T&UC

TUNNELING & UNDERGROUND CONSTRUCTION

THE OFFICIAL PUBLICATION OF UCA OF SME WWW.TUCMAGAZINE.COM VOLUME 3 NO 4 DECEMBER 2009

Atlanta's South Cobb tunnel project

Grouts made from ultrafine cement

Planning Los Angeles' subways

Tunnel Demand Forecast

Special Editorial Section from the publisher of *Mining Engineering*

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COVER STORY

CONTENTS — The South Cobb Tunnel and Pump Station project in Atlanta, GA will include the 8.8-km- (5.5-mile-) long South Cobb waste water tunnel. When completed in about four years, the tunnel will help the fast-growing southern part of Cobb County in addressing its waste water capacity needs. Cover photo by Dwayne Easterling, Jacobs Associates.

TUNNELING & UNDERGROUND CONSTRUCTION (ISSN 0026–5187) is published quarterly by the Society for Mining, Metallurgy, and Exploration, Inc., at 8307 Shaffer Parkway, Littleton, CO, 80127–4102. Phone 1–800–763–3132 or 303–973–9550. Fax: 303–973 –3845 or e-mail: sme @smenet.org. Website: www.smenet.org. **POSTMASTER:** Send changes of address to TUNNELING & UNDERGROUND CONSTRUCTION, 8307 Shaffer Parkway, Littleton, CO, 80127–4102. Article copies and back issues available on microfilm or microfiche from Linda Hall Library in Kansas City, Mo. Printed by Cummings Printing Co.

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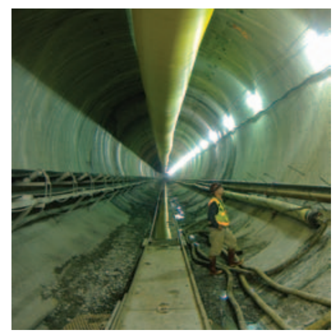

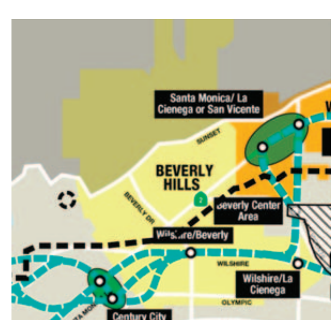

Special editorial section from the publisher of *Mining Engineering*

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CHAIRMAN'S COLUMN

UCA of SME Chairman's fourth quarter report

I am pleased to report that the Underground Construction Association of SME is quite strong, as its membership continues to increase. The members of the UCA of SME Executive and working committees are working to support the membership and the industry by planning the NAT 2010 and working on special committee projects. One of the main goals of our organization is to be a conduit for the exchange of ideas and technical information in a professional format that will benefit our society, industry and membership.

On Sept. 10 and 11, 2009, the UCA held the Shaft Design and Construction Short Course in Atlanta, GA. The short course was coordinated by Jamal Rostami from Pennsylvania State University. On behalf of the Executive Committee, I want to thank Dr. Rostami for his efforts in the coordination and planning of the short course. There were 22 papers given along with a site visit to the South Cobb Tunnel Project. I want to thank Dan Martz, project manager, Shea-Traylor JV and Refik Elibay, director-tunneling services, Jordon Jones and Goulding Inc., for facilitating the site visit. It is very important to observe actual projects under construction. The feedback I received from the industry was most positive, a job well done by all involved.

As I write this column, I am pleased to state that the tunnel industry remains strong. During the past three months, I have been to Europe twice for business and the tunnel market there is also quite vibrant compared when other types of construction. Wherever I travel in the United States and abroad, I am advised that there is still a strong demand for experienced tunnel design engineers and tunnel construction personnel. The UCA has established a Student Outreach Program and a scholarship fund to assist the industry in meeting future industry staffing requirements. I would encourage all members to contribute to the scholarship fund, as this is important to our future.

The UCA is still accepting nominations for awards to be given out at NAT 2010 for the following categories: Lifetime Achievement, Outstanding Individual, Outstanding Educator and Project of the Year. Nominations should be sent to Mary O'Shea at the UCA of SME, phone 303-948-4211, e-mail oshea@smenet.org. Please make plans now and budget accordingly to send your personnel to NAT 2010. Mark Ramsey and the conference committee are developing an excellent program.

As I travel across North America and Europe, I am always asked if the federal stimulus money, formally called the American Recovery and Reinvestment Act (ARRA), is benefiting our industry. The truth is that there is some benefit but not as great as the general public may think. Of the $787 billion appropriated, only about $140 billion has been allocated to infrastructure construction projects. And this money is divided among the various federal agencies. Some of the major transportation projects in the New York-New Jersey area and the Caldecott Tunnel in California have received federal funding and we are starting to see some mid-sized utility tunnels come out for bid. But the industry must now be aware of how each project is funded.

On Nov. 4, 2009, I attended a legal seminar in New York City for Moles members titled "Contracting with Federal Dollars," conducted by the law firm of Smith, Pachter, McWhorter, PLC. The industry

Continued on page 42

David R. Klug,
UCA of SME Chairman

Four Lovat TBM's to go to work on Spadina subway extension

When construction on the Toronto-York Spadina Subway Extension project begins in 2010, four Lovat RME241 SE earth pressure balanace (EPB) tunnel boring machines (TBM) will be used to carve out twin-bored tunnels for the 8.6-km- (5.3-mile-) long subway extension.

The tunnels will extend northwestward from the existing subway and will include six stations.

Ground conditions anticipated along the tunnel alignment consist of quaternary deposits consisting of glacial till, glaciolacustrine, and glaciofluvial sand, silt and clay deposits, and beach sands and gravel. Cobbles and boulders are anticipated along the tunnel alignment with compressive strengths of up to 185 Mpa. The entire tunnel alignment is below ground water levels.

Each 6.12-m- (20-ft-) diameter mixed face TBM will be equipped with Lovat chromium carbide -plated ripper teeth manufactured with high tensile steel, interchangeable with 394 mm (15.5 in.) disc cutters. The main drive consists of variable frequency drive electric water-cooled motors providing a total of 1,200 kW (1,600 hp) available power to the cuttinghead.

The project is expected to cost \$2.6 billion and is expected to be completed in 2015.

To ensure the project schedule is met, the design and manufacturing process for each machine is already under way.

The first two TBM's are expected to be delivered in winter 2010, and tunnel excavation is anticipated to begin shortly afterwards.

The remaining two machines are expected to be delivered by spring 2011. ■

M29 transmission feeder line nears completion

A 15 km (9.5 mile) tunnel under New York's Harlem River that will carry 345-kW of power from Consolidated Edison's Sprain Brook power station in Yonkers to the New Academy susbstation in Manhattan is expected to be completed soon.

Excavation of the shaft was completed in late October and the concrete pouring for the shaft is expected to be completed in January with the entire project scheduled for a June 2010 completion.

The project, called Consolidated Edison's M29 Transmission Feeder Line, is a \$432-million project that required digging a 201-m (660-ft) subriver tunnel, running high-voltage lines for 16 km (10 miles) and repurposing an out-of-date facility with a new switching station. The project used existing Con Edison land and rights of way.

The project's big aim is to offer a stopgap power source to an Upper Manhattan district that has made headlines several times in recent years because of localized blackouts. It will connect to Upstate power sources in Westchester County through a new feeder line running south through the Bronx, down through the new tunnel under the Harlem River and over to the new Academy Switching Station in Manhattan's Inwood neighborhood. The 350 MW of electricity the lines could supply is close to the production of a mid-sized power plant, and the project will fill other goals in the region, such as laying groundwork for backup capacity that can reach as far south as 49th Street in Manhattan.

Work began in November 2007 at the Academy site.

As part of the project, Con Edison created two tunnel shafts, one around the River Plaza shopping center on the north side of the Harlem River, and the other around NewYork-Presbyterian Hospital's campus on the south side of the river. The shafts have been built using the drill-and-blast method, 33 to 39 m (109 to 128 ft) below the ground level.

The team, which includes Kiewit Constructors as general contractor on an \$85.2-million contract, will later add waterproof membranes, reinforcing steel and concrete liners to cap the effort.

When completed in April 2010, the 3.6-m- (12-ft-) wide, 3.9-ft- (13-ft-) high horseshoe-shaped tunnel will be ready for installation of the 345 kV feeder cable, other utilities and a 152-mm-(6-in.-) diameter return line circulating oil back and forth in order to control temperature levels.

Con Edison has a 914-mm (36-in.) cast iron gas main that was built in 1912 crossing under the river. The new tunnel will reinforce that supply with a new 406-mm- (16-in.-) high-pressure main, bringing gas from the Bronx to the tip of Manhattan. And several electric distribution feeders will connect Manhattan power sources to reinforce the Riverdale neighborhood of the Bronx, backing up some of the cables in use since 1913 to 1918. ■

Hatch Mott MacDonald awarded New Irvington tunnel contract

The San Francisco Public Utilities Commission (SPPUC) has selected Hatch Mott McDonald to perform construction management services for $230 - $263 million on the New Irvington tunnel project.

The existing Irvington tunnel, which was built in the 1930s, is the lifeline of an extensive system delivering drinking water to Bay Area residents. If damaged in an earthquake, repairs could not be made to the tunnel without disrupting water service. A new tunnel will be constructed parallel to the existing tunnel using modern engineering and construction techniques to withstand a major earthquake and ensure uninterrupted flow to customers. Construction is expected to begin in spring 2010 and be completed in 2013.

Black & Veatch (B&V) and CH2M Hill were chosen as major sub-consultants for the project, in addition to Local Business Enterprise (LBE) subconsultants: ARA Engineering Group, Lee Inc., Thier PR and Applied Technology & Science. More than 18 percent of the total scope of work is committed to LBE sub-consultants. The project's construction manager will be Dan McMaster, a senior tunneling expert with Hatch Mott MacDonald who has constructed nearly 80 km (50 miles) of tunnels.

"We are delighted to be selected for this vital water project," said Ervon Koenig, Hatch Mott MacDonald's vice president and San Francisco area manager. "The New Irvington tunnel demonstrates the SFPUC's ongoing commitment to providing its growing customer base with clean, dependable drinking water. We're looking forward to working with them on this exciting project."

Hatch Mott MacDonald is an engineering company with roots dating back 100 years with 59 offices and 1,900 staff in North America, and access to staff resources of more than 22,000 worldwide. ■

California governor vetos freeway tunneling bill

California Gov. Arnold Schwarzenegger vetoed a bill that would have eliminated the possibility of constructing a surface route for Interstate 710 to complete the "missing link" of Los Angeles' highway system. If he had signed it, a tunnel route would have been the only way to finish that controversial freeway, the *Los Angeles Times* reported.

Interstate 710 ends at Valley Boulevard at the edge of Alhambra. It does not connect to the interchange of the 134 and 210 freeways.

Construction on the 710 began in 1951 but stopped short of completion in 1965 because of South Pasadena residents' assertions that the freeway would divide their community.

As a compromise, transportation officials in recent years introduced the idea of a tunnel — at least 7.2-km- (4.5-miles-) long — to connect the route. The tunnel bill, SB 545, was written by state Sen. Gil Cedillo (D -Los Angeles).

Schwarzenegger said in his veto letter that the bill was unnecessary and he said Caltrans and the Los Angeles County Metropolitan Transportation Authority should be allowed to study various ideas without the restrictions in the bill.

"There is absolutely no need to enact statutory restrictions that would mandate certain project design options or remove others from potential consideration," he said. "In addition, several properties belonging to the state would be subject to sale for less than fair market value as a result of this bill, resulting in the loss to the state of hundreds of millions of dollars." ■

Austin buys lot for Waller Creek tunnel construction area

Austin city officials are negotiating to buy a half-block parking lot in the Waller Creek corridor, the *Austin Business Journal* reported.

For about four years, the lot will be used for massive tunneling operations, Gary Jackson of the Public Works Department said at an advisory committee meeting.

The project will remove more than 93,000 m^2 (1 million sq ft) of land from the floodplains of the lower Waller Creek watershed, allowing denser development in the area.

Because of ongoing negotiations with different property owners, he declined to discuss a price range.

After construction is completed, the lot will either go on the market, be used by city departments or be used for a range of other projects.

The city hopes to close the deal before spring.

The city had initially approached the owners about a long-term easement, but the owners said they would rather sell it, Jackson said.

An easement allows someone or an entity besides the land owner to use the property. ■

Balfour Beatty to acquire Parsons Brinckerhoff

London-based Balfour Beatty, the engineering and construction services group, announced in September that it is buying Parsons Brinckerhoff, the American professional services company, for $626 million.

Parsons Brinckerhoff is the world's 11th largest engineering design company and is famous for designing New York's first subway. More recently, it has worked on the Bay Area Rapid Transit, San Francisco's public transport network.

Ian Tyler, Balfour's chief executive, said the deal was a key step in making the company a global integrated leader in infrastructure services and would strengthen its position in emerging markets. It would also put Balfour Beatty in a better position to take advantage of increased infrastructure spending.

"In professional services, this will make us very much a global player. The combination will create huge value and, as a project manager in particular, it gives us an opportunity to work in territories we simply couldn't move into, such as India, China and South Africa," he said.

The proportion of Balfour's turnover generated in the United States would rise from 28 percent to 35 percent after the deal. He added that the key issue for New York-based Parsons Brinckerhoff, which is owned by 4,750 of its 12,650 employees, had been coming up with a way of ensuring its top managers were happy with the deal.

Keith J. Hawksworth, the chief executive officer of Parsons Brinckerhoff said, "We have for some time sought a strategic partner that complements the services we provide that would assist us in our ongoing global expansion," Hawksworth said. "Balfour Beatty shares our values, our culture and our commitment to professionalism, integrity and technical excellence – principles that have guided us for nearly 125 years and Balfour Beatty for the last century."

In a letter to all employees, Hawksworth explained, "The combination [of Balfour Beatty] with PB creates an organization with world-class capabilities in project development (including financing), design, management or delivery of construction services, and the operations and maintenance that can be provided through our combined local office-global footprint."

Parsons Brinckerhoff, which last year had global revenues of $2.34 billion, now has 150 offices worldwide, including 13 across the United Kingdom, including sites at Bristol, Exeter, London, Birmingham, Manchester and Glasgow.

The publicly traded Balfour Beatty (London Stock Exchange, BALF.L) has approximately 40,000 employees and last year had revenues of approximately $15 billion. ■

MTA awards $659 million East Side Access contract

A joint venture team of Granite Construction Northeast Inc., Traylor Bros. and Frontier-Kemper Constructors, Inc., has been awarded a $659-million contract by the New York's Metro Transit Authority Capital Construction (MTACC) to build the Queens Bored Tunnels and Structures for Long Island Rail Road's (LIRR) East Side Access project in New York. In conjunction with the award, the MTACC also issued a full notice to proceed on the project.

The Queens Bored Tunnels and Structures contract is part of the LIRR's East Side Access project and is the last major link in the tunnels from Queens to Grand Central Terminal in Manhattan. When completed, the East Side Access project will bring Long Island Rail Road service, the busiest commuter railroad in the country, into New York's Grand Central Terminal, providing a direct route between Long Island and eastern Queens to Manhattan's eastside.

Scope of the work includes the excavation and the precast concrete lining of four bored tunnels beneath an active rail storage yard. Totaling more than 3,000 linear m (10,000 ft) or nearly 3.2 km (2 miles) in length and approximately 6.7 m (22 ft) in diameter, the tunnels will be excavated utilizing two tunnel boring machines, each weighing more than 453 t (500 st). The work also includes the excavation of three emergency exit structures, underpinning of existing bridges and the demolition of various rail yard buildings. Work on the project will begin immediately and is estimated to take 42 months to complete. ■

New Crystal Springs Bypass gets its TBM

A single-shield tunnel boring machine (TBM) was lowered 47 m (155 ft) to the launch shaft to begin tunneling the New Crystal Springs Bypass Tunnel (NCSBT), a 1,280-m- (4,200-ft-) long horizontal tunnel in San Francisco, CA.

The single shield TBM and trailing gear are 47-m-(155-ft-) long. The main body is 3.7-m- (12 ft, 2-in.-) in diameter with a taper to its tail shield, which is 3.4 m (11-ft, 11-in.-) in diameter because of the potential to encounter squeezing ground. Hitachi-Zosen fabricated the cutterhead and shield Rotek provided the main bearing. Herrenknecht fabricated the 431-mm- (17-in.-) disc cutters. M.L. Shank Co., Inc. designed the machine and the Shank crew assembled it and built the trailing gear on the project site.

The NCSBT will provide redundancy to the existing pipeline and will improve the delivery reliability. The existing pipeline is a 2.4-m (96-in.) prestressed concrete cylinder pipe that was installed in 1969 below the hillside along Polhemus Road. The pipeline and soils in this area are subject to failure during high precipitation or major seismic events. This pipeline is a critical link in the transmission system, carrying water from the East Bay to peninsula cities and San Francisco.

Jacobs Associates is leading the construction management team, which includes client (San Francisco Public Utilities Commission) staff and the Shank/Balfour Beatty Joint Venture, which is the general contractor on the project.

The tunneling process is expected to last approximately six months. The project began in 2008 and is expected to be completed in September 2011. ■

A TBM is lowered at the New Crystal Springs Bypass Tunnel.

Bids for U-Link tunnel project arrive below original estimate

Bids for the U-Link light rail project between downtown Seattle and the University of Washington (UW) were opened in August and the lowest bid came in at $153.5 million, 12 percent below the Sound Transit's original estimate of $173.4 million, the *Seattle PI* reported.

"Contractors are obviously hungry for work and trying to keep their crews working," said King County councilmember Larry Phillips, who chairs the Central Link Oversight Committee. The 22.5-km- (14-mile) Central Link that opened July 18.

"Today was a good news day, continuing the good news of the last several months in terms of the contracts. It bodes well for getting this done on budget and on time in 2016," Phillips said.

Sound Transit opened bids on construction of a dual tunnel between the Downtown Transit Tunnel and Capitol Hill. The lowest bid was submitted by JCM U-Link Joint Venture, made up of Jay Dee Contractors of Livonia, MI.; Frank Collucio Construction Co. of Seattle; and Michaels Corp. of Brownsville, WI, according to Sound Transit.

The next lowest bid, at $154.1 million, was submitted by Kenny/Shea Joint Venture, formed by Kenny Construction of Northbrook, IL and J.F. Shea Construction of Walnut, CA.

The $1.9-billion, 5-km- (3.15-mile-) all-underground line is scheduled to be completed in 2016. It has three tunneling projects, including a longer tunnel between the UW campus and Capitol Hill. Bids on all three contracts have come in much lower than Sound Transit estimated, potentially saving $117 million.

Sound Transit said it will review the lowest bid to "ensure it meets all project requirements and prepare a motion for review by the Sound Transit Board this fall."

Work has already begun at locations of the future stations and along Interstate 5 at Olive Way, where the tunnel boring machines will pass through. The U-Link line is expected to add 70,000 daily riders to the system when it opens. ■

Ground freezing rods keep subway stations dry during excavation work

Congested with automobile and pedestrian traffic from its almost 1 million residents, the streets of Cologne, Germany can be a snarl of traffic on any given day. Underground, though, the city has made a significant investment in its infrastructure, including a new subway line spanning 4 km (2.5 miles) with eight subway stations. Managed by Bilfinger and Berger, Wayss and Freytag and Züblin, the Stadtbahn subway development will travel beneath the "Philharmonie" (city hall) and several market squares. Most of the new subway stations and tunnels are situated below the ground water level, leaving the construction site exposed to the nearby waters of the Rhein River.

To make excavation near the river possible, slurry walls were dug 45-m- (147-ft-) deep to reach the non-aquifer zone and prevent large amounts of ground water from seeping into the tunnels and corridors connecting the subway stations. However, even with the slurry walls in place, the project required the soil surrounding the site to be frozen during construction of the underground stations.

To achieve this, Boart Longyear drilled a total of 1,300 holes in four stations, installing 7,000 m (23,000 ft) of rods. The holes were drilled at a distance of 0.8 to 1.2 m (2.6 to 4 ft) apart, using a drive-drilling method. Standard 108-mm (4.2 in.) rods were used with a specially designed thread to ensure tight joints, in addition to seal material on the inner rod thread to prevent fluid loss. Then, a coolant with a temperature of -35° C (-31° F) was introduced to the rods to lower the soil temperature and cause the ground to freeze. The "freezing method" of soil works like a refrigerator — by using a refrigerating machine that works with ammoniac, the brine cools down to -35° C (-31° F), extracting the heat from the soil.

With an effective cooling radius of 60 cm (24 in.) around each rod, contractors were able to achieve overlapping zones between holes, creating a wall of ice that protected the excavation site by stabilizing soil to a depth of 20 to 26 m (66 to 85 ft).

Operations and engineering personnel from the Boart Longyear Eiterfeld facility in Germany worked in cooperation with the joint venture construction group to execute the freezing rod approach. In addition, the rods were designed to be used as drifting rods to further enhance drilling productivity onsite.

"Wherever incoming water is threatening the construction work, "freezing rods" will solve the problem," said Stefan Hofmann, chief construction site manager, Züblin. The freezing rod approach has already utilized in several additional projects, including the Leipzig Railway Station, where more than 12,000 m (39,300 ft) of rods were installed. ■

More than 7,000 m (23,000 ft) of rods were installed to complete construction of a subway line in Cologne, Germany.

Chile, Argentina to build a pair of trans-Andes tunnels

Chile and Argentina agreed to build road and railway tunnels across their common border in a project aimed at opening two new routes through the towering Andes, officials said.

Chilean President Michelle Bachelet and Argentina's President Cristina Kirchner signed the agreement as part of a broader treaty to promote integration and cooperation along their mountainous 5,000-km (3,100 miles) border.

Bachelet said the agreement was the first of its kind in Latin America, while Kirchner said the aim was to "unite the potential that helps generate better living conditions for our people."

The railway project, which is not new, calls for a 23-km (14-mile) tunnel through the Andes mountain chain to link the cities of Mendoza in Argentina and Los Andes in Chile.

It would take between eight and 10 years to build and cost an estimated $3 billion.

The agreement also calls for boring a second cross-border tunnel through the Andes at Paso de Agua Negra for a highway linking northern Chile and Argentina.

The tunnel would supplement the Los Libertadores tunnel in the central part of the country, which is often closed by snow. ■

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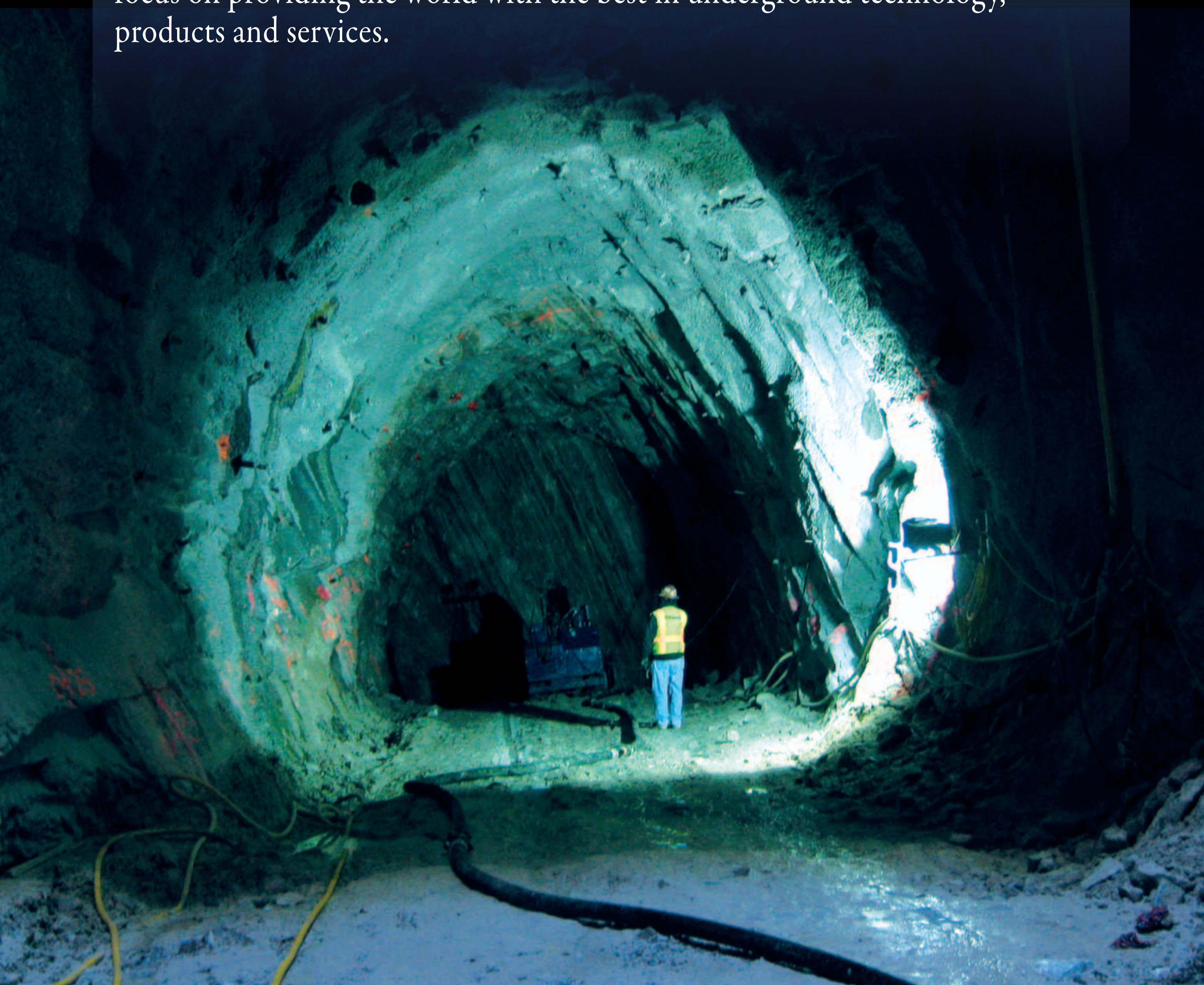

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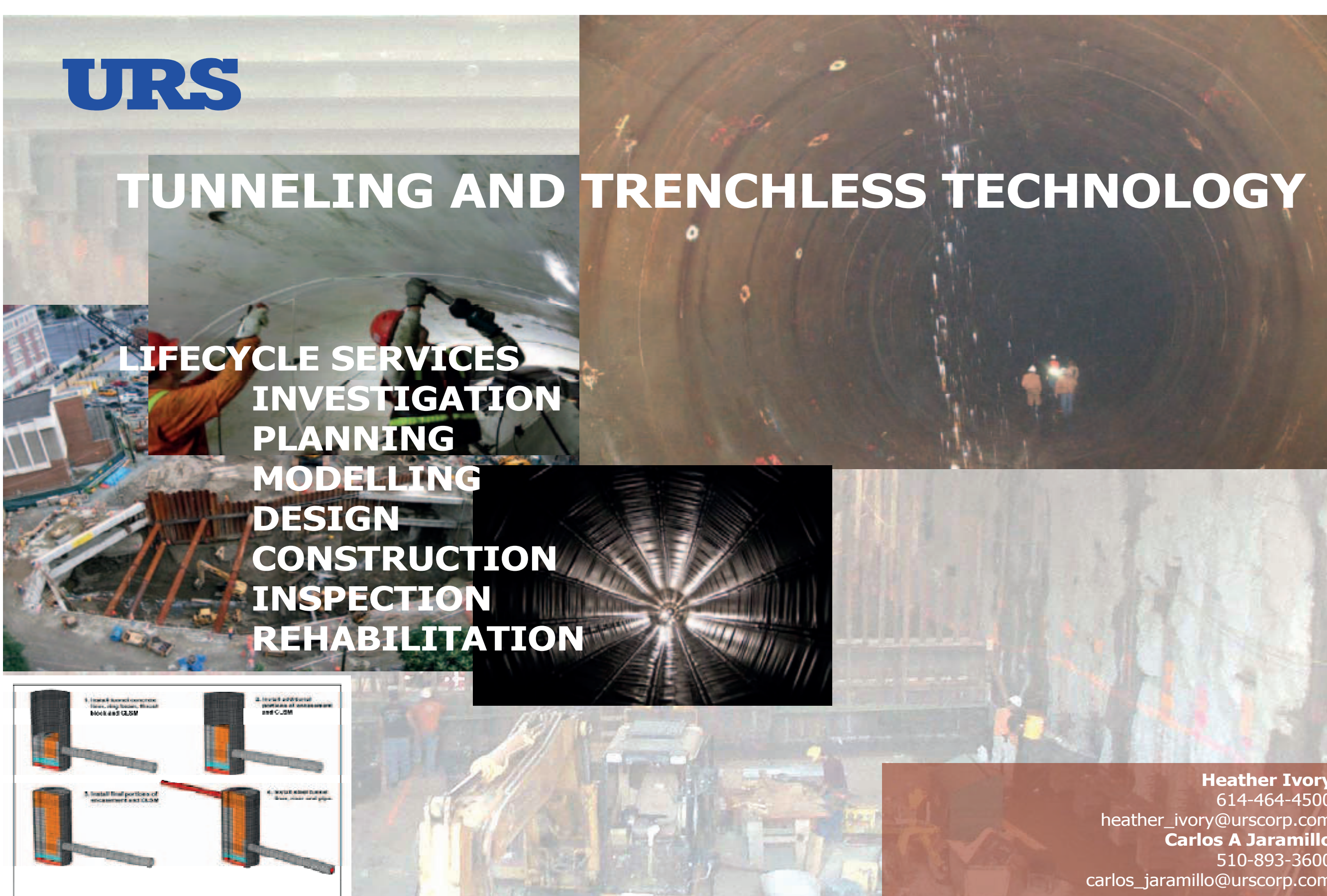

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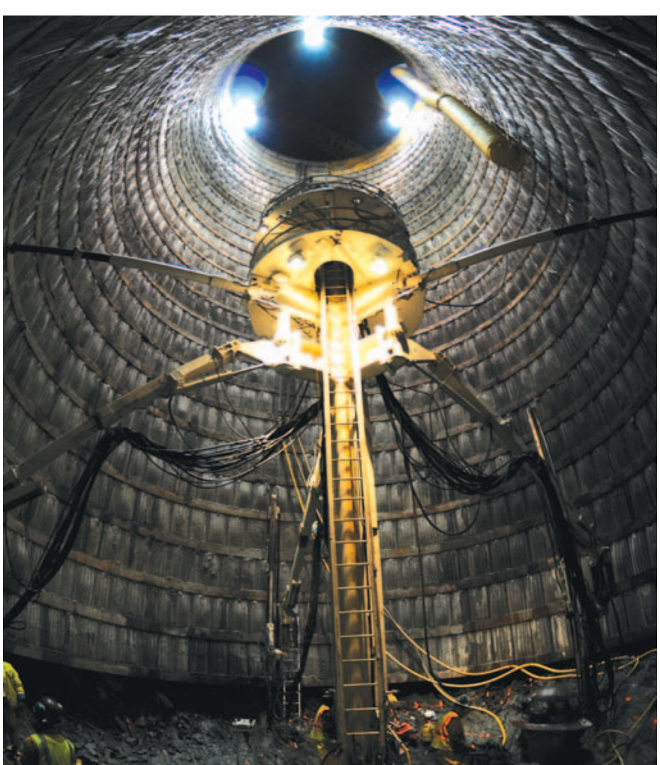

Robbins Revolutionizes Soft Ground Tunneling

The Robbins Company, the world's foremost supplier of advanced, underground construction equipment, is now offering soft ground TBMs worldwide. Robbins Earth Pressure Balance Machines (EPB TBMs) are now making swift headway on a dozen projects in multiple countries. Although known in the industry for its hard rock machines, innovative machine designs are expanding the company's product offerings to now include machines for mixed ground and soft soils at high pressures.

Over 50 years of Experience

In 1952, James S. Robbins developed the first rock tunnel boring machine in South Dakota, after witnessing the relatively slow rates achieved by a prototype drilling and blasting machine. Subsequent TBM designs, at the Humber River Project in 1954, saw the first use of rolling disc cutters—the discs effectively excavated limestone up to 200 MPa (29,000 psi) UCS.

From those inventive beginnings, The Robbins Company has grown into an international supplier of underground equipment, with foundations in the soft ground, hard rock, and trenchless construction markets. Today, 12 offices and 22 representatives are located in 28 countries around the world, with many local offices providing comprehensive support on regional projects.

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In 2010, Robbins will launch three 8.9 m (29.3 ft) diameter EPB TBMs for Mexico's largest infrastructure project—the 63 km (39 mile) long Emisor Oriente waste water tunnel. The tunnel will add much needed capacity to Mexico City's aging and deteriorated sewage system.

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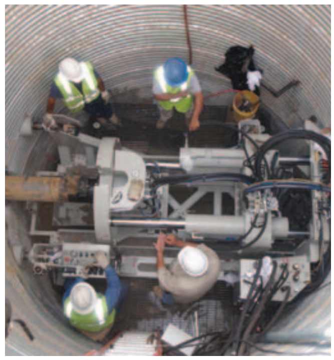

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Akkerman Inc. is located in Brownsdale, MN – USA. For more information on all of Akkerman, Inc.'s products and services please contact us via the web: www.akkerman.com, e-mail: akk@akkerman.com, or by phone: 800-533-0386.

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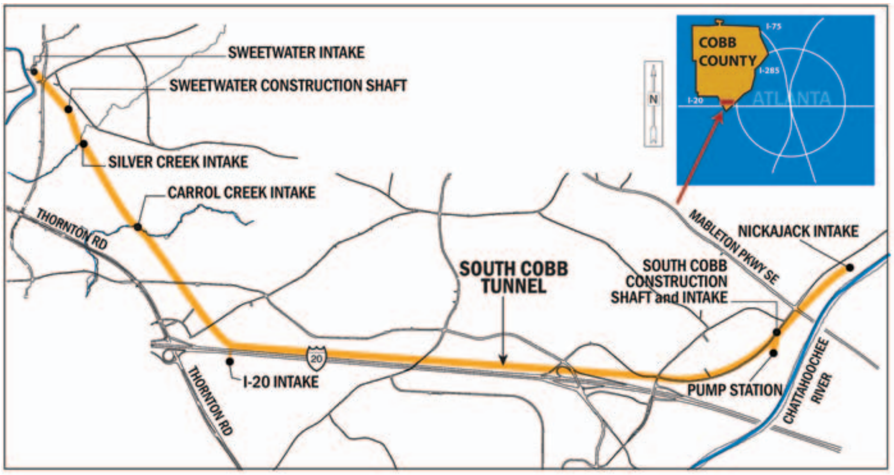
FEATURE ARTICLE

South Cobb Tunnel – Cobb County's solution to meeting future waste water capacity

Cobb County, located on the northwest side of Atlanta, GA, is continually growing and, like many other metropolitan areas, it needs to increase the capacity of its waste water system to meet future demand. The Cobb County Water System (CCWS) is the responsible agency for water distribution, waste water collection and treatment in most areas of the county. CCWS, one of the most progressive agencies in the metro-Atlanta area, is addressing its future waste water capacity needs in the southern part of the county with the construction of the South Cobb Tunnel and Pump Station. This project consists of an 8.8-km- (5.5-mile-) long, 8.2-m- (27-ft-) diameter, tunnel boring machine (TBM) excavated waste water storage and conveyance tunnel; six tangential vortex-flow intakes ranging from 1,533 to 5,700 L/s (35 to 130 mgd) peak flow capacity, two construction shafts, six 1.8-m (6-ft) finished diameter connecting tunnels ranging in length from 6 to 975 m (20 to 3,200 ft) and a 5,700-L/s (130-mgd) wet/dry pit pump station.

FIG. 1

South Cobb Tunnel plan.



The pump station will have a semi-circular wet well with a dividing wall that extends almost to the top of the shaft and a spilt dry well for reliable operation. Roller gates will control the flow to the wet well from the tunnel. The pump station will have six 1,420 L/s (32.5 mgd) pumps and two sets of stair wells and elevators. With a finished diameter of 32 m (104 ft) and a depth of 62 m (204 ft), this is the largest pump station shaft constructed so far in Georgia for the dewatering of a waste water tunnel. The pump station shaft was also the highlight of the well attended and successful 2009 Shaft Design and Construction Short Course held in Atlanta, Sept. 10-11. The two-day course was sponsored by the Underground Construction Association of SME and Pennsylvania State University and concluded with a field trip to the pump station shaft.

Wojciech Klecan

Wojciech Klecan, member SME, is senior associate and tunnel disciple director with Jordan Jones & Goulding, Inc., Norcross, GA, e-mail wojciech.klecan@jjg.com.

The tunnel starts south of the city of Austell and finishes at the South Cobb Water Reclamation Facility (WRF), located on the banks of the Chattahoochee River just north of Interstate 20 (Fig. 1). The South Cobb Tunnel will run 30 to 137 m (100 to 450 ft) below the surface, with an average depth of about 91 m (300 ft), through metamorphic rocks (Fig 2). The construction contract was awarded to Shea-Traylor JV with the lowest bid price of $305 million and notice-to-proceed was given on July 14, 2008. Jordan Jones & Goulding, Inc. (JJG) is the project designer and performed the geotechnical investigations. Parsons/Jacobs Associates is the construction manager.

The South Cobb Tunnel is CCWS's second deep hard rock tunnel. The 15.3-km- (9.5-mile-) long, 5.5-m- (18-ft-) diameter TBM excavated the Chattahoochee Tunnel was the first deep tunnel to be construced in Cobb County. Construction began in 2000 and the project was completed four years later. It is located about 16 km (10 miles) northeast of the South Cobb Tunnel in similar geology. It was designed by JJG to meet east Cobb's long-term waste water capacity needs and provide flow equalization to the R.L. Sutton WRF. The Chattahoochee Tunnel was named "Outstanding Civil Engineering Project of the Year" by the Georgia Section of the American Society of Civil Engineers in 2006.

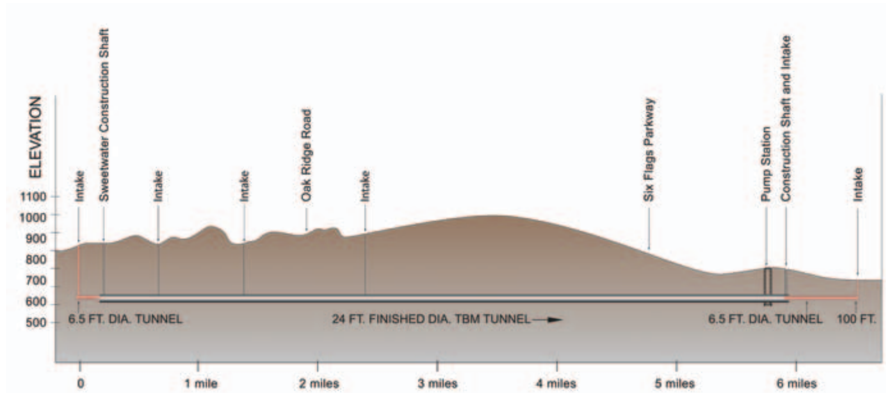
Geology and ground conditions

The South Cobb Tunnel is located in the Piedmont Province of Georgia. It is being bored through medium-grade metamorphic rocks, consisting mostly of granitic gneisses, gneisses, schists, mylonites, quartzites and amphibolites. The rock has a well-developed foliation that dips on average about 35° to the southeast.

A key characteristic of the Piedmont region is the thick mantle of residual soil that grades downward into the underlying bedrock. This sequence is divided into the soil zone, transition zone and bedrock zone. The soil zone consists mainly of saprolite and overlying surficial deposits. Saprolite is residual soil that has the texture, structure and fractures of the parent rock. The transition zone consists mainly of partially weathered rock but can also contain layers of fresh rock and saprolite. The transition zone typically behaves as a weak rock mass. The bedrock zone consists mainly of fresh rock but can also be locally weathered along major fractures.

FIG. 2

South Cobb Tunnel profile.



The topography along the tunnel alignment contains numerous long, linear or slightly curved depressions referred to as "lineaments" that mostly run two directions; southeast to northwest and southwest to northeast. Lineaments are the result of differential surface weathering in which softer layers have eroded more rapidly than the surrounding stronger bedrock or could be indicative of a structural weakness in the rock mass such as deep-seated fracture/shear zones. The rock mass also contains closely to widely spaced joints that generally fall into three groups: foliation joints; north-south high-angle joints and east-west high-angle joints.

Intact fresh rock strengths vary widely depending upon rock type. They range from an average unconfined compressive strength (UCS) of 220 MPa (32,000 psi) for the granitic gneisses and quartzites to about 34.5 MPa (5,000 psi) for the chlorite schists. The average UCS for the 101 samples of rock tested generally perpendicular to the foliation during the site investigation stage was 162 MPa (23,500 psi). The metamorphic rocks along the tunnel alignment contain large amounts of quartz (average quartz content is 47 percent) and even garnets in some places, making the rock abrasive. Cutter wear will be significant, particularly in the granitic gneisses and quartzites. The amounts of quartz and garnet on the South Cobb Tunnel are similar to those from the Chattahoochee Tunnel, but considerably higher than on other tunnels in the Atlanta area.

FIG. 3

Herrenknecht's 8.2-m- (27-ft-) diameter tunnel boring machine. Photo courtesy of Dwayne Easterling (Jacobs Associates).

The intact fresh rock is effectively impermeable. However, water is found in the network of widely distributed fractures throughout the rock mass. The permeability of the rock mass varies considerably and depends on the apertures, density and interconnection of the fractures. It is not uniformly distributed and most of the significant inflow to the tunnel is expected to occur in a few places and long sections of the tunnel will be dry or produce negligible inflow. The foliation joints tend to be the principal pathways for ground water flow in the bedrock zone and become more open as they approach the ground surface.

TBM excavation and initial ground support

The 8.8-km- (5.5-mile-) long tunnel will be excavated using an 8.2-m- (27-ft-) diameter hard rock Herrenknecht TBM (Fig. 3) that was previously used on the West Area CSO Tunnel for the city of Atlanta. The TBM was launched in late August 2009 from the 12.2-m- (40-ft-) diameter, 85-m- (280-ft-) deep Sweetwater construction shaft located on the western end of the project. It is being driven downgrade at a slope of 0.1 percent to the South Cobb retrieval shaft at the eastern end of the project. The TBM had mined 780 m (2,560 ft), about 9 percent completed by Oct. 31, 2009 with a best advance of 42 m (138 ft) in a single day.

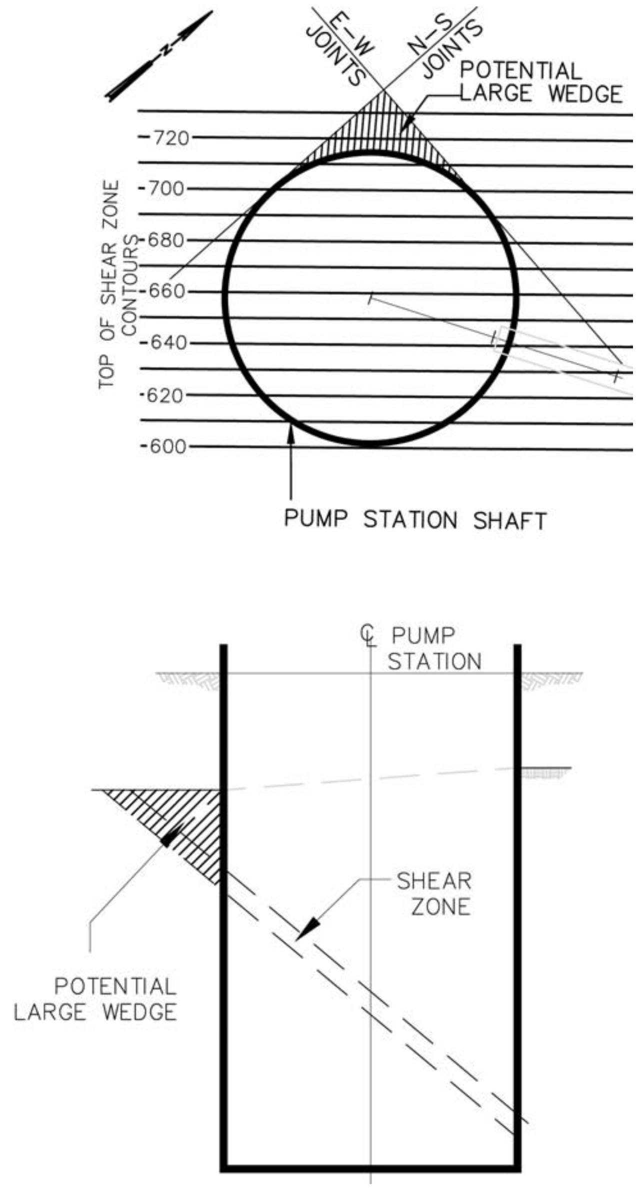
The ground is divided into three types: Types A, B and C. Type A is the best ground, consisting of fresh or faintly weathered competent rock with excellent to good rock quality designation (RQD), moderate to wide joint spacing, and two sets of joints or less and a rock mass rating (RMR) greater than 60. Type A ground is generally stable except for the possibility of the occasional isolated

FIG. 4

Excavated TBM tunnel in Type A ground.

FIG. 5

Location of potential large rock wedge in the sidewall of the pump station shaft.



wedge detaching from the crown. The support design for this ground consists of four, 3-m- (10-ft-) long grouted bolts in the crown and upper sidewalls, spaced 1.5 m (5 ft) apart along the tunnel axis, plus welded wire fabric (Fig. 4).

Type B ground is somewhat blocky with large wedges. Joints tend to exhibit significant weathering and are closely spaced with three or more sets. The RQD is fair to poor and the RMR is between 60 and 41. The initial support for Type B ground consists of eight, 3-m- (10-ft-) long bolts in the crown and sidewalls, spaced 1.5 m (5 ft) apart along the tunnel axis.

Type C ground is the most difficult, requiring substantial support. It is generally blocky, seamy and prone to raveling and can contain thick layers of thoroughly weathered rock. The RMR is typically 40 or less and rock bolts are difficult to install and generally ineffective. Circular steel ribs with welded wire fabric or lagging is usually installed in this type of ground to maintain stability.

The distribution of the three different ground types along the tunnel alignment cannot be predicted accurately. However, expected quantities of each ground type can be estimated and a baseline established by a combination of geological correlation and statistical analysis. A majority of the tunnel is expected to consist of Type A ground with most of the Type B and C ground concentrated in the last 1,675 m (5,500 ft) of the eastern end of the tunnel where the tunnel is shallower and the rock is more weathered and fractured.

Ground water inflow

Ground water inflow during construction depends on rock mass permeability, recharge conditions, stored volume of water, opening size and head of water. The cumulative inflow into the TBM tunnel during construction is expected to not exceed 76 L/s (1,200 gpm) at the downstream end of the tunnel. There appears to be little correlation between ground type and ground water. While much of the Type A ground will be dry or have minor drips or seeps, some of the Type A ground will produce large inflows because Type A ground can support individual, large open joints. Type B ground will commonly have moderate to large inflows. Type C ground could have less inflow than Type B ground because the joints are commonly collapsed or filled with lower permeability silt and clay.

Final lining

The TBM tunnel will be partially lined with a 460-mm- (18-in.-) thick cast-in-place concrete, generally unreinforced, and installed where needed for structural support and ground water control. About 70 percent of the tunnel is expected to require lining. The actual quantity of lining and the specific locations where it will be installed will be determined by the engineer once the tunnel is excavated. All TBM tunnel sections excavated by drilling and blasting will receive cast-in-place concrete lining. The final lining will be used to limit inflow to a small amount, consistent with criteria for reinforced concrete pipe (200 gal/day per inch diameter per mile).

Panning will be needed in areas where ground water is seeping or flowing into the tunnel from rock bolts, joints or between the steel ribs. Based on previous experience in Atlanta, the amount of panning needed is expected to be about 25 percent of excavated surface area covered by the lining. The actual quantity of panning and specific locations where it will be installed will be determined by the engineer once the tunnel is excavated.

Modified contact grouting (Bedell, 2006) will be used behind the cast-in-place concrete in order to complete the final lining. Modified contact grouting uses high pressure to fill the small annulus typically found in the tunnel crown between the concrete lining and the rock and to force grout outward into open rock fractures against the head of water.

Pump station shaft support

The bedrock at the pump station consists of mylonite comprised of mainly very fine crystalline to microcrystalline quartz, feldspar and mica and has a pronounced foliation. Four borings were drilled 6 m (20 ft) into competent

FIG. 6

Secant piles supporting the soil zone in the pump station shaft.

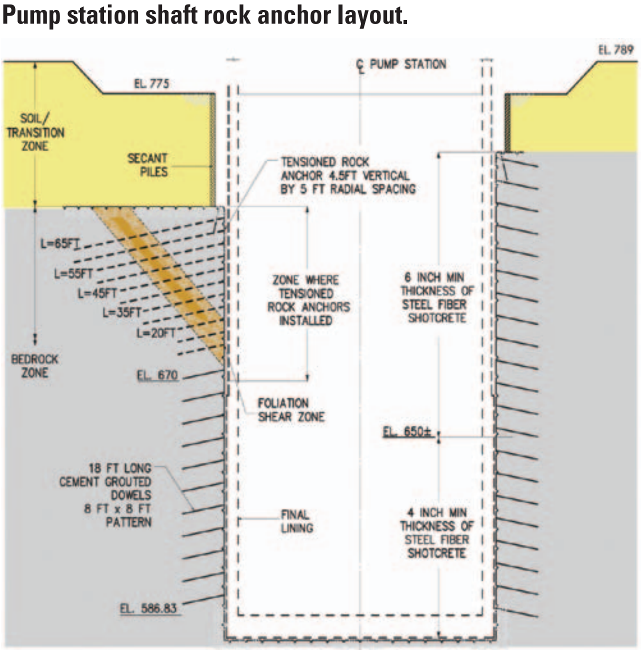
rock around the perimeter of the pump station shaft and revealed a very irregular soil-to-rock transition. The thickness of the soil zone ranges from about 9 to 18.3 m (30 to 60 ft) and the transition zone from about 3 to 9 m (10 to 30 ft) across the area of the pump station shaft. The top of the bedrock zone occurs from 12 to 21 m (40 to 70 ft) below surface. The water table occurs at a depth of about 12 m (40 ft) in the transition zone. The rock has a well-developed foliation that contains open or clay filled joints running parallel to it. The foliation dips to the south-east at about 35° to 45° and several high angle joints sets, (steeply dipping fractures), typically filled with calcite, chlorite, clay and other minerals, cross cut the foliation. The high angle joints sets combine with the jointing along the foliation to produce surfaces of detachment that allow sliding wedges to form.

A shear zone, up to about 4.5 m (15 ft) in thickness and consisting of shattered and weathered rock with graphite and clay, was encountered in two deep boreholes drilled at the pump station shaft (Fig. 5). The zone enters the northwest side of the shaft at a depth of about 23.8 m (78 ft) and passes downward and across the shaft, exiting the southeast side at a depth of about 55 m (180 ft) and nearly parallel to the main foliation. When combined with the other joints in the area, the shear zone had the potential to form the base of a very large wedge, estimated to be about 15.2-m- (50-ft-) high and 18.3-m- (60-ft-) wide, that could slide into the 34.7-m (114-ft) excavated diameter shaft during construction.

The location of the pump station shaft was fixed be-

FIG. 7

Pump station shaft rock anchor layout.



cause of the limited space available at the surface and the requirement for the pump station to be situated next to the existing treatment facilities. Consequently, the shaft could not be moved and the significant shear zone with the potentially large rock wedge could, therefore, not be avoided. The challenge was designing a ground support system with the flexibility to provide different levels of support around the shaft perimeter: heavy face support on the northwest side of the shaft to prevent the large wedge from sliding out and less support in the remaining areas containing only small to medium sized, random loose blocks of rock. The method selected consisted of rock anchors and bolts as the primary support and shotcrete for preventing minor rock falls in between the anchors and bolts.

Due to the numerous methods available for overburden support, Shea-Traylor JV was allowed to select the method and provide a design for support for the soil zone. The Shea-Traylor JV elected to install 900-mm- (36-in.-) diameter secant piles arranged in a ring (Fig. 6). Two circular steel ribs (W14 x 233) provide additional lateral support to the middle portion of the pile ring. Rock anchors were installed near the base of the piles to hold back the toe section, especially where the piles had to extend for a considerable distance below the lower circular steel rib. This type of support system works well for large diameter shafts in piedmont geology, where the top of rock elevation can vary significantly from one side of the shaft to the other.

The design of the initial ground support system in the bedrock first involved developing an adequate support system for the large rock wedge in the northwest side of the shaft and then determining the support requirements for remaining portion of the shaft (outside of the shear zone area). The limit equilibrium method was used in analyzing the support requirement for the large wedge in which the resisting forces are compared to the disturbing forces along a kinematically feasible plane and expressed in terms of a factor of safety against sliding. This method involves determining the geometry and weight of the potential wedge, estimating the shear strength of the sliding plane and the high angle joints, and then calculating a factor of safety against sliding. If the calculated factor of safety is below an acceptable value, the wedge will need to be supported.

Determining the geometry accurately and, hence, the weight of the wedge can sometimes be difficult because it depends on identifying critical joints, usually from only borehole joint data. Performing the analysis for several joint combinations is recommended in order to ascertain the most probable wedge. Estimating the shear strength of the sliding plane and cross joints is not easy and can have a pronounced effect on the final support system. Ground water pressure along the sliding plane can reduce the factor of safety considerably by pushing the surface of the discontinuity apart and reducing the normal stress. This condition is usually not a major concern if the water can readily drain from the joints into the excavation and the quantity/rate of water flow through the joint network is low.

For the design of the rock anchors, a range of probable wedge volumes were evaluated based on the joint patterns identified. The surcharge load from the weight of the overlying soil directly over the wedge was factored into the analysis. The continuous shear zone through the shaft contains thin, completely weathered seams and clay layers. Therefore, a friction angle of 20° was selected for design purposes and no cohesion. Since the shaft would be excavated in stages, the rock mass would have time to drain prior to exposing the entire wedge. So hydrostatic pressure was not a significant factor in the design. A factor of safety of 1.2 was used for the initial support design because the initial support is temporary and would be followed by a final reinforced concrete lining.

Figure 7 shows the designed rock anchor layout for supporting the large wedge above the shear zone. For support of the large wedge, both tensioned and nontensioned anchors were considered. Tensioned anchors were

FIG. 8

Tensioned rock anchor detail.

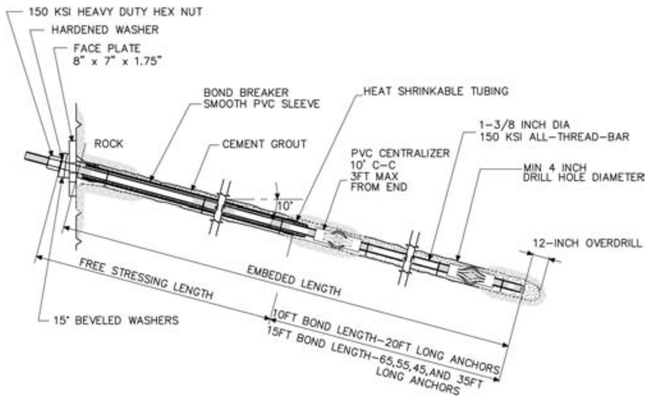


FIG. 9

Rolled out view of the initial ground support installed in the pump station shaft, location of MPBX's and extent of the potential large rock wedge.

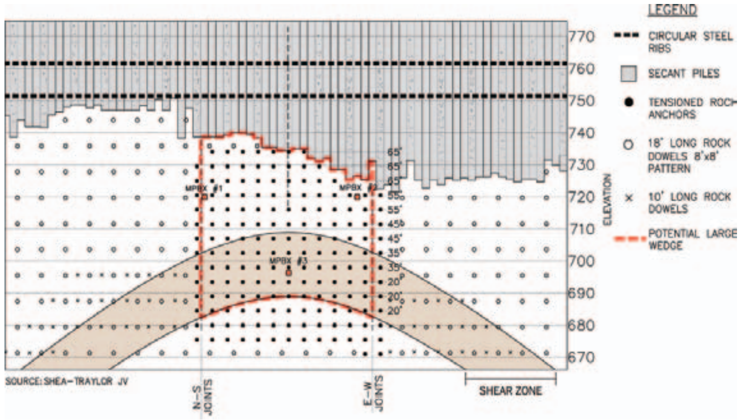
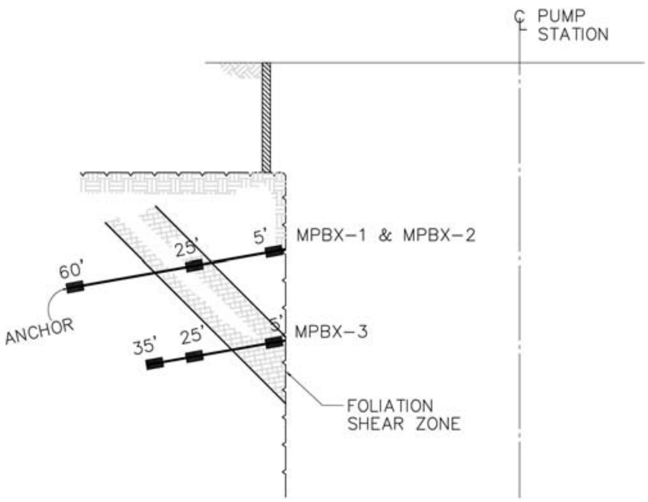


FIG. 10

Pump station shaft rock anchor layout.

FIG. 11

Location of MPBX's in relation to the shear zone in the pump station shaft.



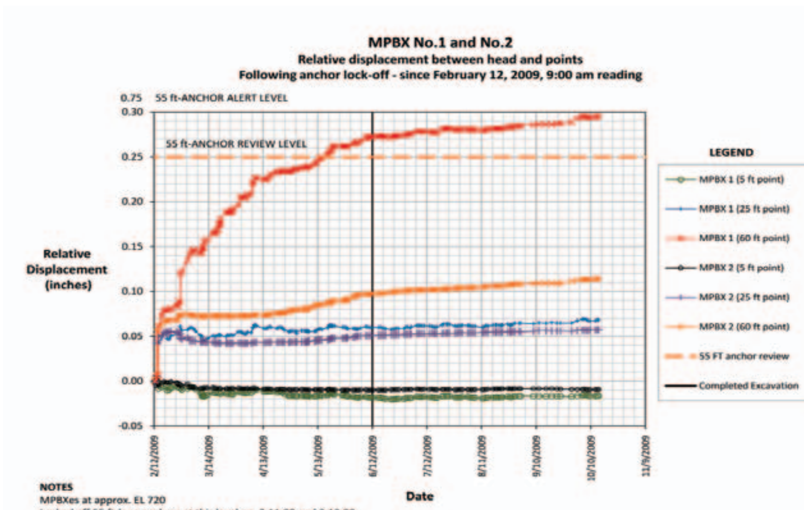
selected because they provide an active force to the wedge and limit movement of the wedge during excavation. The tensioned anchors also allow the opportunity to test each anchor following installation. Each anchor is a grade 150 steel bar, 35 mm (1-3/8 in.) in diameter and spaced 1.5 m (5 ft) apart horizontally and 1.4 m (4.5 ft) apart vertically with a design capacity of 632 kN (142 kips) and anchored using cement grout (Fig. 8). Rock anchors of different lengths, ranging from 20 to 6 m (65 to 20 ft), were required to ensure that the bond (anchorage) section was beyond the shear zone. The bond length of the anchors was 4.6 m (15 ft), except for the 6-m- (20-ft-) long anchors that had a bond length of 3 m (10 ft). Each row of rock anchors was installed concurrently with shaft excavation, several feet above the shaft floor and post-tensioned to 70 percent of the design capacity 443 kN (99.5 kips). The installed rock anchor arrangement is shown on Figs. 9 and 10. Only minor adjustments from the original design were made due to the actual location of the shear zone being slightly higher in the sidewall by a couple of feet than anticipated.

For the areas of the shaft that are not influenced by the shear zone, the initial support design was based on a combination of previous experience with the pump station shaft for the Chattahoochee Tunnel that was comparable in size and located in similar geology, evaluation of the rock mass quality using the Q-system and an evaluation of potential wedges from joints and foliation using the computer program Unwedge Version 3. The support comprises of cement grouted, grade 60, 25 mm (1 in.) No. 8 rock dowels, 5.5-m- (18-ft-) long, spaced 2.4 m (8 ft) apart (Fig. 7) with 100 to 150 mm (4 to 6 in.) of fiber-reinforced shotcrete. For areas of the shaft where the shear zone daylights in the shaft walls but does not create a large planar sliding condition, additional 25 mm (1 in.) No. 8 dowels, 3-m- (10-ft-) long were required to be installed between the 5.5-m- (18-ft-) long dowels.

The performance of rock anchors during excavation of the shaft was monitored by three multi-point extensometers (MPBX) to provide advance notice of the support approaching its design limit and to provide time for modifications to be carried out to the support system. The MPBX's were located in the potential

FIG. 12

MPBX No. 1 and 2 monitoring record.



large unstable wedge. MPBX 1 and 2 were installed at about the mid-height of the wedge, with anchor points at 18.3, 7.6 and 1.5 m (60, 25 and 5 ft) from the rock surface/face plate and MPBX 3, with anchor points at 10.7, 7.6 and 1.5 m (35, 25 and 5 ft) from the rock surface/face plate, installed near the toe of the wedge (Fig 11). Review and alert response levels were specified to determine if the relative displacements measured in the MPBX's are indicative of potentially unstable ground behavior. The review and alert levels were based on the calculated elongation of the nongrouted portion of the various anchor lengths.

MPBX recording of ground movement (MPBX head displacement relative to each MPBX anchor point) commenced on Feb. 12, 2009 within a day of "locking off" the 16.8-m- (55-ft-) long anchors. After several weeks of monitoring, it became apparent that movement was taking place along the shear zone in the vicinity of MBPX 1 between the 18.3-m- (60-ft-) and 7.6-m- (25-ft-) deep measuring anchor points. This was because the 1.5 m (5 ft) and 7.6 m (25 ft) points showed little displacement relative to the reference head while noticeable movement was detected between the 18.3 m (60-ft) point and reference point (Fig. 12). In the case of MPBX 2, the relative movement between the 18.3 m (60 ft) point and 7.6 m (25 ft) point was considerably less, suggesting that this portion of the wedge was approaching a state of equilibrium. MPBX 3 also was showing a certain amount of relative movement between the measuring points and the reference head (Fig. 13). Rotational sliding of the wedge is one possible explanation for behavior of the wedge.

On May 13, 2009, the review level was reached for the 16.8-m- (55-ft-) long anchors based on readings from MBPX 1. The project team immediately performed a visual inspection of the exposed rock anchors/face plates, checked the surface condition of the shotcrete for any signs of spalling or cracking and jointly assessed the necessity to modify the support plan and develop a contingency. No evidence of problems with the support could be detected visually. However, a contingency plan was prepared in the event that the rate of displacement did not decrease with time. After reaching the review level, the rate of movement began to diminish. Latest MPBX readings taken mid-October 2009, show practically no additional movement. Monitoring will continue until the shaft concrete lining reaches the top MPBX locations, but readings may be taken less frequently.

The designed rock anchor/bolt and shotcrete support system successfully maintained the shaft transition and bedrock zones in a stable condition. Work in the shaft is now focused on constructing the concrete invert, shaft walls and internal structures.

FIG. 13

MPBX No. 3 monitoring record.

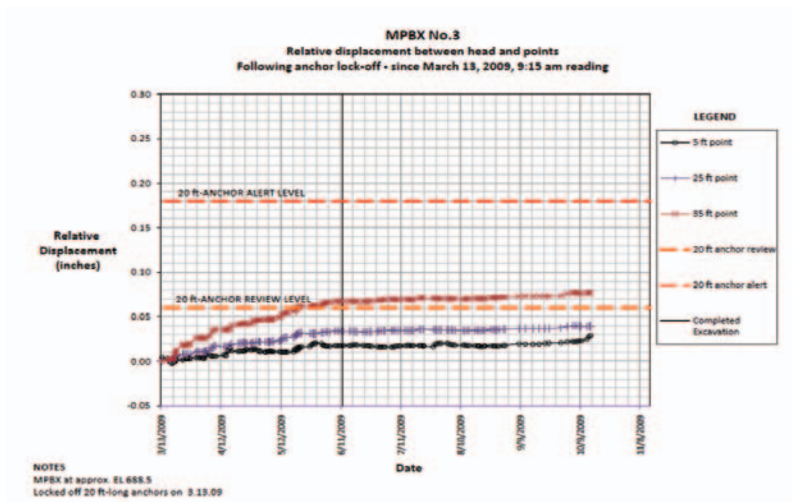


FIG. 14

Installing rebar at the base of the pump station shaft for the concrete invert.

Summary

The South Cobb Tunnel project is expected to take another four years to complete but is off to a good start. The project will have its challenges: the largest intake on the project needs to be constructed close to Sweetwater Creek, which is subject to flooding during major rainfall events and some of the strongest rocks in the Atlanta area are still ahead of the TBM. Unlike typical pipelines, the South Cobb Tunnel will continue to convey and store waste water for many decades with little maintenance and risk of overflow. CCWS is looking well ahead and is addressing current capacity limitations and the needs of the future generations in the County. ■

References

Bedell A., Crenshaw B., Raymer J. & Klecan W., 2006 "Tunnel liner systems: design and construction of cast-in place concrete tunnel liners," North American Tunneling Conference.

FEATURE ARTICLE

2009 permeation test results for grouts made with ultrafine cements

The 30th annual short course "Grouting Fundamentals and Current Practice" was held at the Colorado School of Mines, June 22-26, 2009. The field demonstration portion of the course was conducted June 25, at Hayward Baker, Inc.'s yard in Broomfield, CO.

The full-scale field demonstration annually presents many different types of drilling equipment being operated as well as various grouting methods being performed under different field conditions.

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

The goal of the sand column demonstration is to show the students the effect of the water cement ratio and the use of admixture as well as the fineness of the cement, portland versus ultrafine, used has on the engineering properties of the grout and the grout's vertical permeation through the sand.

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

Raymond W. Henn and Benny Siljenberg

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Past demonstrations

Demonstrations have included cement grouts made with various brands of Type I - II portland cements and various brands of ultrafine (microfine) cements. The grouts were batched with and without admixtures. The water cement ratios have ranged from approximately 0.7:1 to 1.25:1.

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

Basic field testing has always included mix temperatures, specific gravity and marsh funnel viscosity. Several additional field and laboratory test procedures including cohesion testing, flow cone tests and unconfined compression strength testing of the cured grouted sand sample have been performed during several of the

FIG. 1

Project location plan and alignment.

previous demonstrations.

More detailed information for a better understanding of the data available and how it compares with the results of the 2009 results presented below is available in the two papers published in RETC proceedings, (Henn et al. 2001 and Henn et al. 2005).

2009 demonstration and testing

The 2009 demonstration consisted of five grout mixes (batches) and five sand columns labeled T-1 through T-5. There was one mix (T-1) of Type I-II portland cement and four mixes made using ultrafine (microfine) cements. Specifics, such as the cement manufactures, name of the product, water cement ratios and the admixtures used for each mix, are given in Table 1. Supervision of the demonstration as well as inspection, testing and record keeping were performed by Lyman Henn Inc. of Denver, CO. The maximum injection pressure of 10 psi (0.7 bar), and the maximum injection time of 20 minutes per column remained unchanged from previous demonstrations.

Equipment

A model CG600 / 3L6/A ChemGrout grout plant was used for the demonstration. The plant consists of a 0.36-m^3 (97-gal) high shear (colloidal) mixer tank, a 0.36-m^3 (97-gal) agitator tank and a progressive helical cavity (moyno) pump with a maximum output capacity of 77 L/min (20 gpm) at a maximum discharge pressure of 265 psi (18 bar). The plant used for the demonstration as shown in Figure 1.

A custom build grout header with two flow control valves and a pressure gauge was used (Fig. 2).

The sand columns used for the 2009 demonstration were new columns. The new and improved columns were redesigned and fabricated by ChemGrout. The columns dimensions, 191 mm (7.5 in.) inside diameter and 1,524 mm (60 in.) tall, remained the same. However, the column's base and its connection to the clear plastic tube were strengthened as was the connection of the grout injection port to the plastic columns. Figure 3 shows the five sand columns just after completion of the demonstration.

Inspection, record keeping and testing

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

Three field tests were performed on each batch of grouts. These tests were grout temperature, specific gravity and marsh funnel viscosity. The results of the inspection and testing are given in Tables 1 and 2.

FIG. 2

Custom-built grout header.

FIG. 3

Tunnel cross sections.

Table 1

Permeation grouting test data summary (June 25, 2009).

Test Number	Supplier	Name of product	(W:C)	Cement lbs (kgs)	Water lbs. (kgs)	Water gallons (L)	Admixture	Mixing time (minutes)	Abient air temp F° and C°
T-1	Cemex	Type II portland cement	(4:1)	94 (42.6)	376 (170.6)	45.1 (170.7)	None		
Comments: Grout stopped rising in the column three minutes into the test. The bleed water above the stationary grout continued to raise until the completion of injection at 20 minutes.									
T-2	Surecrete	Nittetsu Super	(4:1)	88 (39.9)	352 (159.7)	42.3 (160.1)	Mighty 150 (Kelco-Crete) 10 oz Diutan Gum 6.5 table spoons (97.5 mL)		
Comments: The column of sand lifted. The test stopped at 4:30 +/_ minutes. The cap of the sand column lifted about two inches.									
T-3	DeNeef	MC 500	(4:1)	110 (49.9)	440 (199.6)	52.8 (199.8)	Super P 14 oz.	4	lower 80s (mid to upper 20s
Comments: Ended test at 2 minutes and 37 seconds due to not wanting to lift cap of sand column.									
T-4	Surecrete	Nittetsu super	(1:1)	176 (79.8)	176 (79.8)	21.1 (79.9)	Mighty 150 (Kelco-Crete) 20 oz		
Comments: Stopped test at 11 minutes and 30 seconds because of no vertical grout movement									
T-5	DeNeef	MC 500	(1:1)	165 (74.8)	165 (74.8)	19.8 (74.9)	NS-200 (Dispersent) 21 oz		
Comments: Test ran the full 20 minutes.									

Discussion of test results

The 2009 demonstration was the first time a water cement ratio of 4:1 was used. The 4:1 w/c was used for Type I-II portland cement batch and for one batch of the Surcrete superfine and for one batch of the DeNeef microfine cement products. The results of these three batches were as expected (Table 2, page 22). Note the bleed experienced during the injection of the batch made with the portland cement.

The remaining two ultrafine (microfine) cement batches used a 1:1 water cement ratio. The penetration results of these two batches were not what were expected. The final grout injection heights for the Nittetsu product were 292 mm (11.5 in.) and 438 mm (17.25 in.) for the DeNeef product. These are some of the poorest results ever recorded for both the Surecrete and the DeNeef products. There are two possible explanations for these below average results.

The supply sources of the sand used in the sand columns was changed for the 2009 demonstration. The sand used for the 2009 demonstration looked fine, as noted by several people who have been involved with past demonstrations, from the sand used in previous years. Because of the demonstration results, gradation tests were conducted on the sand used in 2009 and on the sand used in previous demonstrations. The gradation results are given in Table 3 (page 23) and Figures. 4 and 5. As can be seen from the gradation, the sand used in 2009 is somewhat finer than the sand used in previous demonstrations.

The second possibility for the 2009 results lies in the method used to densify the sand in the columns during the column filling. Prior to 2009, the bagged sand was poured into the column while the outside surface of the column was tapped with a rubber mallet. However, during the sand column fillings for the 2009 demonstration, each column was vibrated at its base while the sand was poured in using a plate vibrator. It is believed that this vibration method might have resulted in the sand within the column being in a denser state than in previous years.

Grout temp F° and (C°)	Specific gravity	Unit weight (pcf) and kg/m³	API (13 B-2) Marsh funnel viscosity (sec/946cc)	Duration injecting into colum(min)	Injection pressure psi & (bar)	Final grout injection height in column in. and (mm)	Final bleed water height in Column in in. and (mm)
84 (28.9)	1.13	70.5 (1,229)	28	20	10 psi (0.7)	18 (457)	49 (1,244)
83 (28.3)	1.15	72 (1,153)	28	4:30 +/-	10 psi (0.7)	55 (1,397)	None
76 (24.4)	1.15	72 (1,153)	29	2:37	10 psi (0.7)	58 (1,473)	None
78 (25.6)	1.51	94 (1,505)	34	11:30	10 psi (0.7)	11.5 (292)	None
77 (25.0)	1.47	92 (1,473)	32	20	10 psi (0.7)	17.25 (438)	None

Conclusions

The demonstration and testing of the grout penetration in the sand columns has evolved and modifications have been made to mixes and injection procedures from year-to-year. In the planning for the 2010 demonstration, an effort will be made to determine the in-place density of the sand within the column. Also, there is discussion of filling some of the sand column with the "older" pre-2009 sand and some of the columns with the "newer" 2009 sand while keeping the grout mix the same for both sand gradations.

Although the testing conducted during the annual demonstrations are performed to standards that may fall somewhat short of those used in a testing laboratory, the authors and the other contributor to the demonstration believe the test data obtained during the years provides valuable information to the grouting and construction industries, as well as providing a good teaching tool for the course's students.

Ideas or suggestions for future demonstrations are welcomed. Contact Ray Henn, e-mail rhenn@lyman-henn.com. Also if you are working with or have data on a completed project that used grouts made with ultrafine / microfine cement, Henn would like to like to hear about it.

Acknowledgment

The authors thank Joe Schatz of ChemGrout for providing the grout plant, fabricating the new and improved set of five sand columns, and for providing the labor for the setup and batching of grouts. Thanks to Fred Sherrell of Surecrete for supplying the Nittutsu superfine cement and to Brian Iske of DeNeef for supplying the MC500 microfine cement. Thank you Don Hegebarth, independent grouting consultant for doing all the behind-the-scene things that you do before, during and after the demonstrations. A special thank you to Joe Harris of Hayward Baker for providing their yard as well as support equipment and labor. ■

Tables continued on page 22

Table 2

Grout penetration heights.

T-1 10 psi (0.7 bars)					T-2 10 psi (0.7 bars)			T-3 10 psi (0.7 bars)		
Injection duration (min)	Height in column (mm)	Height in column (in.)	Bleed height in column (mm)	Bleed height column (in.)	Injection duration (min)	Height in column (mm)	Height in column (in.)	Injection duration (min)	Height in column (mm)	Height in column (in.)
1	431.8	17	508	20	1	800.1	31.5	1	965.2	38
2	431.8	17	647.7	25.5	2	1079.5	42.5	2	1320.8	52
3	431.8	17	736.6	29	3	1257.3	49.5	2:37	1473.2	58
4	431.8	17	838.2	33	4	1397	55			
5	431.8	17	863.6	34						
6	431.8	17	914.4	36						
7	431.8	17	939.8	37						
8	457.2	18	965.2	38						
9	457.2	18	1016	40						
10	457.2	18	1016	40						
11	457.2	18	1054.1	41.5						
12	457.2	18	1066.8	42						
13	457.2	18	1066.8	42						
14	457.2	18	1092.2	43						
15	457.2	18	1104.9	43.5						
16	457.2	18	1143	45						
17	457.2	18	1168.4	46						
18	457.2	18	1193.8	47						
19	457.2	18	1219.2	48						
20	457.2	18	1244.6	49						

Robbins will cut through permeable ground

Chengdu, China's 11 million inhabitants will soon have a reduced commute time thanks to an extensive new metro system. Five lines totaling 126 km (78 miles) will be constructed using multiple tunnel boring machines (TBM). Robbins signed a contract with China Railway Construction Corp, Ltd. (CRCC) in January 2009 for a 6.26-m- (20.5-ft-) diameter earth pressure balance (EPB) and back-up system on Line 2, Lot 18 of the Chengdu Metro. A commissioning ceremony was held in Chengdu on Oct. 14, 2009.

Geology will include a matrix of weathered rocks found nowhere else in China, consisting of highly permeable pebbles, sand and clay. Subsidence will be intensively monitored — crews will use probe drilling and ground consolidation if settlement is detected.

A mixed ground cutterhead, mounted with 431-mm- (17-in.-) diameter disc cutters and carbide bits, will be used to effectively excavate the variable geology. Cobbles averaging from 20 to 80 mm (0.8 to 3.1 in.) in diameter are predicted, with diameters of as much as 120 mm (4.7 in.) possible. Muck will be removed using an 800 mm (31 in.) diameter shaft-type screw conveyor and battery-operated rolling stock.

Assembly of the TBM was completed in a manufacturing facility in Chengdu. The machine is due for an Autumn 2009 launch, and will bore two 1.35-km- (0.8-mile-) long sections in a suburban area of the city. The tunnel alignment will allow the machine to pass 25 m (82 ft) below residential buildings, and includes several curves with a minimum 400 m (1,300 ft) radius. Active articulation will be used to prevent ring deformation in curved portions of the tunnel.

The Chengdu Metro will open in three stages, with Line 1 operational by 2010. The 26.7-km-

T-4 10 pis (0.7 bars)			T-5 10 psi (0.7 bars		
Injection duration (min)	Height in column (mm)	Height in column (in.)	Injection duration (min)	Height in column (mm)	Height in column (in.)
1	279.4	11	1	342.9	13.5
2	292.1	11.5			
			3	381.0	15
4	292.1	11.5	4	387.4	15.25
6	292.1	11.5	6	393.7	15.5
8	292.1	11.5	8	406.4	16
10	292.1	11.5	10	412.8	16.25
			12	419.1	16.5
			14	431.8	17
			16	431.8	17
			18	431.8	17
			20	438.2	17.25

Table 3

Chronological project developments.

2009 sand gradation

Sieve size	accum. soil soil mass. (g)	% retained	%pass
#16		0.0	100.0
#30	2.4	0.2	99.8
#50	1285.1	83.1	16.9
#100	1502.9	97.2	2.8
#200	1542.5	99.7	0.3
-200	1546.1	100.0	0.0

2008 sand gradation

sieve size	accum. soil soil mass. (g)	% retained	% pass
#16		0.0	100.0
#30	75	6.4	93.6
#50	1103	94.1	5.9
#100	1170.4	99.9	0.1
#200	1171.2	99.9	0.1
-200	1171.4	100.0	0.0

Differences (Δ) in percentage passing (2009 Sand - 2008 Sand)

Δ #16	0.0
Δ #30	6.2
Δ #50	11.0
Δ #100	2.7
Δ #200	0.2
Δ -200	0.0

The 6.3 m (20.5 ft) diameter Robbins EPB will excavate highly permeable ground on China's Chengdu Metro.

(16.6-mile-) long Line 1 will provide service between Honghuayan and Shiji Square stations at speeds of 80 km/h (50 mph). The 50.6-km- (31.4-mile-) long line 2, for Chengdu Metro LLC, (with 17.6 km/ 10.9 miles of underground tunnels) will include 26 stations between Longquandong and Shiniu areas. Seven lines totaling 274 km (170 miles) are planned to be in service by 2035, servicing 13.1 million daily passengers. ■

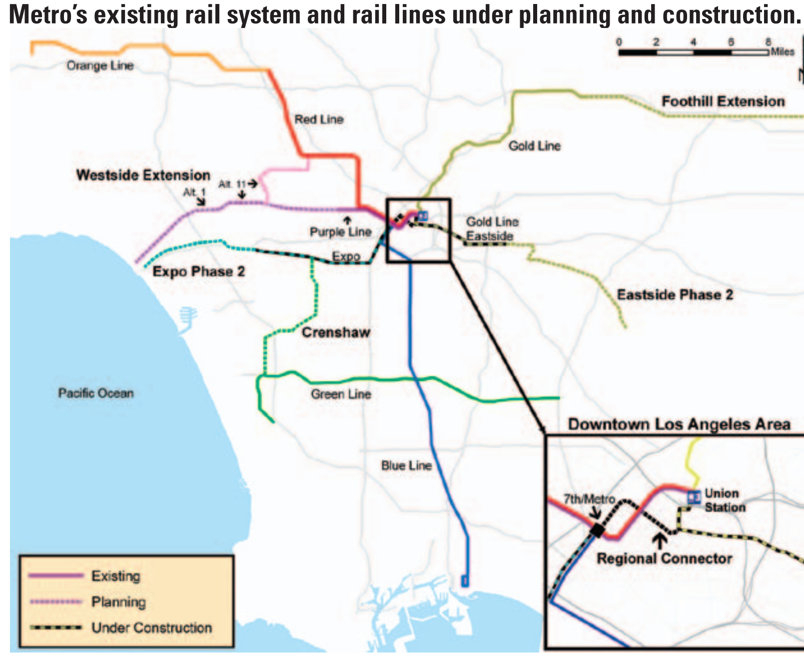
FEATURE ARTICLE

Planning new metro subways — Los Angeles, CA

Success of the Gold Line Eastside Extension rail tunnels in Los Angeles, CA has prompted the Los Angeles County Metropolitan Transportation Authority's (Metro) planning new rail lines to include underground alternatives. The Westside Extension Transit Corridor alternatives include up to 27 km (17 miles) of subway to be constructed in soft ground. The routes will require construction in Los Angeles' "potential methane zone," which was not considered for subway construction until recently. Slurry face tunnel boring machines (TBM) will likely be specified.

FIG. 1

Metro's existing rail system and rail lines under planning and construction.



Background

The Los Angeles County Metropolitan Transportation Authority's (Metro) existing rail transit system includes 29 km (18 miles) of heavy rail (HRT) subway, 101 km (63 miles) of light rail (LRT) and currently has 11.2 km (7 miles) of LRT under construction. Additionally, a fixed guideway (Orange Line Bus Rapid Transit — BRT) extends the system 22.5 km (14 miles) in the San Fernando Valley (Fig. 1).

The Metro has recently completed an alternative analysis (AA) studies for new rail lines (January, 2009) including the Westside Extension. The Westside study included subway as well as aerial sections for the analyses. A heavy rail subway for the westside extension of the Red and Purple lines will provide a viable alternative to driving in the heavily congested Westside Extension Transit Corridor.

Underground alternatives have, in part, been considered due to the recent success of Metro's Gold Line Eastside Extension (MGLEE), which includes almost 3.2 km (2 miles) of LRT in tunnels with two underground stations. This new line went into revenue service on Nov. 15, 2009. Tunnels were constructed in soft ground using earth pressure balance (EPB) technology, a single-pass (double-gasketed) precast liner and were completed with virtually no surface settlement (Choueiry et al., Robinson and Bragard, RETC 2005).

Heavy rail had not been considered along Wilshire Boulevard, the major east-west street connecting downtown to the westside city of Santa Monica, since 1997. At that time, all rail projects in planning and design were suspended due to funding issues and a perception that tunneling was not suitable in Los Angeles' subsurface conditions, including gassy ground. This perception evolved from tunneling issues that occurred during the Red Line construction (1986 to 2000) and the presence of subsurface gases in the area around the La Brea tar pits.

Now that the MGLEE tunnels have been completed — with minimal disruption to the community — Los Angeles mayor, Antonio R. Villaraigosa, and other elected officials have announced their support for major extensions to the rail transit system, including and extension to the existing Red Line (now Purple Line) Subway to the west, and the 2.7-km- (1.7-mile-) connection of two separate light rail lines through downtown Los Angeles. Support of these, and other transportation projects, has been affirmed by the residents of Los Angeles County. In November 2008,

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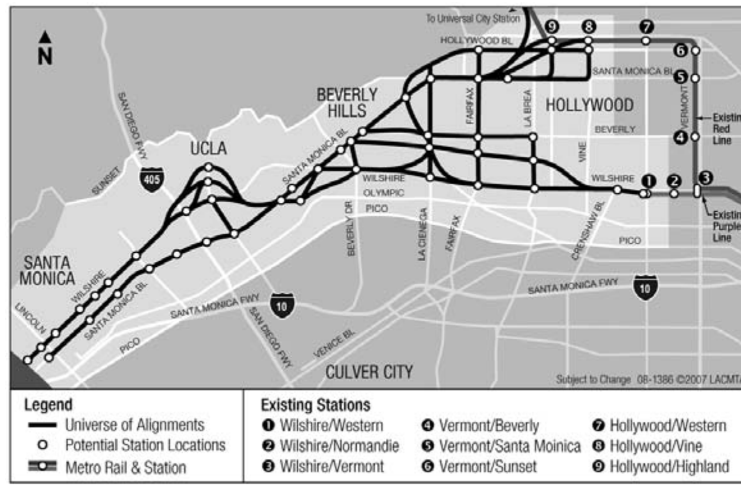
Editor's note: This article is an excerpt of a paper that was first presented at RETC 2009 and was published in the RETC 2009 Proceedings.

the voters passed Measure R, an initiative to fund transportation projects by raising the local (Los Angeles County) sales tax by 0.5 percent. Over a 30-year period, beginning July 1, 2009, the tax revenues are projected to generate $40 billion for congestion relief.

FIG. 2

17 initial alternatives for screening.



Westside extension

In 2007, Metro initiated the AA study to begin the project definition process. The AA study is the first step in defining a project in the Federal Transit Administration's (FTA) New Starts Program. The analysis included an evaluation of a range of transit alternatives (alignments and transit modes), screening the alternatives against criteria and selecting those most promising to proceed into an environmental review. For the Westside Study, the HRT option in subway emerged from the alternatives analysis as the best transit mode. The initial set of alternatives included 17 alternative alignments known as the "universe of alternatives" to extend the existing Red and Purple lines from either the existing Wilshire/Western station or Hollywood/Highland station or both. All alternatives ended in the city of Santa Monica (Fig. 2).

A series of 17 community meetings were held to present alternatives and receive public comments. Results were that the communities' overwhelmingly supported transit improvements, favored a Wilshire Boulevard alignment and also supported a line to West Hollywood. There was limited support for aerial, monorail or BRT alternatives. Ridership demands and travel times over the 26-km (16-mile) distance from downtown to Santa Monica showed that the area would best be served by the HRT transit mode. Preliminary models estimated travel times from downtown to Santa Monica at 27 minutes, a trip that can currently take more than an hour by car in rush hour traffic. Two alternates, Alternatives 1 and Alternative 11 of the original 17 (Figs. 3 and 4) were selected to proceed to the next phases of study — environmental analysis and advanced conceptual engineering (ACE).

As noted, the study included subways previously prohibited from funding in areas along Wilshire Boulevard due to legislation passed in 1986. At that time, the U.S. Congress enacted legislation that funded the initial Red Line segment, but prohibited the use of federal funds for subway construction in Los Angeles' high potential methane zone, deemed an unsafe area for tunneling after a serious nontunneling related methane explosion occurred in 1985. In 2007, Congress repealed the 1986 legislation due to advances in technology and demonstrated successes in underground construction projects including those in Los Angeles. Key to the repeal of this legislation were conclusions by a panel of experts assembled by the American Public Transportation Association (APTA). The panel reviewed new data and evaluated advances in worldwide tunneling technology and the safety of buildings related to operating transit tunnels in the methane hazard zone along Wilshire Boulevard (Fig. 5).

The panel concluded that advances in technology and tunneling practice during the last 20 years would permit tunneling — such that it "could be undertaken at no greater risk than other subway systems in the United States." Supporting the APTA panel's conclusions were that, since 1986, there have been advances in TBM technologies such as use of pressure face TBMs; improvements in gas measurement and instrumentation technology; more local tunneling experience gained and successful operation of the existing Metro system.

With these general conclusions, the panel also made

FIG. 3

Westside Extension Alternative 1.

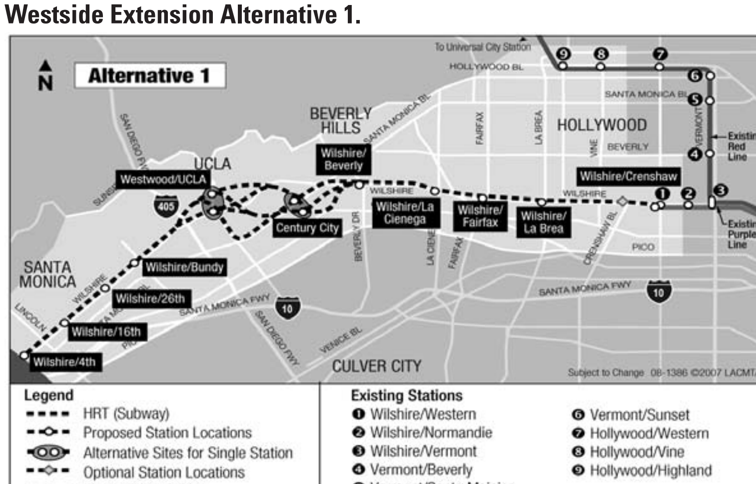
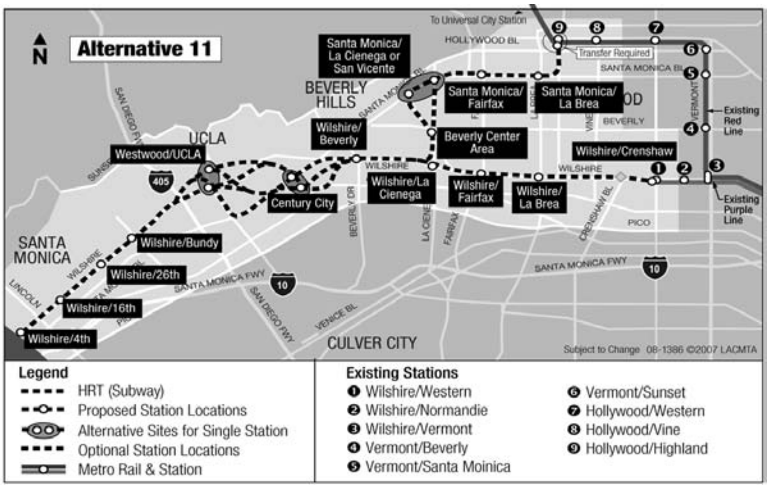


FIG. 4

Westside Extension Alternative 11.



recommendations for future design and construction that involved the use of pressure face (slurry) TBMs in high gas-risk areas, minimizing construction in the gas and tar bearing formations as much as possible, particularly the San Pedro Formation's unsaturated zones, incorporating lessons learned from other projects as information becomes available, and developing procedures for repair of sealing systems — should seismic events or fires occur.

For the AA study, special tasks were undertaken to followup on recommendations of the APTA panel, to obtain additional geologic data and develop further recommendations for future study and design phases. These would be based on obtaining more detailed geologic information as well as additional experience in Metro construction since the 2006 study. In particular, successful completion of the MGLEE tunnels and cross-passages constructed through the former Boyle Heights oil field. Among the study tasks was a literature review to compile previous Metro work and a survey of projects worldwide that could have similar gas conditions. Much of this previous work supported APTA's recommendations to use slurry face TBMs (SFM), examine ground treatment methods to reduce hazards from gas encounters and consider shallow stations to avoid geologic formations having the high gas concentrations (Elioff, et al., 1995, Jacobs et al. 1999).

Geologic conditions

Geologic conditions and profiles for the initial study alternative alignments were assessed from research of more than 230 geotechnical reports in Metro and the consultant team's files as well as other published data. Data was collected on geologic formations and their properties, ground water, gas conditions and seismicity is summarized.

Geologic setting of study area. The study alignments are located in the northern portion of the Los Angeles Basin, approximately 0.8 to 4.8 km (0.5 to 3 miles) south of the eastern portion of the Santa Monica Mountains. The geomorphic surface along the alternative alignments was largely formed by the aggradation of sediments shed out from the mountain front, subsequently uplifted and later modified by the erosion of broad channels into the alluvial surface. Regionally, the alignment is located near the boundary between the Peninsula Ranges and the Transverse Ranges, two major geomorphic and structural provinces of southern California. The Santa Monica and Hollywood faults are considered the boundary between the two geomorphic provinces within the area of the alignments under study.

Geologic conditions. The Wilshire Boulevard tunnel profile (Alternatives 1 and 11) will encounter several geologic units that range in age from Miocene to Holocene. From oldest to youngest in geologic age, are the Miocene-age sedimentary bedrock of the Puente Formation, Pliocene-age sedimentary strata of the Fernando Formation, Pleistocene-age San Pedro and Lakewood formations, Pleistocene-age (older) alluvium, and Holocene-age (younger) alluvium. Pleistocene- and Holocene-age alluvial deposits comprise the surficial geologic units along the alignment. The San Pedro, Fernando and Puente formations would be encountered beneath the Holocene and late Pleistocene sediments in the subsurface along portions of the Wilshire Boulevard alignment.

The Holocene-age sediments generally consist of interlayered silty clay, silty sand and sandy silt. These surficial deposits are underlain by variably thick late-Pleistocene-age older alluvial deposits and semi-consolidated continental and marine sediments of the late Pleistocene-age

FIG. 5

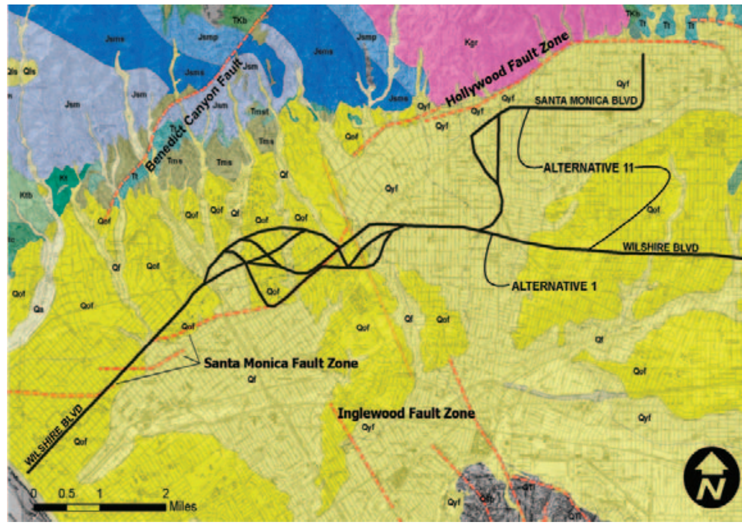
Methane Zones, Los Angeles Westside.

Lakewood Formation consisting generally of gravel, sand and silty sand with some interlayers of silt and clay. The lower portion of the undifferentiated older alluvial sediments/Lakewood formation consists primarily of interlayered silts and sandy clays with some silty sand and is anticipated to be the primary geologic unit that would be encountered at tunnel depth along the Wilshire tunnel alignments under study.

The Lakewood Formation materials are underlain by sediments of the early Pleistocene-age San Pedro Formation. These materials generally consist of stratified sand with some fine gravel, silt and clay layers. The Pleistocene age alluvial deposits are underlain by Tertiary age sedimentary rocks of the Fernando and Puente Formations. The Fernando Formation, where encountered in prior borings along the alignment, mainly consists of massive yellow brown to olive-gray siltstone and claystone with few sandstone interbeds. The claystone and siltstone was described as friable and weak (CWDD/ESA/GRC, 1981). The Puente Formation is comprised of massive, light brown to medium-brown siltstone and zones of claystone that are interbedded with thin laminae of sandstone and siltstone. The Tertiary age sedimentary rocks deepen in the subsurface toward the west. There are anticipated to be encountered primarily in the eastern portion of the alignment at tunnel depth. These formations were tunneled for the existing Metro system (to the east of the study area) using open-shields.

FIG. 6

Geologic map showing Santa Monica fault traces.



Ground water. Exploratory borings drilled along Wilshire Boulevard between Western and Fairfax Avenues in 1980 to 1981 for the Metro Rail project encountered shallow ground water, probably perched, between approximately 3 to 10 m (10 to 35 ft) below ground surface. Locally, ground water as shallow as 1.5 to 3 m (5 to 10 ft) below ground surface has been reported in borings drilled along Wilshire Boulevard in the Wilshire/Fairfax area.

Seismic considerations and faulting. The numerous faults in southern California include active, potentially active and inactive faults. The Santa Monica and Hollywood fault zone form a portion of the active Transverse Ranges Southern Boundary (TRSB) fault system. The Santa Monica fault zone (SMFZ) is the western segment of the Santa Monica-Hollywood fault zone. The fault zone trends east-west from the Santa Monica coastline on the west to the Hollywood area on the east (Bryant, 2005, and U.S. Geological Survey, 2005). Urbanization and development within the greater Los Angeles area has resulted in a poorly defined lateral extent, location and rupture history

FIG. 7

Conceptual profile Wilshire/Fairfax area.

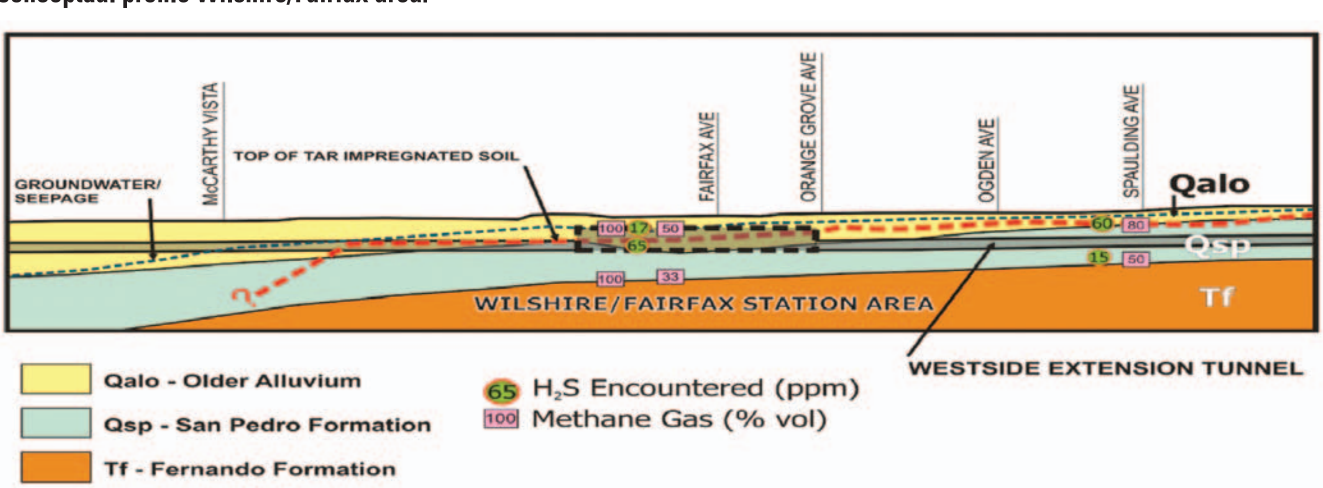
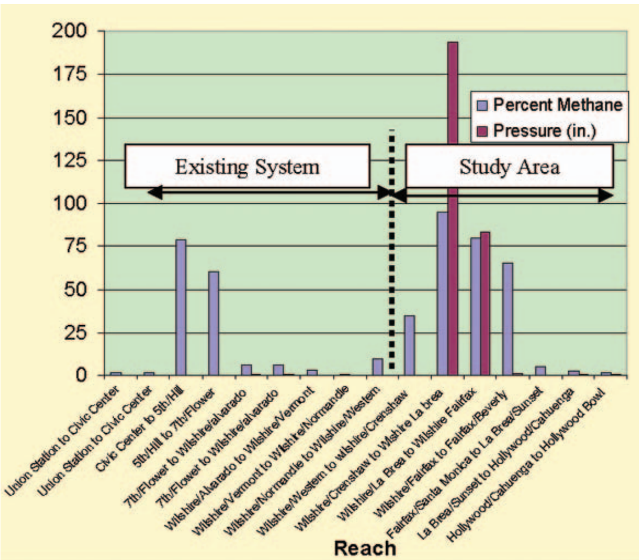


FIG. 8

Gas measurements (1980s) for Metro Red Line.



of the SMFZ. Thus, the Wilshire tunnel alignment may traverse the SMFZ (Fig. 6).

Gas conditions. Of primary concern are subsurface gas conditions in the 1986 Methane Risk Zone, the area surrounding the La Brea tar pits. The tar pit area is northeast of the intersection of Wilshire Boulevard and Fairfax Avenue, a planned subway station area (Fig. 5). It has long been documented, that in the Mid-Wilshire area, tar seeps and associated gases (methane and hydrogen sulfide) are present. These gases migrate up to the surface from deeper Miocene formations and are usually associated with the many oil fields of the Los Angeles Basin. In the Mid-Wilshire area, the gases, primarily methane with some amounts of hydrogen sulfide, are mainly found in the San Pedro and Lakewood formations at approximately 3 to 15 m (10 to 50 ft) below the ground surface — or at least to typical depths of foundation excavation. In some areas near the La Brea tar pits, methane can reach up to 90 to 100 percent by volume. Additionally, hydrogen sulfide, has been found in the range of 10 to 600 parts per million (ppm) in the Wilshire/Fairfax area. Methane is explosive in the range of 7 to 14 percent in air, and hydrogen sulfide is considered unsafe at concentrations of more than 10 ppm.

Historically, there have been occasions when the gas has accumulated. In 1985, there was an explosion at the Ross Dress for Less store at Fairfax Ave. and 3rd St. (about a half-mile north of Wilshire Blvd and Fairfax Ave.) where methane had accumulated in the basement of the store. Because of this, and the knowledge of the presence of methane in the city, the city of Los Angeles has implemented special building code provisions for "methane risk zones" and "methane buffer zones" within the city to address this natural occurrence and provide mitigation. These measures include proper investigation, construction of barriers/liners, passive venting systems beneath building slabs, special HVAC requirements and detection and alarm systems. Since 1986, the city has revised the methane risk zone boundaries (Fig. 5) to correspond to oil field maps and reported gas seepage.

Figure 7 shows the conceptual profile of the Wilshire/Fairfax station area developed during the Westside study. Gas data has been collected during the last 30-plus years, beginning with the original Metro explorations in 1985 to the present time, as monitoring wells have been maintained. Methane and hydrogen sulfide measurements were plotted on the profiles, indicating 0 to 100 percent methane by volume (maximum) and hydrogen sulfide gas concentrations at more than 50 ppm, in the area west of Crenshaw Boulevard to about San Vicente Boulevard.

Construction methods in gas risk areas

Tunnel construction. The existing Metro Red Line tunnels were built with open face tunneling shields in soft ground and siltstones, including ground with high methane levels and some hydrogen sulfide present. The new extension will traverse areas with similar methane concentrations, but higher gas pressures (up to about 5 m or 200 in. of water). Figure 8 presents gas measurements taken in the 1980s along the existing alignment and those measured in the current study area.

From previous Metro studies and APTA recommendations, use of SFMs is now recommended for relatively high gassy ground areas. For other tunnel reaches, the choice between EPB and SFM may be left to the contractor. In the higher gassy ground reaches (as a minimum), a SFM should be required for the following reasons:

- Gas in hazardous concentrations is known to be present in this reach. Using SFMs, the gas is always confined in a pressurized system in the tunnel making the tunnel safer for workers.
- Spoil treatment is provided at the slurry treatment plant. Gas can be more easily monitored, safely controlled and treated at this plant than within the tunnel.
- APTA panel, and previous Metro study indings (Elioff et al. 1995), lead to recommendations SFMs in areas with high hydrogen sulfide concentrations.

Other reaches requiring SFMs could be identified during later design efforts after additional geotechnical explorations. Other tunneling studies during subsequent phases of design will follow up on experience of slurry face TBM projects constructed in gassy ground including slurry treatment and processing related to presence of gas, measurement of gas inflows through installed liners, and monitoring of the slurry treatment plant, its discharges and work areas. To date, SFMs have not been used for hydrogen sulfide mitigation. However, tunnels in Detroit, MI — known to have similar hydrogen sulfide gas issues

(Hansmire, 2008) — are now under construction. Lessons learned from this project will be used for advances in treatment and handling and possible application on the Westside Extension.

Station construction. To date, Metro stations have been constructed safely using cut-and-cover methods. These methods were also used for construction of existing deep foundations and parking garages built in the methane risk zone, specifically in the Wilshire/Fairfax area. Some were constructed according to city codes developed after defining of the methane risk zone, others prior to that time. Metro reviewed this information and researched additional deep parking garages, having up to five levels of underground parking on one site. Findings were that, of the garages surveyed, some reported no incidences of measured gas intrusions (gas alarms); others occasionally dealt with seepage of tar through fine cracks in the structures. Seeping tar material was collected and disposed of by specialty environmental firms during recent excavation for an underground parking garage project in the vicinity. Hydrogen sulfide gas pockets were occasionally encountered.

Metro considers its existing subway system and operations a success, but there will be additional challenges for the Westside Extension. Because of the presence of hydrogen sulfide and methane gases, tar sands and high ground water, construction and operation of the Westside Extension design and construction will be approached with considerable caution and an added degree of conservatism. The approach for future design and successful accomplishment of construction and operations in the higher gas risk areas will incorporate redundancy in design, focus on construction quality control, state-of-the-art instrumentation for leak detection, activation of emergency operations and repairs and design of ventilation systems along with backup systems.

Current status

At the conclusion of the AA study, Metro proceeded with the Environmental and Advanced Conceptual Engineering (ACE) phase. ACE included geotechnical investigations for alignments remaining for study (Figure 9). The draft EIR is expected to be issued in summer 2010"

Acknowledgments

The authors acknowledge Metro's planning teams for the Westside Extension Corridor and led by David Mieger. They also thank Tom Jenkins, Jim Monsees, and Perry Maljian for their assistance in preparing this paper.

The consultant team for the Westside Extension Transit Corridor Study was led by Parsons Brinckerhoff with MACTEC as the geotechnical consultant. ■

FIG. 9

Study alignments as of December 2009.

References

American Public Transportation Association (APTA), Final Report of Peer Review Panel for the Los Angeles County Metropolitan Transportation Authority, November, 2006.

Bryant, W.A., (compiler), 2005, Digital Database of Quaternary and Younger Faults from the Fault Activity Map of California, Version 2.0, California Geological Survey Web Page, http://www.conrv.ca.gov/CGS/information/publications/QuaternaryFaults_ver2.htm, 8-13-07

Choueiry et al., 2007, Planning and Construction of the Metro Gold Line Eastside Extension Tunnels, Los Angeles, CA, Proceedings, RETC 2007

Converse Ward Davis Dixon, Earth Science Associates, Geo-Resource Consultants, (CWDD/ESA/GRC), 1981, Geotechnical Investigation Report, Volume I; Volume II—Appendices 1 and 2, for Southern California Rapid Transit Metro Rail Project.

Dibblee, T.W., 1991, Geology of the Los Angeles Quadrangles, Los Angeles County, California, Dibblee Foundation Map #DF-22, map scale1:24,000.

Elioff et al., 2007, Geotechnical Investigations and Design Alternatives for Tunneling in the Presence of Hydrogen Sulfide Gas, Proceedings, RETC 1995

Hansmire and Jafri, 2008, "Slurry-Face Rock TBM Outfall Tunnel in Detroit, MI, USA," Proceedings, World Tunnelling Congress, Agra, India

Jacobs et al., 1994, Hydrogen Sulfide Controls for Slurry Shield Tunneling in Gassy Ground Conditions—A Case History, Proceedings RETC.

Lamar, D.L., 1970, Geology of the Elysian Park-Repetto Hills Area, Los Angeles County, California, California Division of Mines & Geology Special Report 101

Soper, E. K., and Grant, U.S. IV, 1932, Geology and Paleontology of a Portion of the Los Angeles, California: Geological Society of America Bulletin, Vol. 43, pp 1,041–1067.

Robinson and Bragard, 2007, "Los Angeles Metro Gold Line Eastside Extension—Tunnel Construction Case History," Proceedings, RETC.

U.S. Geological Survey, 2005, "Preliminary Geologic Map of the Los Angeles 30′60′ Quadrangle, Southern California," Open File Report 2005-1019, Version 1.0, http://pubs.usgs.gov/of/2005/1019, map compilation by R.F., and Campbell, R.H., 2005, prepared by U. S. Geological Survey in cooperation with California Geological Survey.

T&UC TUNNEL DEMAND

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Hudson River Crossing	NJ Transit Board THE Program	Newark	NJ	Subway	8,000 x 2	24.5	2010	RFQ 1st Q 2010
Palisades Tunnel	NJ Transit Board THE Program	Newark	NJ	Subway	5,400 x 2	24.5	2009	Bid date 12/14/09
Manhattan Tunnel	NJ Transit Board THE Program	New York	NY	Subway	6,000 x 2	24.5	2009	Barnard/ Judlau low bidder
THE 34th St. Cavern & Station	NJ Transit Board THE Program	New York	NY	Subway	2,200	100 x 100	2010	Under design
Second Ave. Subway Tunnels	NYC-MTA	New York	NY	Subway	2,200	30,000	2014	Under design
ESA Queens Tunnel	NYC-MTA	New York	NY	Subway	10,500	20	2008	Awarded Granite/ Traylor/ FKCI JV
Water Tunnel #3	NYC-DEP	New York	NY	Water	24,000	20	2012	Under design
Harbor Siphons Tunnel	NYC-DEP	New York	NY	Water	10,000	10	2009	RFQ issued
Cross Harbor Freight Tunnel	NYC Regional Development Auth.	New York	NY	Highway	25,000	30	2013	Under design
Cross Sound Link Highway Tunnels	Sound Link	Long Island	NY	Highway	190,000	55	2014	Under design
Cross Sound Link Service Tunnel	Sound Link	Long Island	NY	Highway	95,000	38	2014	Under design
East Side Water Supply Project	Monroe County Water Authority	Rochester	NY	Water	6,500	8	2009	Bid date 11/13/09
Silver Line Extension	Boston Transit Authority	Boston	MA	Subway	8,400	22	2011	Under design
Near Surface Interceptors	Narragansett Bay Commission	Providence	RI	Sewer	19,500	3-6	2011	Preliminary design
East-West Subway Extension	Baltimore MTA	Baltimore	MD	Subway	32,000	18	2012	Under design
WASA CSO Program Blue Plains tunnel Anacosita River tunnel Northeast Branch tunnel Northeast Boundry tunnel	DC Water and Sewer Authority	Washington	DC	CSO CSO CSO CSO	23,400 12,500 11,300 17,500	23 23 15 23	2011 2013 2018 2021	RFQ 1Q 2010 Under design Under design Under design
Market St. Drainage Improvements	City of Charleston	Charleston	SC	Sewer	3,000	10	2010	Under design
North/South Tunnel	Georgia DOT	Atlanta	GA	Highway	77,000	41	2015	Under design
Snapfinger Interplant CSO Tunnel	Dekalb County	Decatur	GA	CSO	26,400	28	2010	Under design
Port of Miami Tunnel	Florida DOT	Miami	FL	Highway	7,400	39	2011	Funding secured

The editors of Tunneling & Underground Construction encourage UCA of SME members to submit projects to the Tunnel Demand Forecast online at www.smenet.org. The items will be posted on the online TDF once they are verified.

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Sewer replacement	Miami Dade	Miami	FL	Sewer		5	2010	Under design
Lockbourne Interceptor Sys. Tunnel	City of Columbus	Columbus	OH	Sewer	10,000	12	2012	Under design
OSIS Aug. & Relief Sewer Tunnel	City of Columbus	Columbus	OH	Sewer	25,300	18	2010	Under design
Olentangy Relief Sewer Tunnel	City of Columbus	Columbus	OH	Sewer	58,000	14	2012	Under design
Alum Creek Relief Sewer Tunnel	City of Columbus	Columbus	OH	Sewer	74,000	10 to 18	2014	Under design
Black Lick Tunnel	City of Columbus	Columbus	OH	Sewer	32,000	8	2013	Under design
Austin Downtown Tunnel Project	City of Austin	Austin	TX	Sewage	18,600	10	2009	Awarded SAK Construction
Water Treatment Plant #4	City of Austin	Austin	TX	Water intake	15,000	7 to 9	2010	Under design
Waller Creek Tunnel	City of Austin	Austin	TX	CSO	5,300	22	2010	Under design
Thornton Connecting Tunnels Project	Metro Water Reclamation District	Chicago	IL	CSO	1,300	30	2009	Walsh low bidder
Belmont - Southport Plant Connection	City of Indianapolis DPW	Indianapolis	IN	CSO	29,000	12	2010	Under design
Pogues Run Tunnel	City of Indianapolis DPW	Indianapolis	IN	CSO	11,000	18	2013	Under design
Drumanard Tunnel	Kentucky DOT	Louisville	KY	Highway	2,200 x 2	35	2010	Under design
Drumanard Tunnel - Pilot Tunnel	Kentucky DOT	Louisville	KY	Highway	2,200	12 x 12	2009	Under funding review
River Mtn. Tunnel # 3	Clean Water Coalition	Las Vegas	NV	Wastewater	44,000	15	2012	Under design
CWC Reach 3	Clean Water Coalition	Las Vegas	NV	Wastewater	7,500	15	2012	Under design
Univ. Link Light Rail Extension Univ. Link Tunnel U220 Univ. Link Tunnel U230	Sound Transit	Seattle	WA	Subway Subway	22,800 3,800 x 2	19 19	2009 2009	Awarded to Traylor/FKCI; Awarded Jay Dee/Coluccio/ Michels JV
Alaskan Way Highway Tunnel	Washington DOT	Seattle	WA	Highway	10,500	54	2011	Under design
Caldecott 4th Bore	CALTRANS	San Francisco	CA	Highway	5,000	50	2009	Tutor-Saliba low bidder
Third Ave. Subway Tunnel	S.F. Muni Metro	San Francisco	CA	Subway	10,000	20	2011	Under design
New Crystal Springs Bypass Tunnel	S.F. Public Utility Commission	San Francisco	CA	Water	4,200	13	2008	Awarded Shank/B-B JV
Bay Tunnel	S.F. Public Utility Commission	San Francisco	CA	Water	26,200	10	2009	Bid date 11/10/10
New Irvington Tunnel	S.F. Public Utility Commission	San Francisco	CA	Water	18,200	10	2009	Advertising mid 2010
Sunnydale Aux. Sewer Tunnel	S.F. Public Utility Commission	San Francisco	CA	Sewer	4,000	11	2010	Under design

AWARDS

UCA calls for award nominations

The Underground Construction Association (UCA), a division of SME, will present the UCA awards at the 2010 North American Tunneling Conference (NAT) in Portland, OR.

The awards to be presented are: Outstanding Individual, Project of the Year, Outstanding Educator and the Lifetime Achievement Award. The nominations for the awards will be reviewed and the winners selected by the UCA Executive Committee at its January meeting.

The recipients' photos and biographies will appear in the March issue of *T&UC*. Guidelines and nomination forms are available on the UCA of SME Web site, uca.smenet.org.

Please submit your nominations by Jan. 5, 2010 to Mary O'Shea at oshea@smenet.org. ■

Pressure grouting book coming in 2010

UCA member Raymond W. Henn has just completed a text book on grouting methods associated with underground construction. *Ultrafine Cement in Pressure Grouting* is the third text in a series of three books on grouting. It is scheduled to be available from the American Society of Civil Engineers (ASCE) late in the first quarter of 2010.


HENN

Henn is a principal with Lyman Henn Inc., Denver, CO. Nate Soule, a senior geological engineer with Lyman Henn Inc., is the co-author of the book.

Until recently, almost all information available on ultrafine cements and the grouts made from them has come from the materials suppliers. Henn's first two books are *Practical Guide to Grouting of Underground Structures* and *AUA Guidelines for Backfilling and Contact Grouting of Tunnels and Shafts*.

The books can be ordered at http://pubs.asce.org/books/. ■

CHAIRMAN'S COLUMN

Continued from page 2

needs to be aware that, if ARRA funds are part of the funding of a specific construction project, there are new regulations for quality control, allowable permanent materials, claims development, and reimbursement and reporting requirements. These requirements are not only applicable to the general contractor, but also the first and second tier subcontractors. Designers now need to advise in their bid packages if there are ARRA funds involved in the project and advise what is required to meet the new federal regulation.

This is a very serious industry issue. The regulations have established inspector general offices within the different federal funding agencies that have legal authority to subpoena, fine or prosecute. Please review this closely in conjunction with your legal counsel. I am investigating if we can include a session on this matter at NAT 2010.

The UCA Executive Committee and the UCA of SME membership acknowledges the contributions made by the Lovat family to our industry. Richard Lovat was a true entrepreneur in that he saw a need for mechanization in the tunnel industry and set about to develop equipment that improved the safety and productivity of underground construction.

I have talked to Richard many times and was often at his plant in Toronto because I was involved in the supply of the tunnel support system and he was supplying the TBM to the project. Richard always had a passion for his work and a deep appreciation for the people that worked for him and his customers. With this business philosophy, he developed a highly respected, worldwide organization. He brought his son, Rick Lovat, into the family business, who assisted him in growing the company and its reputation. The service that Richard and Rick Lovat gave to this industry is greatly appreciated, as their work has provided Caterpillar the strong groundwork to continue to build upon the fine heritage of Lovat Tunneling Equipment. I want to congratulate Richard on his retirement and extend the best wishes to Rick in his new business endeavors.

If any member or reader has any questions, would like to comment on any of the above items or have suggestions on how the UCA of SME can be of service to you or your organization, call my office, 724-942-4670, or e-mail me at dklug@drklug.com. ■

• Denotes new listing.

Industry Events

March 2010

17-19, The International Symposium on Tunnel Safety and Security (ISTSS) 2010, Frankfurt, Germany. Contact: Andres Lonnermark, SP Technical Research Institute of Sweden, phone 46-10-516-56-91, e-mail andres.lonnermark@sp.se, Web site www.sp.se/en/units/fire/news/ISTSS2010.

• **17-19, Intertunnel 2010, Moscow 3rd International Tunnel Exhibition,** Moscow Expocentr. Contact: Natalia Charman, Mack Brooks Exhibitions Romeland House, Romeland Hill St. Albans, AL3 4ET, Great Britain, phone +44 0 1727 814 400, fax +44 0 1727 814 401, e-mail: intertunnelrussia@mackbrooks.com, Web site: www.intertunnelrussia.com.

May 2010

• **2-7, NASTT'S No-Dig 2010,** Renaissance Schaumburg Hotel & Convention Center, Schaumburg, IL. Contact: Michelle Magyar, Benjamin Media, Inc., 1770 Main St., P.O. Box 190, Peninsula, OH 44264-0190, phone 330-467-7588, fax 330-468-2289, e-mail mmagyar@benjaminmedia.com, Web site www.nodigshow.com.

• **114-20, ITA-AITES 2010, World Tunnel Congress and 36th General Assembly,** Vancouver Convention Center, Vancouver, Canada. Contact: Congress Secretariat, WTC 2010, National Research Council Canada, 1200 Montreal Road, Building M-19, Ottawa, ON K1A 0R6, Canada, phone 613-993-0414, fax 613-993-7250, e-mail wtc2010@nrc-cnrc.gc.ca, Web site www.wtc2010.org.

June 2010

12-19, North American Tunneling Conference, Portland, OR. Contact: Meetings Dept., SME, 8307 Shaffer Parkway, Littleton, CO 80127, phone 800-763-3132 or 303-948-4200, fax 303-979-3461, e-mail sme@smenet.org, Web site www.smenet.org.

May 2011

• **21-26, ITA-AITES 2011, World Tunnel Congress and 37th General Assembly,** Finlandia Hall, Helsinki, Finland. Contact: ITA-AITES, c/o EPFL GC D 1 402, Station 18 CH-1015 Lausanne, phone 41-21-693-23-10, fax 41-21-693-41-53, e-mail secretariat(at)ita-aites.org, Web site www.wtc11.org.■

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

UCA of SME

George A. Fox Conference
January 26, 2010
Graduate Center, City University of New York
New York, NY

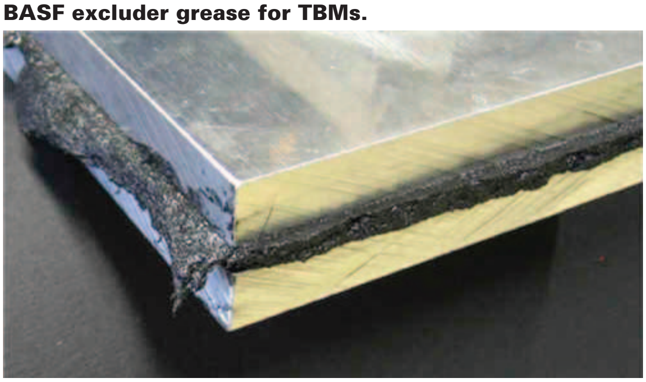
FOR ADDITIONAL INFORMATION CONTACT: Meetings Dept., SME 800-763-3132, 303-948-4200 fax 303-979-4361, e-mail sme@smenet.org

BASF introduces excluder grease for use on TBMs

BASF Construction Chemicals has introduced a line of sealant grease designed to stand up to the rigors of tunnel boring machines (TBM). BASF entered the market with its own dedicated production plant. The new product line, Meyco BSG excluder greases for TBMs, have been used in significant quantities on selected machines of the leading manufacturers and the test results were excellent.

Additionally, the main bearing sealing manufacturers Merkel Freudenberg (Germany) and James Walker (United Kingdom), have qualified the Meyco BSG excluder greases. They are consequently appropriate for all worldwide operating tunnel boring machines.

BASF excluder grease for TBMs.



The Meyco BSG excluder greases complete the portfolio of BASF specialty chemicals for TBMs that include:

- Meyco SLF and Rheosoil soil conditioning agents.
- Meyco ABR anti-dust and anti-abrasion agents.
- Meyco TSG tail sealants.
- Meyco GA admixtures for annulus grouts.

Furthermore, BASF Construction Chemicals offers for this market segment Meyco MP injection products, Rheocem microcements as well as concrete admixtures for segmental lining.

www.basf.com

Case introduces CX800B excavator

To meet the next generation of full-sized excavators, Case has raised the bar for the entire industry in terms of fuel efficiency, operator comfort and serviceability with the B series excavators.

The new Case CX800B excavator comes with a Tier III-certified 15.7 L Isuzu engine that delivers 397 kW (532 hp). It is available in standard and mass excavation configurations and features regenerative hydraulics on the boom and arm as well as the bucket curl. This helps increase the cycle time required to get the bucket to the dirt.

The CX800B has a bucket capacity of 4.5 m^3 (5.91 cu yd), a bucket digging force for 43,850 kg (96,668 lb) and a maximum dig depth of 11.6 m (35 ft).

Case offers a full line of excavators, from 1,650 kg to 80 t (3,638 lbs to 88 st). Five compact models offer zero tail swing and a center-swing boom for maximum productivity in the tightest spaces. Three Case minimum swing radius models excel at digging and lifting in cramped construction sites or along busy highways. Case also offers nine full B series excavators.

Case CX800B excavator.

www.casece.com

TUNNELING & UNDERGROUND CONSTRUCTION INDEX TO VOLUME 3
March, June, September, December 2009
Feature Articles, Industry Newswatch, Technology News
Chairman's Column and New Media

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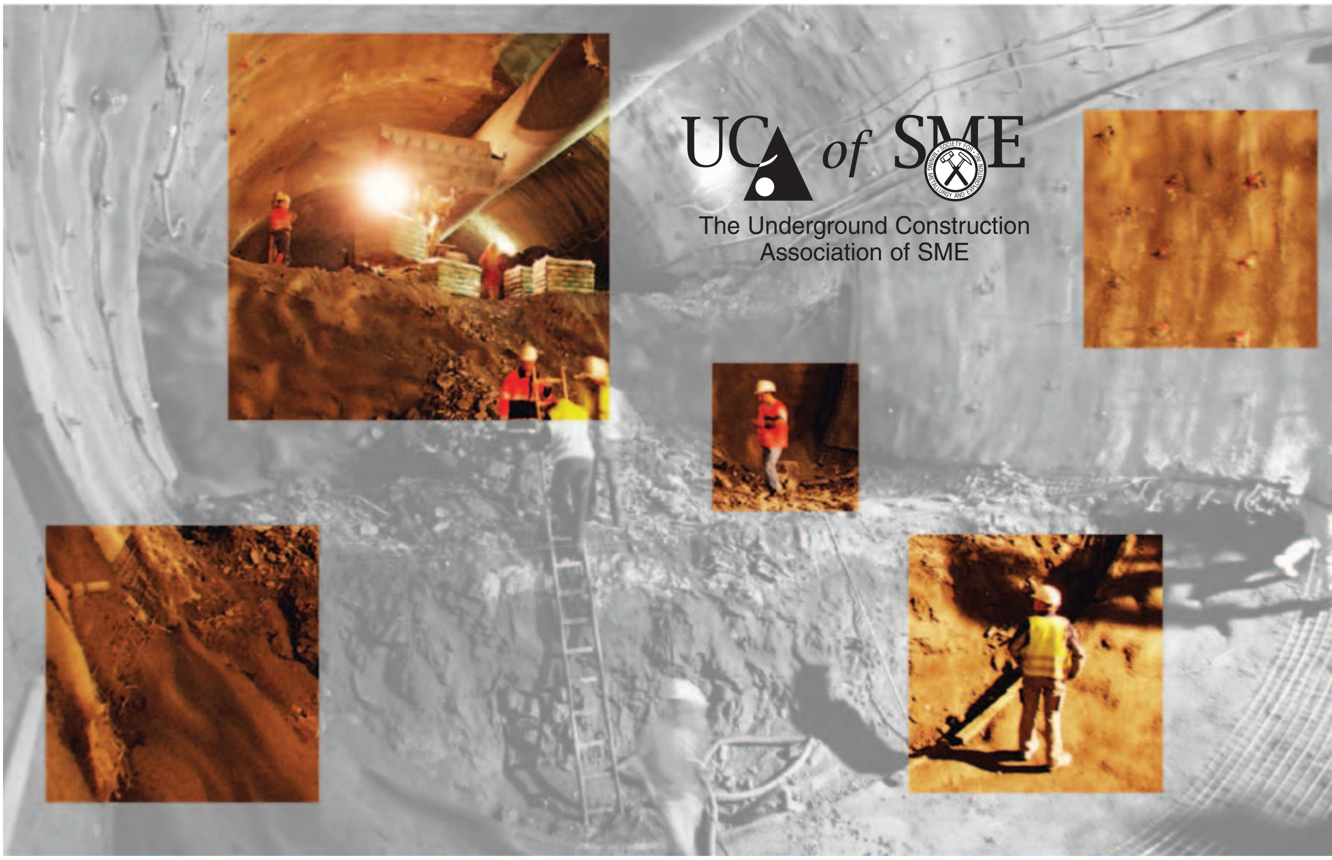

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