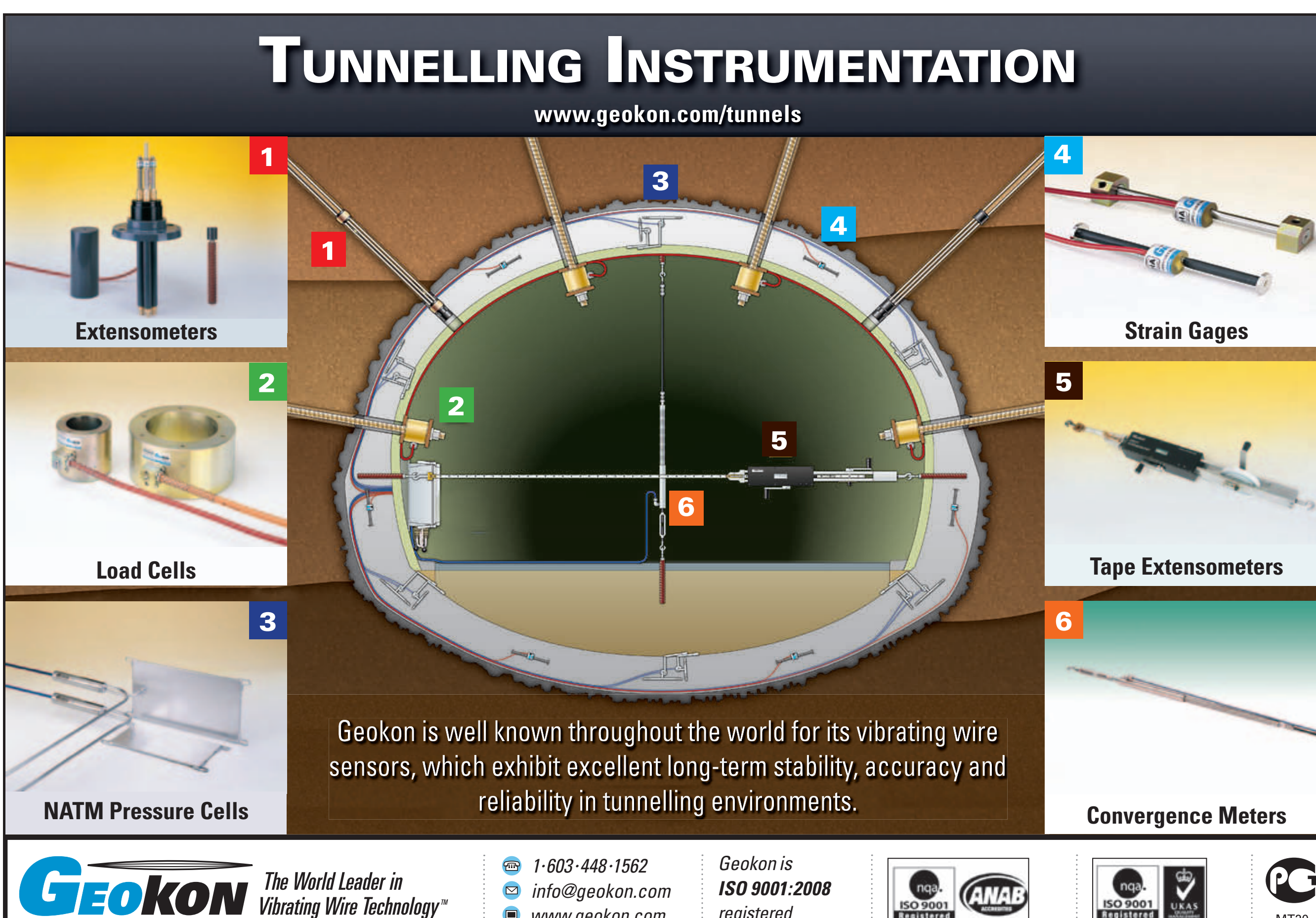

Bit By Bit Controls

At Bit By Bit Controls, Our Philosophy is Simple, Plan, Design, Fabricate, Implement…

A track record of proven reliability, plus devotion to customer service has been our strongest element. While we will continue to grow according to the changing needs of our customers, our commitment to service will never change.

Bit By Bit Controls provides custom control designs that bring solutions, and makes production function the way you need. Our designs find balance between minimizing energy usage and maximizing operation efficiency.

UL-certified B3 controls, a certified UL508A panel shop, builds panels from our design or yours. We specialize in low-cost, robust designs, with emphasis on prompt delivery. Our design and assembly team stresses detail, quality, and fast turnaround. For most custom and large jobs, we deliver your panel in as little as two to three weeks - inspected, tested, ready to install.

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New York City Water System – Damascus Corporation

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

Damascus Corporation
PO Box 610
Abingdon, VA 24212 USA
Telephone: 800-390-7636
Email: sales@damascuscorp.com
www.damascuscorp.com

Lil' MAC

MAC-2DT

MAC-XP (Permissible)

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 50 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 8000 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 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 650 business professionals in 28 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.
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Telephone: +1-262-878-5760
Email: info@normet.fi
www.normet.fi

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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Specialty Products and Services for the
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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.

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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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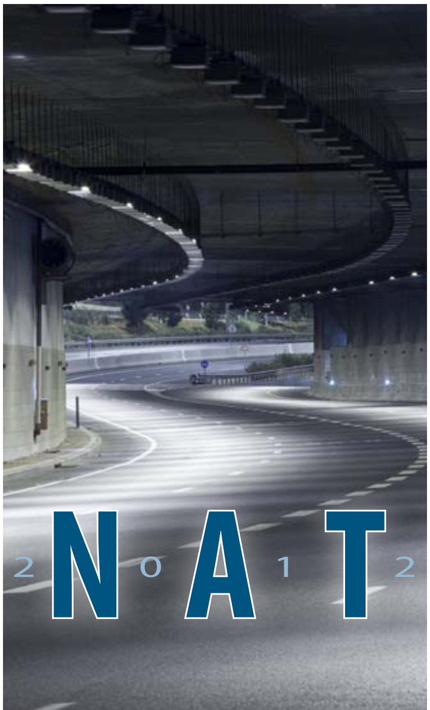

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Surecrete Inc. specializes in furnishing bagged cementitious materials, mixing and placing equipment, and related accessories to the heavy civil tunnel, geotechnical and mining markets. Our product lines include Nittetsu Super Fine ultrafine cement,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


Concrete materials for Chester Creek Dam, Metlakatla, AK

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Bradshaw Offers Innovative Tunnel Engineering and Construction Technology

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

Bradshaw Construction Corporation
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Tunneling Equipment Design Specialists

Kelley Engineered Equipment, LLC was founded in 2007 by Brian and Cindy Kelley. The firm has a growing staff of engineers and drafters with extensive experience in tunneling and mining equipment design. Brian has 7 years of experience at Robbins, 12 years at Kiewit Underground Division, and 4 years at Kelley Engineered Equipment. The company has PE licenses in Nebraska, New York, and Washington State. The company specializes in custom tunneling equipment design, including lifting systems, mucking systems, gantries, pipe carriers, trailing gear, custom attachments, conveyors, lift cars, equipment modifications, personnel access systems, and more. KEE partners with select shops, or customers can choose the manufacturer. Kelley Engineered Equipment has a growing line of standard products including mobile reelers for wire rope and conveyor belt and high rail drive axle kits.

Kelley Engineered Equipment, LLC
11281 S. 232nd Street
Gretna, NE 68028 USA
Telephone: +1-402-267-0143
www.KEELLC.com

Caldecott Breakthrough!

The Caldecott Fourth Bore Tunnel achieved a major milestone on November 29, 2012 when the east top heading broke through to the west top about 655 feet from the West Portal. Presupport, face support, and careful operation resulted in a controlled excavation of the less than 3-foot-wide rock pillar separating the two headings. Excavation and support of the bench are anticipated to be completed in April 2012. The three existing highway tunnels are located on State Route 24 and pass through California's Berkeley Hills, connecting the cities of Oakland and Orinda. The new tunnel will provide another two-lane traffic tunnel dedicated to west-bound traffic and will be approximately 3,399 feet long and 50 feet wide. Jacobs Associates is currently providing design support services during construction.

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

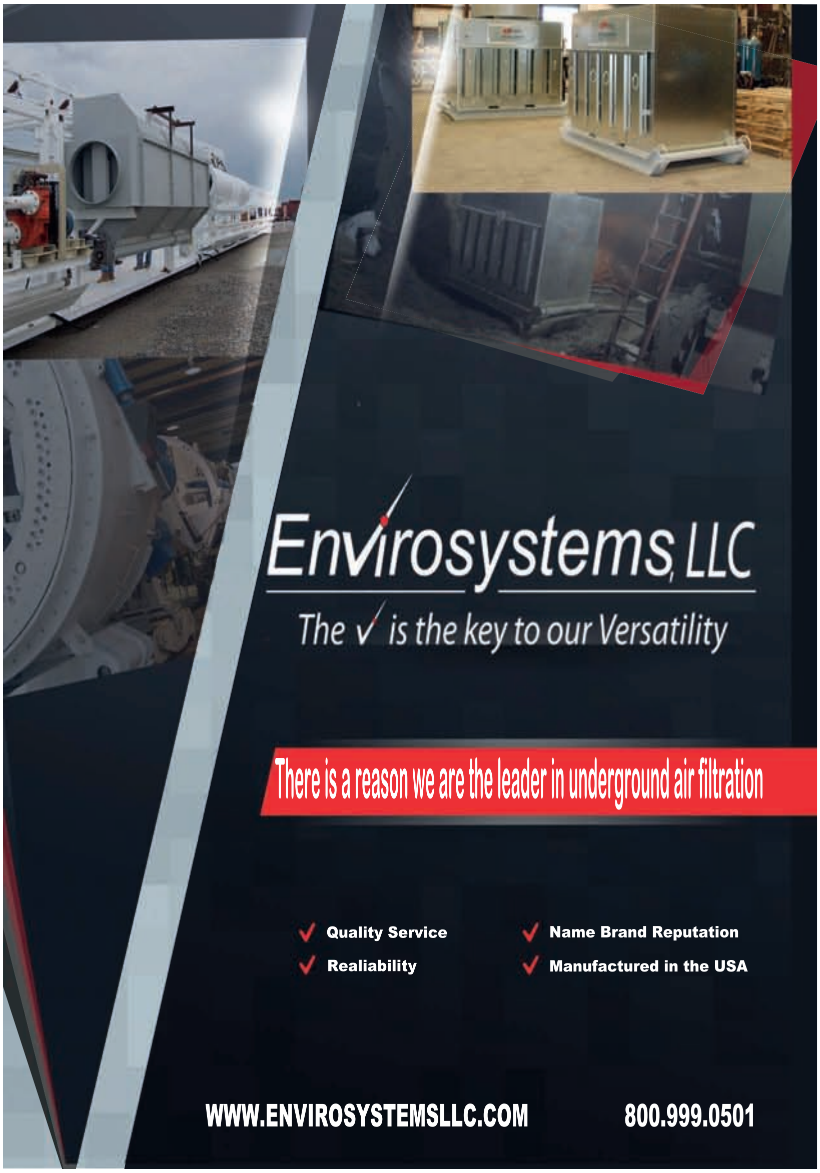
Envirosystems, LLC

ENVIROSYSTEMS has been designing and manufacturing industrial dust collection systems since 1988 for use in all types of manufacturing processes resulting in airborne contamination.

The current line of AirWall dust collection products have evolved into a very robust product design. Envirosystem's main product line is the many standard and custom versions of that initial AirWall dust collection unit, ranging from 1,200 CFM to over a million CFM. Adaptable to most variations of underground equipment the AirWall will provide underground dust capture at the source.

The high reliability and extremely low energy consumption per CFM of the AirWall units have lead to a high customer satisfaction, with a high percentage of sales attributed to repeat orders from existing customers.

Envirosystems, LLC
Telephone: +1-800-999-0501
www.envirosystemsllc.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

Engineering a Better Solution

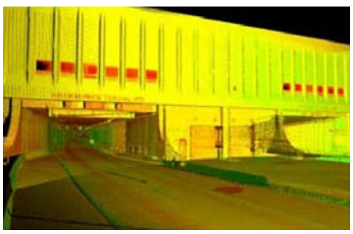
Maccaferri is a world leader in the design and development of advanced solutions for erosion control and reinforcement structures. Maccaferri has been providing engineered solutions for over 130 years. Over time, the company has innovated and evolved so that today it is also a reliable partner for complex civil and environmental engineering applications, with a specific focus on the underground works.

Maccaferri strives to provide a cost effective and dependable environmental solution to each and every project. Our team of highly trained professionals is available to offer advice, guidance, and design solutions for all Maccaferri products.

Maccaferri
Telephone: +1-800-638-6910
www.maccaferri-usa.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

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.

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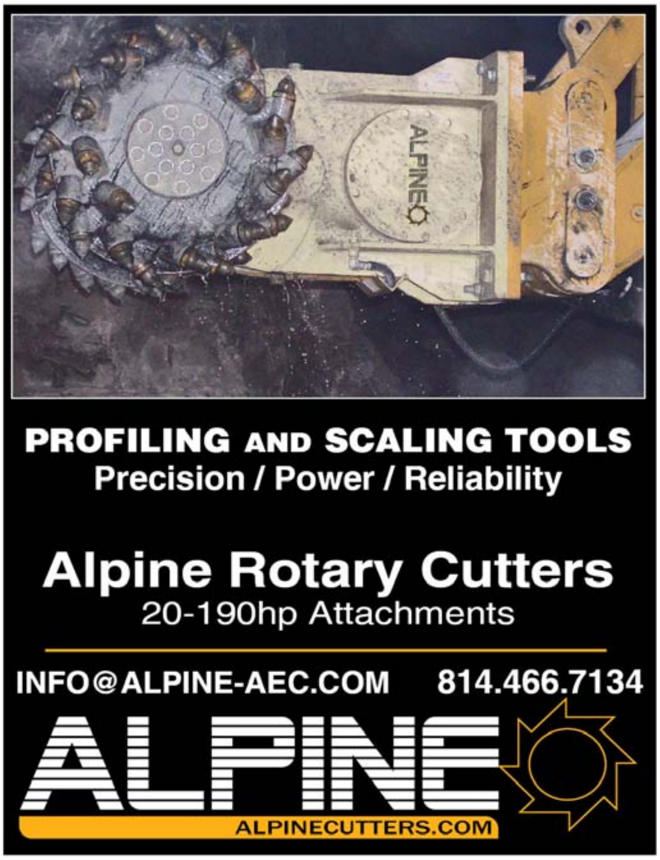

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FEATURE ARTICLE

Handling the impacts of blasting on Grand Central Terminal for the MTA's East Side Access project

Bench progress in the westbound cavern of the East Side Access project.

The Metropolitan Transportation Authority (MTA) East Side Access project (ESA) will, when it is complete, provide a new link to the east side of Manhattan from Long Island, NY that, linked with the Second Ave. Subway currently under construction, will assist in relieving overcrowding at Penn Station as well as the Lexington Ave. subway.

ESA will bring Long Island Railroad (LIRR) directly from Long Island into a new station located 37 m (120 ft) beneath the existing Grand Central Terminal (GCT) located in the heart of Manhattan. It will connect the LIRR's mainline tracks in Queens, via the existing 63rd Street Tunnel under the East River, to a new terminal constructed within, and beneath, the historic Grand Central Terminal.

The alignment chosen for the project passes primarily beneath MTA property which, especially at Grand Central Terminal, has been overbuilt over the years with the foundations of properties established within MTA property. Given that these structures include the Met Life Building, Helmsley Building, Chase Bank Worldwide Headquarters and the historic and busiest rail terminal in America, the effect of construction operations, especially blasting, on the structures and the public became a significant factor during design and construction.

Construction methods

Cavern construction. To house the various railroad and station facilities, 12 separate enlargements, totaling more than 382,000 m^3 (500,000 cu yd), will be excavated around the previously mined tunnel boring machine (TBM) tunnels. These include the two 18-m- (60-ft-) wide, 18-m- (60-ft-) high and 366-m- (1,200-ft-) long east and west station caverns, located beneath Grand Central Terminal with cover that varies from 13 to 18 m (45 to 60 ft). Excavation of these caverns is currently under way using roadheaders and drill-and-blast methods. Initial support consists of combinations of tensioned rock bolts, weld mesh and shotcrete. Once cavern excavation is completed, a hybrid precast and cast-in-place fully waterproofed final lining will be installed prior to installing the railroad systems and facilities.

Concourse to cavern connections

The 32,500-m^2 (350,000-sq ft) concourse for the new Long Island Railroad station will be located in what was the Madison Yard Storage area on the lower level of Grand Central Terminal. The concourse will be connected to the station caverns by four inclined escalator shafts and five vertical shafts. These shafts are being constructed from the top down using drill-and-blast and mechanical methods. In some locations these shafts are located within 3 m (10 ft) of existing structural column footings and some 7 m (22 ft) below the in-service Upper or Express Level where Metro North Railroad (MNR) continues to operate passenger services during construction.

Impact of methods

The use of drill-and-blast techniques, faced two major issues: Impact to structures due to the close proximity of blasting, and impacts of perceptibility to passengers

A.J. Thompson and Doug Anderson

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and other members of the public who would be in the vicinity of the blasting operations. While mitigating these impacts, there also was the need to avoid imposing overly restrictive blasting criteria for the project so that the overall schedule could be met.

Blasthole locations in Grand Central Terminal 1 & 2 West Wye.

Project environment

Early in the planning phase, it was recognized that the design and construction of the caverns and shafts would be significantly impacted by the physical environment in which they were to be constructed.

One of the major items identified, and the subject of this article, was the effect of close proximity blasting on the surrounding structures, utilities and infrastructure. This, in turn, was influenced by the following issues:

- Protection of MNR personnel, customers and critical operational infrastructure.
- Construction occurring within, and beneath, a 100-year old historical bi-level train shed.
- Determination of the extent and accuracy of information available from as-built records.
- Proximity of structural columns and footings for highway viaducts and air rights structures to proposed excavation perimeter.
- Presence of high pressure steam lines and other utilities within the footprint of the work site.

Metro North Railroad

One of the fundamental principles adopted was that construction work associated with ESA should cause no impact to MNR's revenue operations or affect the safety of MNR's customers, personnel and operational infrastructure. As with any operating railroad, there are elements of the systems infrastructure, such as signals, communications cables, switch machines and instrument huts, that have a degree of sensitivity to construction activities. Older instruments that included relays rather than solid state electronics were identified as specific items of concern that could be impacted by the vibration associated with construction activities.

As the work site from where the shafts would be constructed is located in a former train storage yard on the lower level of the existing Grand Central Terminal, this means that in many places construction took place just 7 m (22 ft) below and 3 m (10 ft) away from operational tracks.

Grand Central Terminal train shed structure

The existing Grand Central Terminal structure is a bi-level, steel-framed structure constructed prior to 1913 in a large opencut, excavated using drill-and-blast methods. The train shed extends from 42nd St. to 52nd St. and stretches between Madison and Lexington Aves. Over time, many structures and cross streets have been built over the structure, requiring columns to be constructed through the train shed to take the loads to the rock beneath the lower level. Once the structures above were completed, the underside of their basement slabs became the roof of the upper level of the train shed. In many locations, the condition of these slabs, as well as the fireproofing of the structural steel, has deteriorated to the extent that chunks of concrete would fall from them onto the track and platforms below. Although critical repair and maintenance work has been undertaken over the years, the general superficial condition of the structure, especially on the upper level, was considered poor, considering the work to be undertaken. The train shed itself is separated into a number of discrete sections with expansion joints between them. So, while giving the appearance of a massive structure, it is, in fact, comprised of a number of individual sections.

In addition, given the age of the structure, the availability and accuracy of as-built records was considered questionable. This was compounded by the fact that the original design calculations were not available for the train shed structure. This meant that the available additional stress that could be carried by the structure as a result of construction impacts was difficult to determine.

Structural footings

There are more than 250 columns within the footprint of Madison Yard that sit on grillages constructed in pits excavated into the rock. These columns, which support different structural elements, had to be taken into account when determining the location and shape of the shafts. Categories of columns were identified during the planning and design phase, including upper level train shed support columns, New York City Department of Transportation (NYCDOT) viaduct support columns, and building columns that pass through the upper level and are not connected to the train shed structure.

The major factor that had to be considered was the transmission of vibration to these columns during the drill and blast operations for the shafts and caverns.

Utilities

Contained within the train shed are a large number of utilities, including sewer and water lines suspended from the roof of the upper level, high voltage power feeders, gas lines, communication lines and high pressure steam lines. When Grand Central Terminal was constructed, tunnels were excavated beneath the lower level to permit the transmission of high-pressure steam throughout the terminal and to the properties above Grand Central Terminal. While the steam lines had been identified as an item of concern, this was reinforced in 2007 when a high-pressure steam line located just outside the footprint of Grand Central Terminal on Lexington Avenue ruptured, leading to significant damage.

Design considerations

Construction effects on existing structures. It was recognized that excavation of shafts, escalator shafts and caverns using drill-and-blast techniques would give rise to a number of concerns including:

- Transmission of vibration and noise through the footings and columns, causing disturbance to building tenants.
- Ability of the existing footings and columns to withstand the additional loads imposed on them as a result of the vibrations.
- Accelerated deterioration of existing fireproofing and under-basement slabs.

Good vibrations

The effect of close-in blasting on existing structures is a subject that is less well understood than perhaps it should be. In addition to the various technical issues that needed to be resolved, one of the major obstacles that had to be addressed and overcome was the innate concern and fear related to the effects of blasting. This issue was exacerbated by the fact that the single largest entity affected by the blasting operations was MNR, which had operational infrastructure and the safety of personnel and customers to consider.

In order to assess the effects of vibration on the overlying and adjacent structures, a series of studies was undertaken to establish baseline vibration levels in the structures, determined primarily from the movement of trains on the bi-level structure. A separate study was undertaken to establish the potential levels of vibration that the structures may experience as a result of blasting operations. Experience from other parts of the project was used to determine the appropriate regression constants used in the calculations to predict peak particle velocity. Vibration levels were calculated for both the upper and lower levels of the train shed, and contour maps of potential vibration levels that could arise from shaft and cavern blasting were superimposed onto plans of Grand Central Terminal.

This initial assessment of blasting impacts indicated that the whole-building response to blast events in the caverns and other underground structures would be negligible due to the relatively large distance of the crown of the caverns from columns and footings, a minimum 13 m (45 ft) below the level of the lowest structures (45th and 48th St. Cross Passages). The response of individual footings and columns in close proximity to shaft blasting then became the controlling element in developing blasting criteria. Based on the information available and the parameters assumed for blasting, it was recognized that levels of peak particle velocity in excess of 51 mm/sec (2 in./second) could be generated in the footings and columns immediately adjacent to the shaft excavations. It was also recognized that the accuracy of seismograph readings taken immediately adjacent to the shaft may be questionable. Following this initial assessment, two separate, although linked, strands were further investigated:

- Alternative measurement techniques to establish effect of vibrations on structure.
- Need for repairs, remedial and protective measures to existing structures/facilities.

Effects of vibrations on structures

For above ground structures, the impact of blasting is usually considered to be primarily related to the free response of the structure, a racking movement, related to the relative movement of parts of the structures in response to an imposed vibration by the ground. The blast wave, and associated vibration, decreases both in amplitude and frequency as it propagates away from the blasting location. For close-in blasts, such as for the ESA shafts, the dominant frequency at the receiver will, therefore, be high, in the hundreds to thousands of Hertz. Structures have resonant frequencies that are primarily related to the stiffness and dimensions of the structure with large engineered structures typically having resonant frequencies in the neighborhood of 1 Hz or lower, far below the frequencies of vibration generated by blasting.

Damage caused by vibration is due to movement of one part of the structure relative to another. This relative motion can be characterized by strain, which is dimensionless, and is simply described as the change of length (Δl) divided by the length

$$\varepsilon = \frac{\Delta l}{l} \qquad (1)$$

It would seem logical, therefore, to use strain to determine building response. However, strain varies substantially within a structure, concentrating at corners and the middle of beams and walls, and varies for different materials. So it is difficult to determine a representative "strain" for a complete structure. However, strain as a criterion for specific structural elements, such as columns, is an appropriate criterion. The strain induced on the columns can be analyzed in terms of their load capacity and failure criteria. To undertake this analysis, an approach was used that calculated the bending strains of the columns from the displacement of the base of the columns. The strain estimates were then calculated as a fraction of the capacity of the columns, as determined from the as-built information obtained.

It was determined that the structural behavior of the columns could be related to a rigid displacement of the base of the columns. To determine the appropriate vibration input for these calculations, the following methodology was used:

- Vibration levels were calculated based upon the upper 95 percent confidence level from the regression equation determined from blasting undertaken previously on the project.
- Displacements are calculated from the peak particle velocities using the sinusoidal approximation, and assuming that the frequency is 100 Hz, displacement D is in inches, *PPV* is in inches/s, and frequency *f* is in Hz.

$$D = \frac{PPV}{2\pi f}$$

Drilling DaMite holes in wellway 1.

Choosing a lower bound frequency of 100 Hz then generates an upper bound for displacement. The displacement at the base, along with the column geometry and fixed/free boundary conditions, determines the anticipated strain on the column. This strain was then related to a failure limit based upon excess capacity, which was, in turn, used to develop the strain criteria incorporating safety factors and the excess capacity.

In order to measure the strain, resistive foil strain gages connected to data loggers were specified to be installed on columns where maximum strain is anticipated.

Repairs, remedial and protective measures

As noted previously, the Grand Central Terminal structure is more than 100 years old. The roof of the upper level has been covered by a variety of structures and roads and these have become the ceiling of the train shed. Leakage of water lines and salt effects on the roadway viaducts have all contributed to a situation where significant portions of the concrete fireproofing and slabs have delaminated from the steel.

Based on the results of vibration analysis on the structure and visual inspections of the condition of the structures, it was determined that it would be prudent to undertake remedial work on all concrete within 30 m (100 ft) of shaft blasts as well as to install a protective mesh system above platform areas and critical MNR infrastructure to prevent spalling pieces of concrete falling on passengers, personnel or this infrastructure.

Associated with this remedial and protective work, the MTA undertook a more detailed visual survey of the train shed structure to establish a baseline condition of the structure prior to construction work commencing. This survey also identified a number of locations where additional repairs might be necessary and the results of the surveys were forwarded to MNR for their action as many of the identified locations were outside the blasting zones of influence.

Drilling holes for rock bolts in eastbound 2.

Metro North Railroad

The effect of having an operational railroad 7 m (22 ft) above and in some places 3 m (10 ft) from the edge of excavations cannot be overstated. In addition to minimizing the potential impacts of blast induced vibrations on operational infrastructure, the effects of noise, flyrock, fumes and dust also had to be taken into account and measures introduced to minimize or eliminate their effect. Major restrictions identified were periods during the day when blasting could not be permitted due to the intensity of train movements and the identification of windows within which the blast and post blast inspection could be undertaken prior to train movements restarting.

Design phase summary

Coming out of the design phase, the following parameters were identified to minimize the impacts of shaft construction on the overlying and adjacent structures and protect MNR operations:

- Inspection and remediation of defective concrete above upper level platforms and critical infrastructure.
- Installation of protective nets on the upper level.
- Use of both PPV and microstrain to measure effect of blasting.
- Restrictions on round lengths and bench heights for both shaft and cavern excavation.
- Mechanical excavation in all shafts for 5 m (16 ft) below the lowest footing level.
- Blasting only permitted at times that do not require MNR to suspend railroad operations.
- Pre- and post-blast inspections of facilities and structures.
- Extensive instrumentation program.
- Shaft covers to be used to minimize potential for flyrock, limit airblast and control blasting fumes.
- Use of channel and line drilling in shaft excavations to minimize vibration transmission.
- Positive ventilation systems to control fumes and dust.

Construction phase

Environmental management. To minimize the migration of dust and fumes from blasting operations to the MNR operational areas, a number of measures were implemented, including:

- Installation of a ventilation system within the work site designed to draw air away from MNR areas and evacuate to the atmosphere through existing ventilation shafts.
- Exhaust fans and scrubbers were used to suck blast fumes and dust from below the shaft collars to capture and control these before they could enter the main body of air.

The natural air flow within the Grand Central Terminal train shed is from north to south where the concourse is located so it was important to ensure dust and fumes did not migrate through to the dining concourse and passenger waiting areas. MTA performed monitoring at the closest operational platform and other locations within Grand Central Terminal. To date, minimal impacts to the air quality have been recorded.

Pre-excavation coordination

Prior to blasting at a particular location, a detailed "score card" system was implemented to ensure that the various elements that needed to be in place had been completed. It should be pointed out that the installation of structural instrumentation, as well as the mesh installation and concrete repair works, were undertaken under separate contracts. It had been determined during the planning phase that construction impacts would be limited to a 30-m (100-ft) influence zone as measured in plan from the location of the blast. Therefore, prior to excavation, influence drawings were produced and all support works required to be undertaken were identified, prioritized and tracked to completion. Only when all items on the scorecard were identified as complete was excavation permitted to start.

Due to the restrictions on blasting times, a detailed notification process was also developed in conjunction with the contractor and Metro North Railroad. Once the contractor was ready to blast, notification was provided to Metro-North Railroad track controllers who would then provide the time, to the nearest minute, when the blast could be detonated. Typically, blasting was permitted when there was a minimum 12-minute window where no train movements were scheduled through the influence zones. This time interval would permit:

- The blast to be detonated.
- Initial vibration results to be obtained.
- A confirmation of no misfires to be determined, through the use of a tattle tale blasting cap attached to each delay sequence.
- A basic visual survey of the train shed within the influence zone to be undertaken.

Once the “all clear” had been received to these items, train service could be resumed.

Results of blasting

To date, three of the escalator shafts and four of the vertical shafts have been completed from the lower level to the caverns. Excavation of caverns and access tunnels by drill-and-blast has progressed significantly, including completion of the top headings for all caverns as well as bench blasting in the main station caverns. Of the 1,600 blasts to date, less than 2 percent of the blasts have exceeded the pre-determined vibration limits, either PPV or microstrain. When such an event occurs, blasting is suspended at that particular location until the cause of the exceedance has been identified. Typically, such issues are due to increased burden due to drillhole alignment, incorrect wiring of the round, or cut-offs causing later charges to break more rock. In addition, problems have been experienced with electrical interference on the strain gages, causing false readings to be generated, although enhanced grounding and shielding of the units and cables has generally eliminated this.

It should be noted that the maximum strain measured due to blasting is similar to that imposed on the structure by the movement of trains, 60 to 70 microstrains. And it is considered unlikely that the blasting will significantly affect the integrity of the structure.

At the outset, the microstrain criterion was used because it was anticipated that vibration levels would exceed the commonly used criterion of 51 mm/sec (2 in./second), but that the close-proximity blasts, with high frequency vibration, would generate small strains in the columns. The use of a microstrain criterion made engineering sense, and was accepted by all parties.

Concurrent with the strain measurements, conventional PPV measurements were made and correlated with the strain measurements. It was determined that the measured strain induced on the columns was so far below the capacity levels that the associated (and less expensive) PPV measurements could be used as a criterion. Furthermore, a modified higher PPV criterion of 76 mm (3 in./second) was instituted. Exceedance of the 76 mm (3 in./second) criterion would initiate a review procedure, and this has rarely happened.

Drilling blastholes in westbound cavern.

Conclusions

Blasting in a densely populated urban setting, with infrastructure elements thoroughly penetrating the project area, can be a daunting task. Thorough preparation during the planning and design phases is necessary to allow a reasonable and cost-effective construction schedule to be developed. Furthermore, methods and appropriate criteria must be developed so that the client, the contractor and potentially affected third-parties all can be brought on board.

These elements have all been brought together for the cavern and shaft excavation for the East Side Access Project. The project has required excavation in very close proximity to the operating Metro North Railroad, historical Grand Central Terminal, and a web of columns and beams supporting structures along New York City’s Park Avenue. A combination of preparatory monitoring and protection measures, along with an innovative use of strain monitoring for close-in structures, has allowed blasting for a project where it was thought there would be too many objections.

As of this writing, excavation had proceeded to the satisfaction of all concerned. Properly designed blasts and rigorous monitoring resulted in excavation with minimal disruptions to a very tight construction schedule, while alleviating the concerns of the public and third parties. ■

FEATURE ARTICLE

Observation methods using real-time surface settlement monitoring on the South Toulon Tunnel project

The Toulon Tunnel project is a key component of the highway corridor on the French Riviera between Marseille and Nice and is a fundamental transportation infrastructure for the region. The first design studies started in the 1960s. The tunnel project is comprised of two separate tunnels: south and north. The north tunnel was built between 1992 and 2002 after 10 years of difficult construction. On March 15, 1996, for example, a collapse of the tunnel in the Marchand area generated a sinkhole in the city center, causing a 20-month delay. The south tunnel alignment runs parallel to the north tunnel below Toulon's historical downtown at a depth of 20 to 40 m (65 to 131 ft) with some areas with less than 10 m (32 ft) of cover. The risk management program was studied to be a state of the art program in urban tunneling construction.

Hydrogeological context

The whole project area is covered with backfills and colluviums 1 to 4 m (3 to 13 ft) thick. The schist, marls and sandstones, randomly distributed along the alignment below the first layer have different characteristics. While the schist is compact, the marls are fractured. The other layers have different characteristics, and many faults are located along the alignment, especially in the limestones. The breccia is heavily decompressed and deformable, as well as the other soils located in the Marchand area. This 80-m- (260-ft-) long area is where the settlements need to be controlled with an extensive monitoring program. The complete geological profile is presented in Fig. 1.

The superficial water table is relatively stable and is located in the superficial layer (Colluvium). The deep water tables are located in the limestones and fractured sandstones. These water tables are independent, as they are separated by impermeable layers. This heterogeneity is hard to monitor precisely as the permeability conditions vary drastically along the alignment.

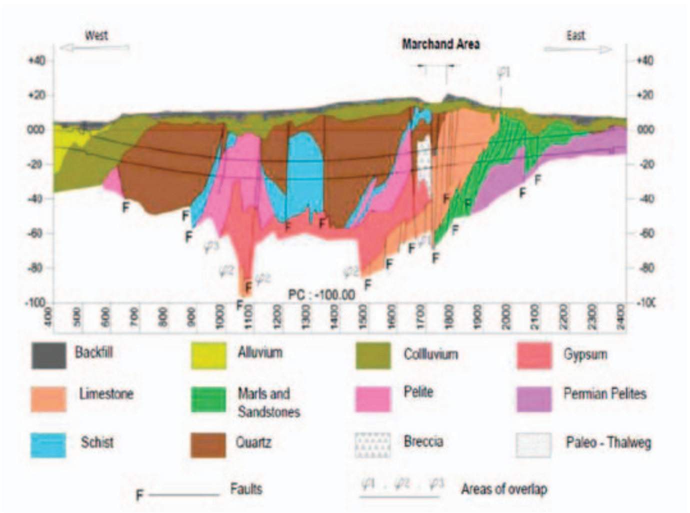
Existing buildings

All the alignment is heavily built. Most of the existing buildings above the tunnel alignments were built in the 1950s in armed concrete, and are superficially founded. But some buildings are part of Toulon's historical city center. The alignment is shown in Fig. 2.

In the Marchand area, two buildings (named K6 and K7) were located in the settlement trough in the most deformable area and were the most heavily instrumented.

FIG. 1

Geological profile along the alignment.



Design factors

The tunneling design was focused to control the settlements and to limit the deformations of the existing buildings. This approach was chosen to avoid the problems encountered during the first phase and because it appears to be the only way to deal with the highly complex hydrogeological profile. Three steps were followed to achieve this purpose:

- Evaluation of the admissible deformations for each building and classification in 13 different sectors. An example of these sectors is shown on Fig. 3.
- Definition of three levels of absolute and differential settlements (notification – anomaly – alert) for each of

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the 13 sectors.
- Design of specific supports and choice of the excavation techniques to respect the deformation criteria defined in step two.

Types of supports and tunneling techniques

The tunneling section is located between two cut-and-cover sections of each portal. The 1,818 m (5,964 ft) of tunnel was excavated using the traditional method full section. The tunneling was started at three locations, in addition to the two east and west ends, a specific shaft in the "Marchand area" was used to start the third front of tunneling. Nine different support designs were defined, from "light" support systems with only one I-beam arch to more complex support systems with umbrella arch, shotcrete and two levels of I-beams closely spaced. Most of the support systems use the umbrella arch technique to be installed (Fig. 4).

Monitoring program

An extensive monitoring program was implemented along the alignment, inside and outside the tunnel. As in other sensitive projects where risk management is critical, most of the instruments installed were automated and all the data management system was linked to a web-based interface software (Geoscope) for a real-time access to all the project data. The monitoring program was mainly based on the use and capabilities of automatic motorized total stations (AMTS) and locally completed with traditional geotechnical and structural instrumentation as detailed in this section.

Ground instrumentation outside the tunnel

From the surface the following instrumentation was installed:

- Multiple borehole extensometers (three, four and five anchors) were installed to measure the vertical ground displacement at several depths between the surface and the tunnel crown.
- Manual inclinometers on both sides of the tunnel and in the vicinity of the shafts.
- Automatic piezometers to measure water level and pore pressure.

The manual data collected from the inclinometers was downloaded into the database, as well as the whole quality control reports of the project. So all the information related to the project was accessible at anytime from a single source. The software was able to generate, in real time, water level isolines, as shown in Fig. 5.

Instrumentation inside the tunnel

In addition to the standard manual survey, the convergence was continuously measured every 4.5 m (14.7 ft) by using automatic motorized total stations and 3D prisms attached to the support system, as shown in Fig. 7.

FIG. 2

Aerial view of the alignment.

In the critical sections, additional automatic instrumentation was installed (radial extensometers, strain gages on the I profiles, pressure cells in the shotcrete).

Structural instrumentation on existing buildings

Once again, most of the instrumentation was automated. The following instruments types were installed on the critical buildings as determined by the preconstruction expertise:

- 3D targets monitored with AMTS.
- Tiltmeters and tilt beams on vertical structural elements.
- Automatic and manual crackmeters.
- Strain gages on key structural elements.
- Vibration monitoring units.

Due to the quantity of automatic data to be transmitted, a specific local Wi-Fi network was set up in the city.

More than 1,500 3D prisms were installed on existing buildings and monitored every two hours for the duration of the project with a required accuracy of 0.3 mm. This

FIG. 3

Definition of critical deformation.

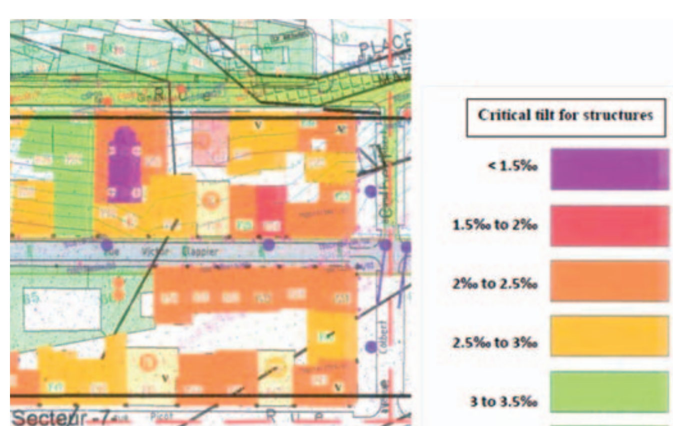


FIG. 4

Example of tunnel support design.

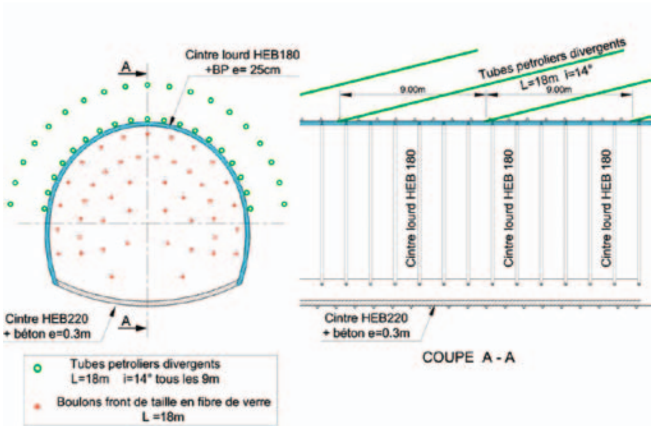


FIG. 5

Water level tables isolines along the alignment.

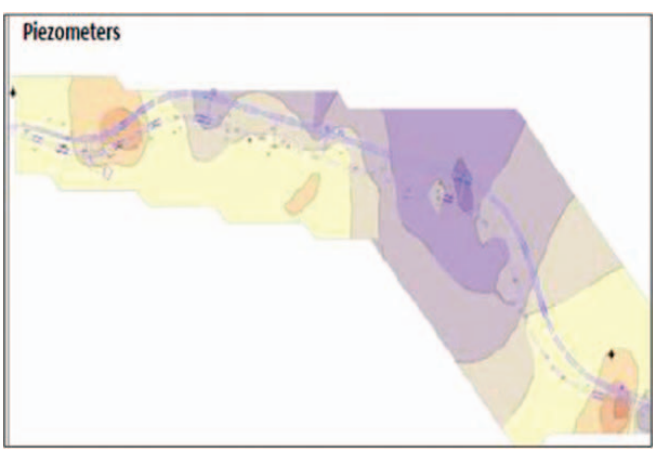


FIG. 6

AMTS and targets inside the gallery.

criteria was achieved due to specific filters on the raw data and least square calculation tools included in the global data management software.

Automatic "prismless" surface monitoring using AMTS

The most innovative solution used on this project was the automatic surface settlement monitoring using AMTS called Centaure. With no need to install any kind of reflector on the monitored area, the system was configured to automatically measure the settlement of a virtual mesh of 1,800 surface settlement points on the existing roads with 36 AMTS positions along the alignment with an accuracy of 0.5-mm at a distance of 40-m- (131-ft-). The maximum monitoring distance is limited by the reflective capabilities of the surface. The system still requires 3D reference targets installed outside the zone of influence to correct the position of the AMTS and achieve the accuracy required. This technique has been used successfully on several other tunneling projects, and more generally on projects where the access to the area to be monitored is limited. The principle is illustrated in Fig. 7.

This technique can substitute any type of standard manual surface leveling, and provides safer real-time risk management, as well of a better understanding of the settlement trough geometry (Fig. 9).

On the specific Toulon South Tunnel project, this system was combined with the automatic monitoring of structures using traditional 3D prisms "Cyclops." An example of this combined AMTS application is shown in Fig. 8.

In this case, the monitoring frequency depended on the location of the excavation front; the monitored "zone of influence" was 45 m (147 ft) before and after the front with five-points arrays every 9 m or 4.5 m (30 or 14 ft) depending on the sensitivity of the area. The monitoring frequency depended on how critical the structure was and on the alert level (from 1 to 8 measures/day).

Once the data was processed, automatic isolines of settlement were generated by the software to have a global "3D visualization" of the construction impact on the surface and buildings (Fig. 9).

Observational method

Construction method and support system. On the majority of the excavation projects, the choice of the best suitable supporting system is done based only on the parameters available before construction (geologic profile, geotechnical investigations logs). On the South Toulon project, in addition to the preconstruction data, the construction method and the supporting system was chosen also with the data retrieved during construction. In addition to the analysis of the on site geological front excavation section, the measured deformations inside and above the tunnel were used to optimize the design. Based on the analysis and the prevision of anticipated settlements in comparison to the initial calculated settlement and the three levels defined by the engineer, the tunneling contractor had to decided whether to:

- Reduce the quantity of support.
- Use the specified support system.
- Increase the supporting system by proposing a reinforced design.

Distance to face graph

The objective was to precisely monitor the initial start of the settlements a few meters in advance from the tunnel position to help the tunneling contractor with the choice of support system. For this specific application, a new monitoring software feature has been developed to compare the reference settlement curves (based on the Peck probabilistic approach) and the curves resulting from the measured deformations, at different positions before or behind the excavation front position. This tool, called the distance to face graph, was part of the real-time monitoring software Geoscope. This special feature requires accurate measurements. Requirements were a 0.5-mm accuracy for surface vertical movements and a 0.3-mm accuracy for 3D buildings movements. This precision was achieved dueto specific AMTS features (Cyclops and Centaure). Through filtering programs, weather corrections least square approximation and median calculation, raw data is transformed into accurate data and transmitted into the monitoring web-based data management system. The distance to face graph can be refreshed every day with the median of the previous 24 hours to have an updated anticipation of the final settlement and optimize the construction process (supporting system, excavation speed) as well as reduce the risk of damage to the existing structures.

An example of the output of this feature is shown on Fig. 10. On the same graph are visualized the three different theoretical curves (each of these referring to an alert level defined during the design process) and the five surface points monitoring data, in relation to their distance with the excavation front. Before the excavation reaches the monitored section, settlement starts to occur. At that stage, the calculation enables the design to anticipate the final settlement (once the excavation front is away from the monitoring section). If this anticipated settlement exceeds the alert level, the design is reviewed for the settlement to stay within the project limits of building deformation specified during the evaluation of admissible deformations. In addition to these longitudinal sections, the settlement was also monitored and compared to the calculated data on the transversal sections. Sections of settlement trough were retrieved using the monitoring data and the Gauss analysis.

In both cases (longitudinal and transversal), the tilt was retrieved by using the monitored data of two adjacent points and compared to the maximum allowable for the building. This information was essential to evaluate the

FIG. 7

3D monitoring points.

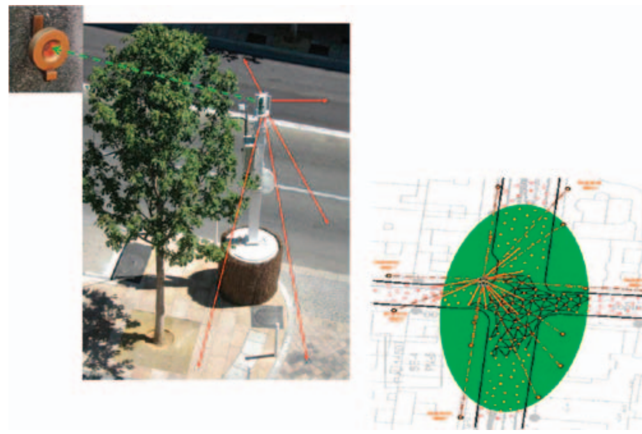


FIG. 8

Example of combined AMTS system: 3D monitoring points (green circles) and virtual mesh of automatic surface settlement points (red points).

FIG. 9

Isolines of settlement from the reflectorless system monitoring.

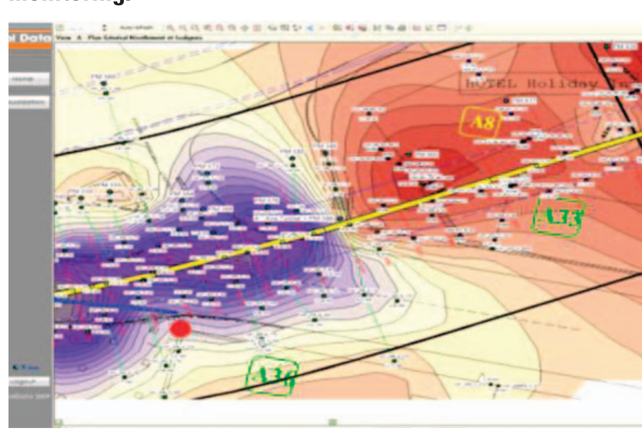


FIG. 10

Comparison between calculated settlement curves and actual measured data.

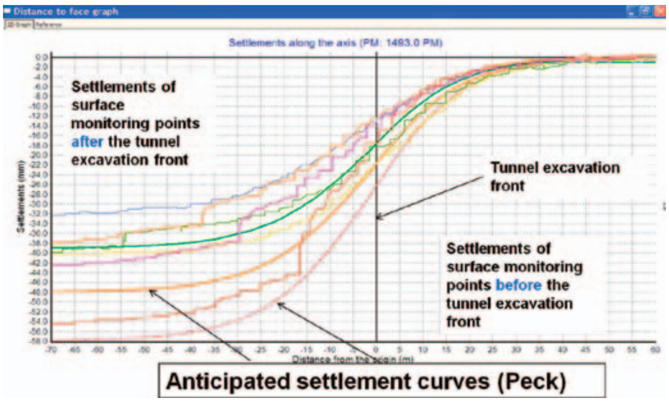


FIG. 11

Settlement Hollow in the Marchand area and compensation grouting program.

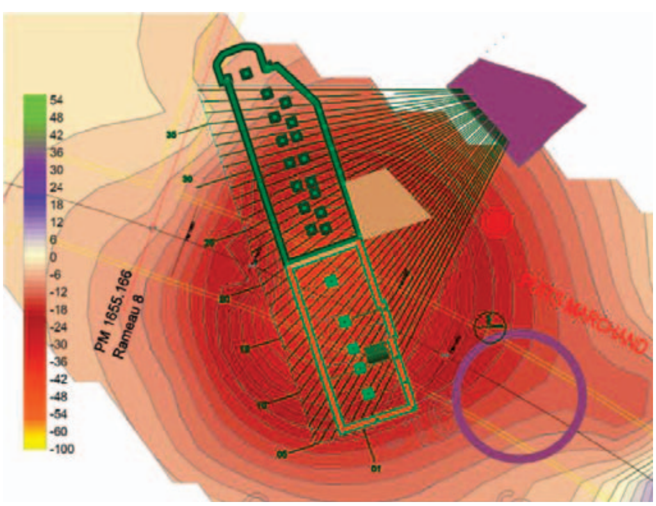
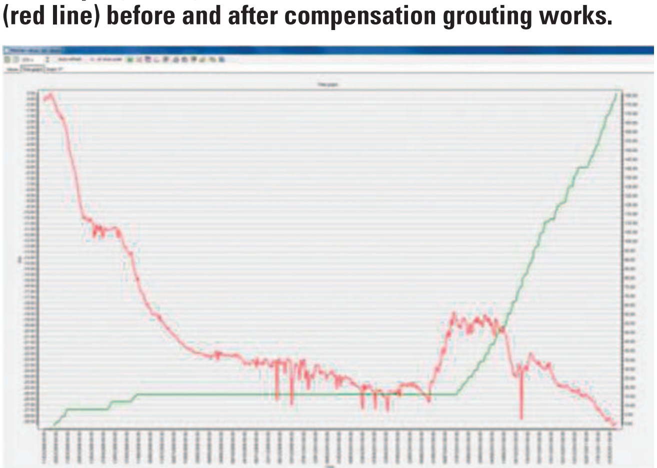


FIG. 12

Tunnel progress (green line) and settlement on road surface (red line) before and after compensation grouting works.



possible damage. The transversal differential deformations (up to 2.8 mm/m) were more damageable to the buildings than the longitudinal ones.

Unpredicted behavior in the Marchand area

This area was anticipated to be the most critical on the project, as most of the problems encountered during the north tunnels were located in the vicinity of this area. The design of the support system was the heaviest of all the alignment, with Umbrella arch, double 220 I-beams and 180 I-beams. The fiberglass blots on the section were repeated every 4.5 m (15 ft).

Since the beginning of the excavation in that area, important settlements were measured on two buildings (K6 and K7). These early settlements would have resulted in unacceptable final deformation for the buildings after the tunneling. An additional compensation grouting program was implemented to prevent further damage to the buildings. The initial settlement hollow below the K6 and K7 buildings is shown in Fig. 11.

Thanks to the real-time settlement monitoring program and feedback analysis, major damages were avoided and construction could proceed.

The real-time surface monitoring program was combined with the compensation grouting monitoring program to have a global control on the operations and ensure the safety of this sensitive operation. Figure 12 shows the evolution of settlement of the K6 building in relation to the tunnel excavation progress, as well as the control of settlements made possible thanks to the compensation grouting program. Correlation between real time settlement data and construction progress was a key to a rigorous risk management.

Conclusion

The Toulon South Tunnel project is a typical example of challenging urban tunneling project in a difficult environment. Thanks to the lessons learned during the construction of the north tunnel, most of the damages were avoided. For this purpose, innovative monitoring solutions, combined with a powerful data management system, have been implemented. However, in some specific areas, the initial design was not enough to anticipate completely some unexpected and abnormal soils behaviors. However, the real-time monitoring program helped to limit the impact of such phenomena and certainly avoided the same type of collapse that happened during the first phase.

The applications of such an approach are unlimited. Not only could this method allow cost savings optimizations during the design process, but it could also limit the impacts of all the risk factors associated with a construction project (delay, collateral damages, cost overruns).

This dynamic process is only possible if the three actors (design engineer, monitoring company and general contractor) work together and use the right tools. (References available from the authors.) ■

FEATURE ARTICLE

2012 Fox Conference turns its focus to international projects

For the first time in its history, the George A. Fox Conference let its focus venture away from the friendly confines of the East Coast of the United States to spend part of the one-day conference looking at projects from around the globe.

With a record-setting attendance of 377 people, the conference, titled "Tunneling: An international perspective," opened with a keynote speech from special guest In-Mo Lee, professor, Korea University in Seoul, South Korea. He is also the president of the ITA-AITES. In a sweeping presentation, Lee walked the packed audience through some of the most fascinating and challenging projects in his home country. Among the projects he spoke about were Korea's longest railway tunnel, the Solahn Tunnel and the Inje Tunnel, a freeway tunnel that is 11.94 km (7.4 miles) long.

Lee also discussed the technical issues in tunneling and the importance of geology in tunneling, as well as the positive impact tunneling can have on a region and the environment. Speaking of the Nowon and Samsung subway projects in Korea, Lee pointed out impressive growth that occured after the completion of the stations. Had it not been for the subway stations, the areas would not have grown the way they have, said Lee.

Lee also spoke of some of the most signficant challenges faced by the industry, including ground water, ventillation and tunneling under existing structures and in densely populated urban areas — a topic many in the New York audience could relate to.

The international flavor of the conference continued through the morning session of the conference.

Felix Amberg, president Amberg Engineering spoke about the Alp Transit Gotthard Base Tunnel.

The twin-tube 57-km- (35-mile-) long Gotthard Base tunnel is the key element of the new highspeed railway link through the Swiss Alps connecting the north and south of Europe with the world's longest tunnel.

After 11 years of construction, the project saw its breakthrough in October 2011. Four Herrenknecht tunnel boring machines (TBMs) were used to carve out a total of 157 km (94 miles) of tunnels, galleries, cross passages and shafts. The tunnels are expected to go into operation in 2016.

Amberg spoke of the history and politics behind the tunnel and the financing hurdles of the project, as well as the technical challenges.

Among the technical challenges were intermediate attacks through an 800-m- (2,600-ft-) deep vertical shaft, TBM drives under more than 2,500 m (8,200 ft) of overburden, rock temperatures in excess of of 43° C (110º F), squeezing rock formations with more than 1 m (3 ft) deformation and rock burst phenomena.

Keynote speaker In-Mo Lee opened the 2012 conference.

Amberg also spoke about how environmental matters were integrated in the project.

A little closer to home for the conference was the presentation from Brian Garrod, executive vice president, Hatch Mott MacDonald, who spoke about the lessons he and his team learned on the Niagara Tunnel Project, a 10.4-km (6.5-mile) tunnel project that will increase the power supply for owner Ontario Power Generation (OPG) by 150 MW and will help to bolster the current power system. The system is close to exceeding its capacity during peak months.

To bore the large tunnel, construction contractor Strabag AG used a main beam TBM built by Robbins. This 14.4-m (47.5-ft) TBM is the largest in the world and included a 105-m- (345-ft-) backup system that transported 1.7 million m^3 (2.2 million cu yd) of muck during three years of work.

Perhaps the most significant challenge faced on the project arose when the TBM encountered the Queenston shale formation after about 793 m (2,600 ft) of excavation. Large rock blocks started to fall from the crown before rock support could be placed. In some cases, significant over-break up to 3 m (10 ft) above the cutterhead support was reported.

Strabag ultimately designed a unique ground support system to cope with the geology, which consisted of 9-m- (30-ft-) long pipe spiles

William Gleason, Senior Editor

in an umbrella pattern at the crown of the tunnel. Using the new spiling method, over-break was limited to about 1 m (3 ft) above the normal tunnel diameter. Nearly 500 m (1,640 ft) of very difficult ground was excavated using this method, at average rates of about 3 m (10 ft) per day.

The new ground support program, done for all excavated ground, consisted of 3- to 4-m- (10- to 13-ft-) long rock bolts, self-drilling anchor bolts, steel straps, wire mesh and wire-reinforced shotcrete. Crews typically bored half a stroke, then began scaling down loose rock and installing rock bolts. After the full 2 m (6 ft) stroke, the rest of the loose rock was scaled down before installing more rock bolts, wire mesh, steel straps and a layer of shotcrete.

OPG and the contractor also opted to alter the vertical alignment of the tunnel, raising it 46 m (150 ft) to move the tunnel out of the Queenston shale. After 1,981 m (6,500 ft), rock conditions were competent enough that spiling was no longer required.

Because of these unforseen setbacks, Garrod joked that one of the lessons learned was "Don't produce and distribute t-shirts showing the completion date at the TBM launch event."

From the large project that is in the finishing stages to one that is just starting, Mike King of Halcrow Group Ltd., spoke about Crossrail, the largest infrastructure project in Europe. Like many other cities in the world, London is growing and with this growth comes increased congestion on its streets. Crossrails will relieve this congestion with an upgrade to 28 current surface stations and the creation of eight new underground stations. Five will be mined and three will be built with cut-and-cover methods.

The first two TBM's for this project will begin working in April and the project will include 22 km (14 miles) of twin bored tunnels.

Other international projects that were discussed included high-speed rail in Spain, the Hallandsas Railway Project and the SMART Project, a dual use traffic tunnel in Kuala Lampur that operates as a roadway traffic tunnel with two levels, as well as a flooding overflow option for Kuala Lampur's city center, which floods often during the storm season.

East Coast

The theme of the conference returned to the United States in the afternoon session. Michael McHugh, vice president Moretrench American Corp., kicked things off with his traditional East Coast update, a look at the extensive list of projects happening all along the East Coast.

Among the biggest of these projects is the East Side Access project, a subway tunnel that will transform how thousands of people commute to and from Manhattan.

Of particular focus was a technically challenging 37-m (120-ft) Northern Boulevard Crossing presented by Kevin Clarke, project manager, Schiavone/Kiewit and Phillip Stummvoll, construction manager, Hatch Mott McDonald.

Outside of New York City, McHugh spoke about a number of ongoing projects including the $2.6-billion Clean Rivers project in Washington D.C. that aims to eliminate combined sewer overflows to the Anacostia and Potomac rivers at Rock Creek with a series of tunnels to be built during the next 15 years.

South Boston CSO storage tunnel project

John Davies, senior associate with Hatch Mott MacDonald, spoke about the South Boston combined sewer overflows (CSO) storage tunnel project. There are seven old CSO in the South Boston area that are not capable of handling the storms. This results in an average of 20 discharges a year on the beaches of South Boston.

The solution for this is a 3,300-m- (10,900-ft-) long, 5.8-m- (19.3-ft-) diameter tunnel with storage capacity of 18.5 million gallons to store CSO overflows during a storm. It is the single largest project for the Massachusetts Water Resources Authority.

The project was completed five months early, $32 million under budget and was given the 2011 NACWA National Environmental Achievement Award.

Second Ave. subway

Andrejs Delle, project manager, Schivone-Shea-Kiewit joint venture and Anthony Del Vescovo, vice president of tunnel operations for Schiavone Construction, closed the conference with a presentation about cavern mining and heavy civil structural work for the Second Ave. subway.

Under the current plan, the Second Ave. subway will be built in four phases. The first phase, which is ongoing, will include tunnels from 105th St. to 63rd St. along Second Ave. Three new stations will be built, as will a connection.

The project is being excavated using drill-and-blast methods and has unique challenges of New York City including the many historical buildings that require shoring and reconstruction of basements.

The surface operations have also been challenging, as the site is in the heart of the Upper Eastside of Manhattan, a very affluent and densely populated residential neighborhood with many shops and restaurants at street level. The surface site area on Second Ave. is less then one tenth the size of the excavation area below ground, yet SSK has roughly two travel lanes and a part of the sidewalk along four city blocks as staging and laydown area.

Because of the limited area to work a 52-m- (170-ft-) long, 9-m- (30-ft-) wide, four-story tall muck house was built to create a controlled environment, which conceals the massive construction that is taking place below ground and provides an innovative and environmentally friendly community sensitive solution to project requirements.

Other projects featured were slurry tunnels for East Side Access in Queens, a siphon tunnel between Brooklyn and Staten Island, and the Second Ave. subway. ■

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Gateway Tunnel project	Amtrak	Newark	NJ	Subway	14,600	24.5	2015	Under study
2nd Ave. Phase 2-4	NYC-MTA	New York	NY	Subway	105,600	20	2012-20	Under design
Water Tunnel #3 bypass tunnel	NYC-DEP	New York	NY	Water	20,000	22	2015	Under design
Water Tunnel #3 Stage 3 Kensico	NYC-DEP	New York	NY	Water	84,000	20	2017	Under design
Cross Harbor Freight Tunnel	NYC Reg. Develop. Authority	New York	NY	Highway	25,000	30	2016	Under design
Silver Line Extension	Boston Transit Authority	Boston	MA	Subway	8,400	22	2014	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 Northeast Branch Tunnel Northeast Boundry Tunnel Virginia Ave. Tunnel Expan. Dulles Silver Line Phase 2	DC Water and Sewer Authority CSX Railroad WMATA	Washington	DC	CSO CSO CSO Rail Subway	12,500 11,300 17,500 4,000 Various	23 15 23 40 20	2013 2018 2021 2012 2014	Under design Under design Under design Under design Under study
ISCS Dekalb Tunnel	Dekalb County	Decatur	GA	CSO	26,400	25	2013	Under design
Olentangy Relief Sewer Tunnel	City of Columbus	Columbus	OH	Sewer	58,000	14	2013	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
Doan Valley Storage Tunnel	NEORSD	Cleveland	OH	CSO	9,700	17	2015	Under design
Lower Mill Creek CSO Tunnel - Phase 1	M.S.D. of Greater Cincinnati	Cincinnati	OH	CSO	9,600	30	2013	Under design
Lower Mill Creek CSO Tunnel - Phase 2	M.S.D. of Greater Cincinnati	Cincinnati	OH	CSO	1.500	30	2015	Under design
Black River Storage Tunnel	City of Lorain	Lorain	OH	CSO	5,700	19	2011	Walsh/Super JV low bidder
ALSCOSAN CSO Program	Allegheny Co. Sanitary Authority	Pittsburgh	PA	CSO	35,000	30	2016	Under design
St. Louis CSO Expansion	St. Louis MSD	St. Louis	MO	CSO	47,500	30	2014	Under design
Drumanard Tunnel	Kentucky DOT	Louisville	KY	Highway	2,200 x 2	35	2012	Under design
Deep Rock Connector Tunnel	City of Indianapolis DPW	Indianapolis	IN	CSO	40,000	18	2011	Shea-Kiewit JV low bidder

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Pogues Run Tunnel	City of Indianapolis DPW	Indianapolis	IN	CSO	11,000	18	2013	Under design
North Link Light Rail Extension	Sound Transit	Seattle	WA	Transit	35,000	22	2014	Under design
East Link Light Rail Extension	Sound Transit	Seattle	WA	Transit	30,000	21	2016	Under design
Chinatown NATM Station	San Fran. Muni Transit Authority	San Francisco	CA	Subway	340	60	2012	Under design
Third Ave. Subway Tunnel	San Fran. Muni Transit Authority	San Francisco	CA	Subway	10,000	22	2013	Under design
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 Phase 1 Phase 2 Phase 3	Los Angeles MTA	Los Angeles	CA	Subway	42,000 26,500 26,500	20 20 20	2013 2014 2016	Under design Under design Under design
LA Metro LAX to Crenshaw	Los Angeles MTA	Los Angeles	CA	Subway	12,200	20	2013	Under design
LA CSO Program	L.A. Dept. of Public Works	Los Angeles	CA	CSO	20,000	14	2014	Under design
CALTRANS Freeway 710 Tunnel	CALTRANS	Long Beach	CA	Highway	26,400	38	2016	Under design
SVRT BART	Santa Clara Valley Trans. Authority	San Jose	CA	Subway	22,700	20	2014	Under design/ delayed
BDCP Tunnel #1	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	40,500	18	2012	Under design
Yonge Street Extension	Toronto Transit Commission	Toronto	ON	Subway	15,000	18	2015	Under design
Downtown LRT Tunnel	City of Ottawa	Ottawa	ON	Transit	21,000	18	2012	Prequalified JV's announced
Second Narrows Tunnel	City of Vancouver	Vancouver	BC	CSO	3,600	14	2013	Under design
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	Hochtief-Flatiron JV awarded

AWARDS

Edgerton receives the Golden Beaver Award

William W. Edgerton, chairman of Jacobs Associates, received the 2012 Golden Beaver Award for Engineering at an awards dinner on Jan. 13, 2012, at the JW Marriott Hotel in Los Angeles, CA. The award was given by the Beavers Heavy Engineering Construction Association, a national organization of construction companies and firms engaged in the heavy engineering construction industry. The Golden Beaver Award is one of the highest honors in the field of heavy engineering construction.

Edgerton's engineering career spans 41 years and includes 17 years working for contracting firms, such as A.S. Wikstrom, Morrison-Knudsen and the Driggs Corp. He received his B.S. in civil engineering from Tufts University and earned an M.B.A. from George Washington University. Edgerton joined Jacobs Associates in 1987 and served as president from 1999 to 2011. During his career at Jacobs, he has been involved with major tunnel and infrastructure projects throughout the United States, as well as in Puerto Rico and Hong Kong.

EDGERTON

In 2002, Edgerton received the American Underground Association's Outstanding Individual Award for the Underground Industry. Some of his most notable projects include the Cove Point Liquefied Natural Gas (LNG) Receiving Terminal in Cove Point, MD, the Tren Urbano – Rìo Piedras Contract in San Juan, Puerto Rico, and the Brightwater Conveyance System project in Seattle, WA. ■

PERSONAL NEWS

SHAWN PAROLINE recently joined Jacobs Associates as a lead associate in the Claims Group. He is based in southern California, working out of the Pasadena and San Diego offices. He has more than 17 years of experience in construction management and program management for public works infrastructure.

Paroline specializes in preparing contract phasing language for complex projects, turnaround of troubled projects, contemporaneous schedule review and monitoring, change management, claims avoidance, delay analysis and developing CPM scheduling specifications. He has served as a construction manager, chief schedule engineer or claims analyst on major California public works building and civil infrastructure programs. ■

MEETINGS

NATJ will host TBM tunneling conference in April

The *North American Tunneling Journal* (NATJ), in conjunction with the UCA of SME, will present the Cutting Edge — Pressurized TBM Tunneling Conference 2012 at the JW Marriott Hotel, Miami, FL, April 23-24, 2012. The meeting will review state-of-the-art tunneling technology and facilitate discussion on the key issues faced during modern day pressurized TBM tunneling.

Sunny Miami is the site of the April tunneling conference.

Informative presentations from worldwide experts, panel debate and forum sessions, a tailored exhibit and the opportunity to visit the Port of Miami Tunnel project site will highlight the two-day conference. The conference will also cover topics such as project specific approaches to TBM selection, procurement and operation; ground control, face support and monitoring; ground conditioning and slurry systems; TBM interventions and hyperbaric safety; research and development and tunnel-lining systems and annulus grouting.

NATJ plans to donate 10 percent of its share of any profits to the UCA of SME's new student scholarship fund, which will be used to sponsor students whose studies specialize in the underground construction industry.

For more information about the conference, exhibit or sponsorship opportunities, contact Amanda Foley, phone 603-452 7577 or e-mail amanda@tunnelingjournal.com. ■

March 2012

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.

27-29, 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.

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.

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

April 2012

23-24, Cutting Edge - 2012 National Seminar on Pressurized TBM Tunneling, JW Marriott Hotel Miami, Miami, FL. 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.

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.

October 2012

17-20, Montreal TAC 2012 - Hyatt Regency Hotel, Montreal, Quebec, Canada. Contact: Marriott Indianapolis, Indianapolis, IN. Contact: Wayne Gibson, conference manager, phone 604-241-1297, e-mail info@tac2012.ca. ■

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