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TUNNELING & UNDERGROUND CONSTRUCTION

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PPP tunneling risks

Shotcrete support solution

NAT in Los Angeles

Special Editorial Section from the publisher of *Mining Engineering*

RETC 2015 ♦ June 7-10, 2015 ♦ Sheraton, New Orleans, LA

The Rapid Excavation and Tunneling Conference (RETC) is the premier international forum for the exchange and dissemination of developments and advances in underground construction. RETC provides innovative solutions to the unique challenges associated with the tunneling industry.

Conference attendance exceeds 1,400 professionals from more than 30 countries. Industry sectors include: construction, mining, geotechnical engineering, exploration, environmental, economics, manufacturing, government, land, water/wastewater and transportation. The conference includes a comprehensive exhibit, short courses, field trips, and tours.

The 2015 RETC Organizing Committee has issued a *call for papers*. Prospective authors should submit the following by June 30, 2014: Abstract of 100 words to www.retc.org/author. **The ideal paper presents an interesting or unique challenge and the solution or outcome of that challenge.**

NEW ORLEANS: A BRIEF OVERVIEW

First-time visitors are often struck by the European flavor of New Orleans, and little wonder. Louisiana was claimed for French King Louis XIV in 1699 and is the only state that was once a French royal colony. It is the only U.S. city where French was the predominant language for more than a century.

New Orleans is also known as the birthplace of jazz. Early jazz greats like Louis Armstrong, Buddy Bolden, Jelly Roll Morton and King Oliver got their start in the nightclubs of Storyville, a red-light district that flourished from 1897 to 1917. The city's musical tradition remains strong as New Orleanians like Harry Connick Jr., the Neville Brothers, and Wynton and Branford Marsalis, and events like the New Orleans Jazz and Heritage Festival and French Quarter Festival, share these gifts with the rest of the world.

The city has a well-deserved reputation for food as well. Chefs at the city's more than 3,000 restaurants combine abundant natural resources such as seafood with Creole, Cajun and other cooking styles to create a unique cuisine scene.

TOPICS

- Contracting Practices and Cost
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Authors will be notified of acceptance by September 2014. Final manuscripts from accepted authors are due January 15, 2015.

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DEPARTMENTS

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CHAIRMAN'S COLUMN

Lots of activity in the UCA

The Underground Construction Association of SME (UCA) is busy. On the strategic planning front, to achieve our mission: "Promote the responsible development and use of underground space and facilities," the UCA Executive Committee has identified three strategic goals. The UCA will:

- Become the primary resource for underground construction issues and information requests.
- Improve the image of underground construction in the minds of the public, government, owners and all key constituencies.
- Improve the effectiveness and efficiency of the underground construction industry.

You probably recently received a request for help in defining the action plan — specific tasks that can be accomplished in the short term — that will enable us to meet these strategic goals. I encourage you to volunteer to serve on the committee of your choice. We need all of the good ideas from our membership to help the UCA meet its mission. At our meeting during the North American Tunneling (NAT) conference in Los Angeles, CA in late June, the committee structure will be established and an announcement made. Stay tuned.

On the international front, this year's ITA World Tunnel Congress was held in Iguazu Falls, Brazil. For those who have not been to the Falls, it is even more impressive than Niagara. The Brazilian rain forest is a beautiful site. More than 50 U.S. members attended the WTC this year to participate in working groups, listen to technical papers, visit the exhibition hall and enjoy Brazilian hospitality. The working groups are an excellent method of technology transfer among underground industry from different cultures. See http://uca.smenet.org/ITA for a listing of the U.S. representatives on the ITA working groups and the material available to UCA members. Another objective of our delegation was to encourage members of the international tunneling community to come to San Francisco, CA in April 2016, when the World Tunnel Congress will be held at the Moscone Convention Center, in conjunction with the NAT 2016 conference.

Domestically, the UCA is planning several conferences during the next year to facilitate technology transfer and training within the United States. In addition to the 2014 NAT conference in Los Angeles, another Cutting Edge conference will be held in New York City Nov. 2-4, 2014. As always, the George A. Fox conference will be held in January 2015, also in New York City. I urge you to plan to participate in these conferences.

Lastly, through the good work of Chris Laughton's committee, the UCA is nearing the release of a presentation entitled "Benefits of Underground Construction." This presentation will be geared toward selling underground instead of above-ground solutions to infrastructure problems, and focused on identifying the advantages of going underground. It will be available on the UCA website for member use in the near future.

UCA membership continues to grow in size, recognizing the benefits that accrue to members. Clearly, there are a lot of things going on. ■

William W. Edgerton,
UCA of SME Chairman

SR 99 engineers consider plans to free Bertha

One of the greatest challenges facing engineers working to free the tunnel boring machine (TBM) trapped underground in Seattle, WA could be ground water.

The TBM, Bertha, which is the largest in the world, became stuck on Dec. 6, 2013. Attempts to restart the Hitachi Zosen-built machine failed when it was discovered that the main bearing seal was overheating. To repair the TBM, a pit will have to be dug.

The Washington State Department of Transportation (WSDOT) released a new schedule for the SR 99 tunnel project that calls for tunneling to resume in March 2015.

The first step of the plan is to dig a pit to access the machine. This plan calls for a watertight ring of buried shafts, allowing the dirt within to be scooped away, to form a circular work zone. Bertha would then grind its way into this concrete-walled pit from the south, before repairs begin midyear.

The fear is that the loss of ground water could damage buildings in nearby Pioneer Square.

The Seattle Times reported that most of the shafts will be 2 m (7 ft) in diameter, to resist tremendous soil and water pressures. Part of the ring will include, not only a row of new columns, but have a dual row, by incorporating some of the buried columns that were previously installed to protect the Alaskan Way Viaduct.

Concrete grout must be injected to fill any gaps, not only in the ring but several yards around.

The worries include that ground water might pour into the repair pit, hampering workers and equipment as they remove the giant cutterhead and fix or replace the damaged main bearing.

And if ground water suddenly rushes in, the water loss elsewhere could destabilize old buildings in Pioneer Square, or the viaduct itself, *The Seattle Times* reported.

Previously, Seattle Tunnel Partners (STP) installed a protective north-south line of buried pillars to shield the viaduct from Bertha's vibrations. Gaps of 12.7 cm (5 in.) were left between them, to let ground water migrate more or less normally. Now in a design change, STP's pit designer, Brierley Associates, is proposing to fill those gaps with grout. That way, water would not follow Bertha into the pit.

"Part of the plan includes sealing the pilings placed along the tunnel route to prevent water from getting inside the access pit when the machine breaks through the wall," Matt Preedy, deputy Highway 99 administrator for the Washington State Department of Transportation told *The Seattle Times*.

Ground water presents a significant challenge. Tests performed in 2002 and 2010 indicated that the water content is nearly 35 percent in the soil where Bertha is stranded, at South Main Street. This generates a pressure nearly three times that of the atmosphere.

The repair ring in Seattle will be 25 m (83 ft) in diameter and 36 m (120 ft) deep, according to diagrams Preedy showed the Seattle City Council.

"The designers are currently predicting, not only what sort of effects the viaduct might see from that shaft, but also any buildings in Pioneer Square," he said. ■

New SR 99 schedule released

The Washington State Department of Transportation (WSDOT) released a new schedule for the SR 99 tunnel project that calls for tunneling to resume in March 2015.

Construction was scheduled to begin in May on the pit that Seattle Tunnel Partners (STP) will use to access and repair damage to the tunnel boring machine (TBM), which stopped tunneling in December. Building the pit is the first of several steps STP has laid out to resume tunneling:

- Late May: Begin building the access pit's underground walls.
- Late July through September: Excavate the pit.
- October: Remove the machine's cutterhead and begin repairing damage to the seal system and main bearing.
- February 2015: Test machine to ensure it is ready to tunnel beneath downtown.
- Late March 2015: Resume tunneling.

WSDOT said STP hopes to recover as much as four months of schedule to meet the November 2016 tunnel opening date that was established in the 2010 request for proposals.

STP plans to have crews replace the machine's main bearing and install a more robust seal system, which could include strengthening the seals, installing redundant systems and adding monitoring equipment. Additional details will be included in a plan to be submitted to for review by June 16, WSDOT said in a statement.

The repair schedule will include additional time to accommodate potential improvements to the machine that STP or the machine's manufacturer, Hitachi Zosen Corp., might choose to make after the cutterhead is removed and crews are able to perform a full inspection. ■

Crossrails project reaches 75 percent completion milestone

With the breakthrough at London's Whitechapel station on April 4, the Crossrail project reached the 75-percent completion milestone.

More than 32 km (19 miles) have been bored as part of the £14.8 billion project, Europe's largest railway and infrastructure construction project.

The 150-m- (500-ft-) long tunnel boring machine, named Victoria, began boring at Limmo Peninsula in east London at the end of 2012. On April 4, Victoria broke into the huge underground space at Whitechapel, where work is taking place 35 m (114 ft) below the surface, to create more than a kilometer of new platforms and passenger tunnels for the new Crossrail station.

Tunneling will continue in the second half of 2014 and the project's focus will begin to shift to the job of fitting out the stations and tunnels. During tunneling operations, more than 2.5 Mt (3 million st) of earth have been removed by eight boring machines, of which three have already finished their tasks.

"We're tantalizingly close to finishing what is without doubt a monumental feat of engineering," said London Mayor Boris Johnson.

"It's quite remarkable what the Crossrail team has achieved so far, and we now look forward to the next exciting stage of the project - the fitting-out of the Crossrail stations of the future."

When Crossrail opens in 2018, it will increase London's rail-based transport network capacity by 10 percent and cut journey times across the city, bringing an extra 1.5 million people to within 45 minutes of central London.

Running from Reading in Berkshire in the west to as far east as Shenfield in Essex, Crossrail will pass through 40 stations and reduce cross-London journey times. ■

T&UC NEWS

$403 million to be directed to East River tunnel repairs from superstorm Sandy damage

The U.S. Federal Emergency Management Agency (FEMA) will award New York's Metro Transportation Authority (MTA) $403 million for its efforts to repair and strengthen two key East River tunnels that were flooded during superstorm Sandy, *Newsday* reported.

The MTA will receive $329 million for fixes to its Hugh Carey/Brooklyn Battery and Queens-Midtown tunnels and another $74.5 million for flood-control projects.

In March, *T&UC* reported that the MTA was awarded $866 million to repair the Montague, Steinway and Greenpoint tunnels (March 2014, pp. 7). Some of that funding was also set aside to fund projects to protect against future flooding.

The funding for the East River tunnels will include the construction of new flood walls at tunnel plazas and other facilities, elevation of mechanical equipment, installation of submersible pumps and flood-proofing of some areas inside the tunnels.

"As a result of this investment, we will be able to rebuild and modernize two of the most vital arteries — not only in New York, but in all of America — better and stronger than they were before Sandy," said Sen. Charles Schumer (D-NY), a sponsor of the Sandy Recovery Improvement Act, under which the funding was authorized.

"When we drafted the Sandy legislation, it was this type of damage and this comprehensive type of reimbursement that we had in mind," he said.

The MTA and FEMA settled on the amount of funding as part of a new pilot program, under which municipalities agree on a cap for reimbursable costs in exchange for expediting payments, federal officials said.

The grant will allow the MTA to "permanently repair" the two passageways and "add additional safety measures," FEMA said in a statement.

FEMA had previously provided the MTA $3 million in Sandy funding, and the Federal Transit Administration provided another $1.2 billion, federal officials said. ■

Judge rules in favor of Westside subway plans

Los Angeles County Superior Court Judge John A. Torribio ruled that transit officials followed environmental laws when choosing a route that will require tunneling under Beverly Hills High School for the long-awaited Westside Subway extension, *The Los Angeles Times* reported on April 2.

It was one of the final hurdles for the project.

In a 15-page decision, Torribio wrote that the Los Angeles County Metropolitan Transportation Authority's (Metro) five-year, $13.8-million environmental review process was thorough and fair.

The Beverly Hills School District and the city of Beverly Hills, which sued Metro two years ago claiming in part that risks of tunneling under the school were not adequately considered, can appeal the decision.

Transportation officials said the ruling effectively ends a generation of controversy and studies over the subway extension, which will connect downtown to West Los Angeles and serve one of the nation's most chronically congested commuter corridors. As currently planned, the 14-km (9-mile), $5.6-billion line, slated to open in 2035, will include seven new stations between Koreatown and Westwood.

Metro staff said in a prepared statement that the agency is looking forward to "working with all the communities along the alignment, including Beverly Hills."

> **"It validates Metro's decision to bring the subway to West Los Angeles safely, while serving the greatest number of riders."**
>
> **L.A. County Supervisor and Metro board member Zev Yaroslavsky**

Had Metro lost the lawsuit, the Westside subway extension could have faced years of delay and millions of dollars in extra costs while new environmental impact studies were completed, Metro spokesman Dave Sotero said.

The route Metro has chosen includes a station near Constellation Boulevard in Century City, two blocks west of Beverly Hills High School. It will require tunneling under parts of the campus. Metro considered an alternative route along Santa Monica Boulevard but discarded it after agency studies found a complex earthquake fault zone in that area.

"The Constellation Station is located in the middle of high rise office buildings that house thousands of potential subway riders," Torribio wrote. The Santa Monica Boulevard station favored by Beverly Hills "would require these same riders to walk a considerable distance to access the subway."

Los Angeles County Supervisor and Metro board member Zev Yaroslavsky, whose district includes the Westside, said in a statement that he was "gratified" by the ruling. "It validates Metro's decision to bring the subway to West Los Angeles safely, while serving the greatest number of riders," he said.

Last year, the city of Beverly Hills sued the Federal Transit Administration and the U.S. Department of Transportation over federal grants and loans allocated to the subway, saying the project violated environmental, transit and administrative laws. ■

Robbins TBMs break through in Malaysia

Malaysia's capital Kuala Lumpur is a humid tropical metropolis with millions of inhabitants, and fresh water is in demand. A new tunnel was commissioned by the Malaysian Ministry of Energy, Green Technology and Water (KeTTHA), drawing water from the rainforest river Semantan and into the capital to address projected shortages for domestic and industrial use.

In 2014, three 5.23-m (17.16-ft) Robbins main beam tunnel boring machines (TBM) successfully completed excavation of the Pahang Selangor Raw Water Tunnel, also the longest tunnel in Southeast Asia. The massive 44.6-km (27.7-mile) long tunnel passes through the Titiwangsa mountain range under cover as high as 1,246 m (4,087 ft) and below geothermal features including hot springs.

The Robbins main beam TBMs excavated high cover hard rock conditions with durable back-loading cutterheads — the smallest ever designed to be mounted with 48 cm (19-in.) disc cutters.

Given the highly variable conditions, including hard granite up to 200 MPa UCS, multiple fault zones and quartz dykes, three separate TBM drives were proposed. Sections of NATM near the inlet and outlet portals were also used in sedimentary rock and granite. KeTTHA selected Shimizu Corp. and Nishimatsu Construction of Japan, along with local companies IJM Corp. and UEM Builders Bhd. (SNUI JV), as the contractor. The decision to use Robbins TBMs for the majority of tunneling was a clear one for the JV: "The open-type main beam TBM is number one in the world. I have used other machines, but this design is simpler and easier to use, and more powerful," said Nakano, deputy project manager for the SNUI JV.

All TBMs recently completed tunneling for this extensive project. The first TBM excavated 11.2 km (7 miles) and broke through in March 2013. The other two machines excavated 11.3 km (7 miles) and 12 km (7.5 miles) and met in the tunnel in mid-February 2014. "This is something we all look forward to in the tunneling industry," said Robbins field service manager, Andy Birch. "We get through all of

(Continued on page 9)

Jacobs Associates opens office in Sydney, Australia

Jacobs and Associates' Sydney office currently supports ongoing projects in the city, including the North West Rail Link. These are the latest in a long list of Jacobs Associates' Australian projects. The firm's history in the region dates back to the 1950s, when its founder J. Donovan Jacobs was involved with the Snowy Mountains hydroelectric scheme. Since that time, the firm has served on more than 40 major tunneling projects and tenders in the region.

Mark Trim, a lead associate with Jacobs Associates, has played a key role in establishing the office. Trim has 15 years of experience as a design engineer specializing in permanent and temporary underground structures, with an emphasis on tunnel design, deep excavation support systems, soil-structure interaction and ground improvement technology. ■

Brierley earns distinguished alumnus award

On March 12, 2014, Tracy Lundin, President of the Civil and Environmental Engineering Alumni Association, presented Gary Brierley the Distinguished Alumnus Award from his alma mater, the University of Illinois at Urbana-Champaign.

Brierley was recognized for his outstanding career working on the design and construction of underground projects, for extensive contributions in the engineering profession as a member of many technical and professional societies, and for teaching and mentoring young engineers on the topics of tunnel design and construction, subsurface investigations, rock mechanics and professional practice.

The evening of the award ceremony, Brierley was accompanied by his friends and colleagues from the underground construction industry. ■

Robbins: Three TBMs were used on project

(Continued from page 7)

the hard work and eventually we break through. It's a great feeling, and I'm very happy for this joint venture and for Robbins."

The machines maintained excellent advance rates throughout the project despite many challenges including fault zones, variable rock conditions, high rock temperatures and frequent electrical storms that required machine stoppage. Due to the hot springs, water ingress at temperatures up to 56° C (133º F) was recorded. Maximum rates of 49 m (161 ft) in one day, 198 m (650 ft) in one week and 657 m (2,156 ft) in one month were nonetheless achieved — good rates that were at least partially attributed to the early installation of fiber mortar shotcrete as primary ground support. The near-zero rebound system, with its quick set time of 30 minutes, saved a significant amount of time compared to conventional ground support methods. Developed by Japan-based Denka and MCM, the project is the first time the material has been used outside of Japan and was able to successfully stabilize tunnel walls even in loose and collapsing ground.

High-tech design was also a factor in project accomplishment. To tackle the high cover and tough geology, all machines were equipped with custom back-loading cutterheads and durable large diameter cutters – the smallest diameter cutterheads to ever be outfitted with 48 cm (19-in.) cutters. The machines also had streamlined operator's cabs with touch screens and wireless operation, able to stream data to site offices and to a project website for worldwide analysis. Behind each machine, Robbins continuous conveyor systems moved muck efficiently from the machine face.

Along with custom design and innovative ground support, the assistance provided by Robbins was integral to the project's success. "The field service team was good and supported us on our project," said Ohashi, mechanical engineer for SNUI JV at the breakthrough of the first TBM, "I am pretty happy [with the result]." ■

FEATURE ARTICLE

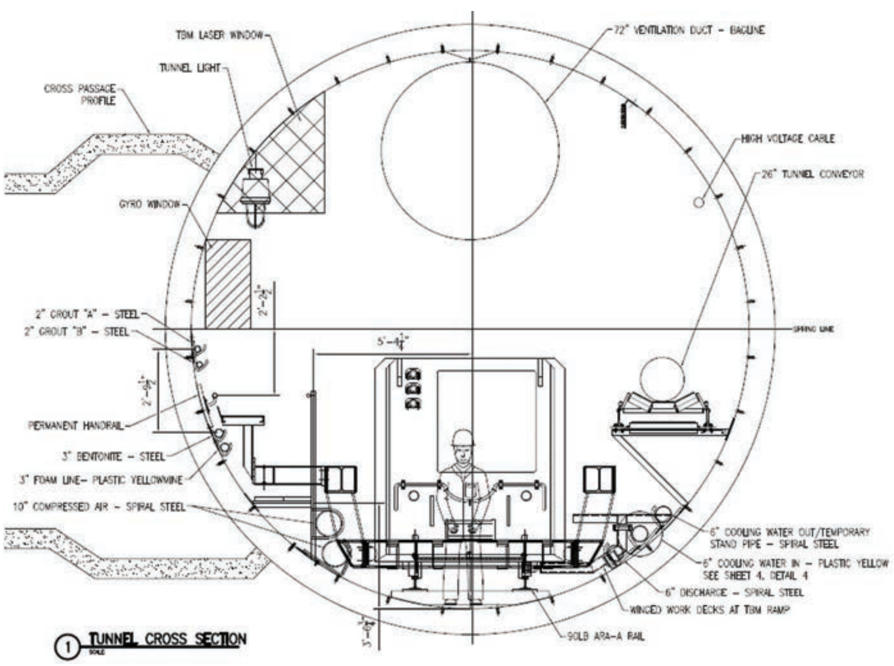
Opening supports to segmental linings: A novel shotcrete support solution

In a world of technology and electronic communication, it is easy to forget what engineers do best with a problem: sitting around a table, exchanging views and ideas with sketches and respecting everyone's view. This was the approach adopted in the project to arrive at a solution for the cross passage opening support for the Seattle University Link Extension.

Schedule and space constraints usually impede concurrent cross passage excavation and tunnel boring machine (TBM) operation. And where the space is constrained, opening support solutions that maximize available cross sections are of great benefit. While there are a number of solutions that minimize space, some of these solutions can require expensive steelwork and extensive drilling and fixing. However, following a detailed round-the-table discussion of the options and constraints, it was identified that a shotcrete shell would not only limit obstruction of the space during installation, but also permit easy installation, particularly around services, and avoid costly steelwork and drilling and fixing.

FIG. 1

Typical tunnel cross section.



Background

University Link Extension is a 5.07-km (3.15-mile) extension of the existing Central Puget Sound Regional Transit Authority (Sound Transit) light rail system that runs in twin-bored tunnels from downtown Seattle, WA north to the University of Washington, with stations at Capitol Hill and on the University of Washington campus near Husky Stadium.

Anthony Harding, Malcolm Chappell, Matt Burdick and Michael Krulc

Anthony Harding and **Malcolm Chappell**, are principal tunnel engineer and chief engineer, CH2M Hill and **Michael Krulc**, member UCA of SME, and **Matt Burdick**, are project manager and project manager, Traylor Bros. Inc., email mkrulc@traylor.com.

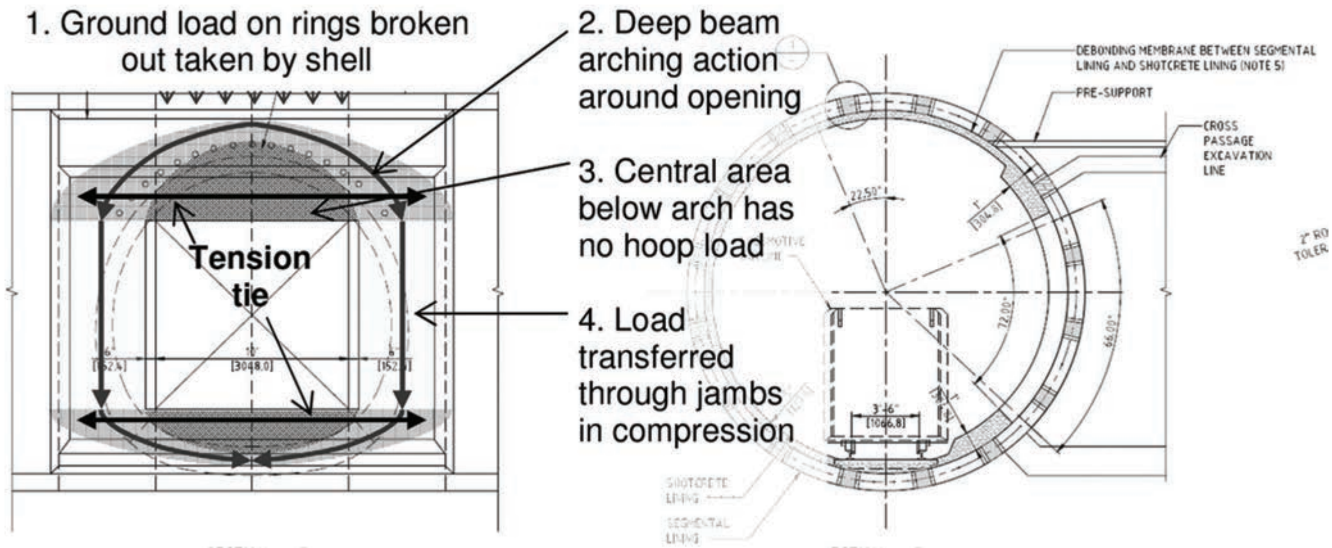
University Link will serve the three largest urban centers in the state of Washington — downtown Seattle, Capitol Hill and the University District. By 2030, the University Link line alone is projected to add 70,000 boardings a day to the light rail system.

Contract U220 comprises site preparation, slurry wall construction and partial excavation of the University of Washington Station box and excavating the 3.48 km (2.16 miles) of twin-bored 6.55 m (21.6 ft) excavated diameter tunnels from the University of Washington Station to Capitol Hill Station as well as construction of multiple cross passages between the twin-bored tunnels, permanent invert and walkway concrete, wet standpipe and permanent electrical installation in the running tunnels. The running tunnel sections were excavated with earth pressure balance TBMs and had the final lining constructed during excavation using bolted and gasketed precast concrete segments.

On March 25, 2009 a joint venture of Traylor Bros. Inc., and Frontier-Kemper Constructors (TFK JV), both of which are headquartered in Evansville, IN, submitted the lower of two bids received at $309,175,274. This was

FIG. 2

Shotcrete support option with indicative structural behavior.



significantly lower than the $354 million bid price offered by the second bidder and the published Engineer's Estimate ($395 million).

Construction management was provided to Sound Transit by a joint venture of CH2M Hill and Jacobs Engineers. Engineering design was provided by a joint venture of Jacobs Associates, HNTB and Earth Tech, including crosspassage design, initial lining design and a potential method for providing temporary support to the TBM tunnel segmental lining around openings cut for access into the cross passages. The offered support option relied upon a series of rolled steel beams and braces (commonly referred to as hamster cages) that are erected inside the tunnel and rigidly blocked against the intrados of the segmental lining. TFK hired Halcrow Inc, which also designed the segmental lining for TFK, to provide design services for the temporary propping system.

Schedule

The contract allotted a total of 41 months from notice to proceed to substantial completion for the U220 project, allowing 15 months for site preparation, station box slurry wall construction, station box excavation and invert concrete construction, and a further 13 months for TBM mining and all cross passage and tunnel finishing work. With 16 cross passages to complete, this would not be possible unless cross passage work started before completion of TBM mining. Thus, TFK decided that cross passage excavation and TBM mining would have to occur simultaneously in the same tunnel to achieve the required substantial completion deadline. Additionally, two cross passages

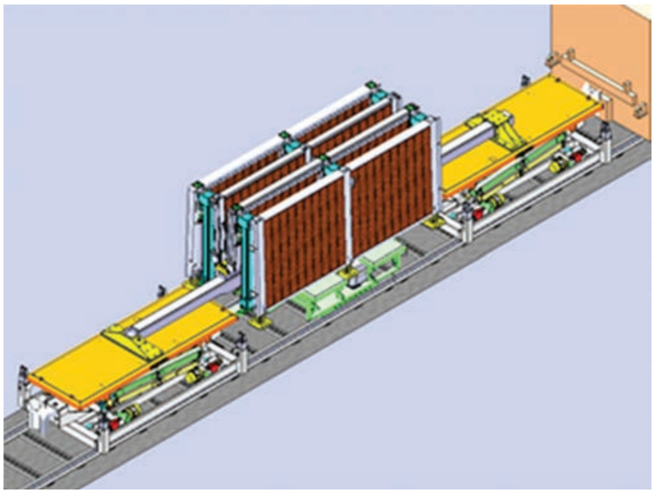
TABLE 1

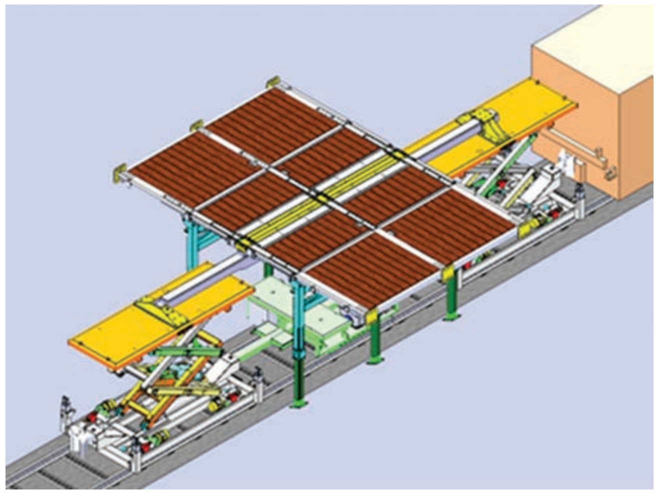
Methods of analysis.

Component	Method of analysis	Reinforcement
Thin shotcrete ring	Closed form analysis for tunnels in soft ground, horizontal load 50 percent of vertical.	#5 bars at 203 mm (8 in.) spacing (1 layer, centrally placed).
The lintel and sill deep beam	Strut and tie model (as per deep beam theory), plus moments and shears from the section above the lintel with no hoop load.	5 #10 bars each face main steel, chained #4 ties at 127 mm (5 in.) spacing.
Section above lintel with no hoop load	Designed as a slab with the thickened section of lintel acting as an edge beam.	
Jambs	Curved columns with uniform horizontal UDL as per normal jambs.	6 #4 bars each face main steel, #4 ties at 254 mm (10 in.) spacing.

FIG. 3

Portal and access adit development.





would have to be excavated simultaneously while several others would be undergoing waterproofing installation and final lining construction.

This was a new approach for the TFK team and the problems that needed to be overcome to make it happen were numerous and challenging. However, it was very clear that the driving tenet during cross passage planning would be "Do not stop the TBM," which created many of the challenges that had to be overcome.

TABLE 2

Difference between hand calculations and FE model.

Value	Hand calculation	Model	Difference
Maximum moment in shell	31 kNm/m	34 kNm/m	10%
Lintel moment	181 kNm/m	190 kNm/m	5%
Lintel tension	1982 kN/m	1947 kN/m	2%
Jamb compression	1982 kN/m	1892 kN/m	5%

Alignment and geology

The tunnel route comprises approximately 3,350 m (11,000 ft) of twin bore tunnel. The depth at the University of Washington Station is approximately 23 m (77 ft), and approximately 14 m (45 ft) at the Capitol Hill Station. The shallowest point in the tunnel has only 4 m (13 ft) of cover below the Lake Washington Ship Canal (Montlake Cut), and a deepest point of approximately 95 m (310 ft).

The soils encountered on the tunnel route comprise glacial and non-glacial deposits, the majority of which have been over consolidated by glaciation. The deposits consist of clays, silts, sands and gravels in varying proportions. Some of the layers form aquacludes, leading to a somewhat complex ground water profile. Water pressures on the lining vary from a minimum of 1 bar at crown, to a maximum of 6.5 bar at invert.

General layout

The TBM tunnel lining is a conventionally reinforced precast concrete lining, 5.74 mm (226 in.) internal diameter and 267 mm (10.5 in.) thick, with a ring length of 1.52 m (60 in.) comprising five segments plus a key, arranged in a trapezoid/parallelogram arrangement. Segments are bolted with spear bolts on the radial joints and push-fit dowels on the circumferential joints. Separate up and down rings are provided to assist in the negotiation of vertical and horizontal curves while maintaining the counter key segment below axis as much as possible.

There are 16 cross passages along the route at approximately 230-m (750-ft) centers. Typical cross passages have a maximum width of excavation of around 3.75 m (12 ft 4 in.), while two larger passages, for a sump and interconnection of Traction Electric conduit, go up to 5.1 m (16.8 ft). All of the cross passages require an opening two rings wide, within which a permanent opening support is cast. The opening requires temporary support from break-out until the permanent concrete has achieved its specified strength. The contract specifies that the temporary opening support to be the contractor's design.

A number of temporary services are installed along the length of the TBM tunnel, as shown in the typical tunnel cross section in Fig. 1, and need to remain in almost continuous operation during cross passage excavation, except for short (less than one hour) interruptions in preparation for temporary support installation.

The design of the opening support also had to allow for the installation of pre support at each cross passage, consisting of a series of spiles over the top of the cross passage excavation profile.

Options and decisions

Temporary propping design had to accommodate continuous supply of the TBM with segments, utility pipe and rail sections and removal of excavated material via belt conveyor, by ensuring that the temporary support system did not conflict with the previously installed utility systems. The hamster cages were eliminated from consideration almost immediately, as their use presented numerous conflicts with the existing utilities, conveyor structure and the requirement to maintain continuous train traffic in the tunnel. After eliminating the hamster cage option, Halcrow started looking at the steel doorframe in detail. Early evolutions of the doorframe design were very heavy and required a high quantity of large diameter anchors to be drilled into the segmental lining around the opening. While technically feasible, the cost to fabricate 10 complete cross passages worth of support was prohibitive, as were the costs associated with the installation and removal of the large diameter anchors. It was at this stage that the designers and contractors sat down together to try to identify a better solution. Following extensive discussion of the constraints of the problem and possible ways around them, the discussion yielded the third, and ultimately the chosen temporary support system, which relied on a reinforced shotcrete shell placed inside the segmental lining around the cross passage opening. A similar system had been successfully implemented on a project in the United Kingdom several years before and appeared to be appropriate for this situation.

Shotcrete shell option. The shotcrete shell concept is similar to the shotcrete opening support that would be provided for a cross passage opening in the SCL lining for a conventionally mined tunnel, except that it supports the two rings of the broken out lining. The concept is illustrated in Fig. 2.

This solution offers a number of significant benefits over the jamb and lintel solution:

- The shotcrete is designed only for temporary loads and is, therefore, much thinner and more flexible than the segmental lining.
- The concrete is predominately in compression, so reinforcement levels are low (except around the opening).
- Service relocation limited to blocking out existing lines by 25 mm (6 in.).

FIG. 4

Top heading and bottom bench excavation.

- No relocation of the conveyor was required, and could be protected from the installation with a plastic sheet.

The relatively low cost of the propping system enabled TFK to have propping in place at every cross passage in both tunnels at the same time.

Design

The design of a novel solution such as this needs careful consideration to ensure that the structural behavior is understood and correctly accounted for in the design. The first step is to understand how the segmental lining is loaded by the ground. Prior to cross passage breakout the shell only supports self weight. No deformation of the permanent lining is expected in the short term (prior to breakout), so no load will be exerted on the shell. Some shrinkage may lead to a small gap between lining and shell.

Once the rings are broken out, hoop force in those rings is removed and all ground load on those rings will be transmitted directly through the segments onto the 127-mm (5-in.) shell inside. The shell then acts as a hoop, transferring hoop around the ring, with load transfer around the opening being provided in a 305-mm (12-in.) thickened section.

Loading. The magnitude of the loading might, at first glance, appear straightforward. This kind of opening is often designed on the basis of the pressures required to ensure a stable tunnel, such as those recommended by Terzaghi, which are easy to calculate and design for. However, these pressures were primarily derived from field observations of conventional tunneling using steel sets, which allow significant relaxation of the ground — and hence reduction in load — prior to installation of the lining. Modern TBMs are specifically designed to limit this movement in order to control settlement, so there is potential for higher loads to be present in the lining. The authors are aware of instances of the grout load pressures essentially becoming 'locked in' to the lining. Furthermore, the presence of cohesive ground also increases the risk of loads significantly above those that would be predicted by Terzaghi in the medium term, which presents further risk if the cross passage excavation occurs significantly behind the TBM.

To address these risks, the design assessed how much movement of the lining would be required to alleviate the load to manageable levels. Using an axisymmetrical finite element model of the tunnel, it was shown that the load would reduce to manageable levels with relatively small inward displacements of the order expected with the shell (ignoring the beneficial effects of shrinkage), but that further movement would provide much less further alleviation of load.

FIG. 5

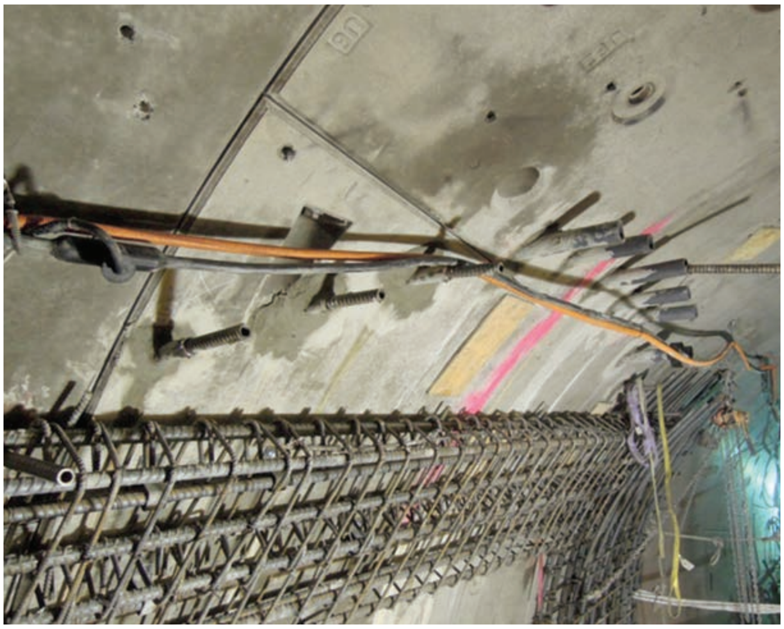
Placing dry mix shotcrete in crown.

Design

With reference to Fig. 2, it can be seen that the design can be broken into a number of component parts that each lend themselves to simple analysis by hand calculation, as presented in Table 1.

FIG. 6

CP 19 pre-support spiles above lintel cage.



Due to the rather novel nature of the design, additional analysis was undertaken using a 3D plate model to verify that all behavior of the system was adequately understood. The finite element model was generally within 10 percent of the hand calculations (see Table 2), which was considered to be very good agreement. In particular, the deep beam behavior of the lintel and sill area was clearly visible in the model, including the slab action of the area with no hoop load. Nevertheless, the modeling did pick up a number of minor unforeseen effects, including:

- Torsion in the jambs. This arises because the inside of the jambs is not supported by the soil. This torsion was within capacity of the section and was verified by hand calculation.
- Longitudinal bending moments between the loaded and unloaded sections of the thin section. These arose in the model because the loaded sections were in compression and moved in, while the unloaded sections inside the intact rings did not move in. There was some doubt as to whether these would occur in reality due to the small relative displacements and effects of cracking. Nevertheless, they were checked and found to be within capacity.

The conclusion of the modeling was that the hand calculations would result in a design that is robust without being conservative. It also identified the need to undertake a torsion check on the jambs when the jambs are only partially supported by the ground behind. However, it is the authors' view that finite element modeling would demonstrate lower levels of torsion, and is, therefore, recommended if hand calculations were to indicate that additional torsional reinforcement was required.

FIG. 7

Lintel beam removal.

Construction

Prework. Installation methodology evolved as TFK's crew became more familiar with the process and were able to refine it. Propping installation boiled down to three basic steps:

1. Segment preparation.
2. Reinforcing steel and formwork installation.
3. Shotcrete placement.

Perhaps the biggest concern about the shotcrete propping system was the impact that a shotcrete shell might have on the finished surface of the TBM tunnel lining; but the shotcrete also had to adhere to the lining during spraying while still being easy to remove. TFK performed a series of tests on a small mockup section of tunnel lining to confirm the suitability of a number of different methods to cover the segment joints and bolt pockets including backer rod, custom cut foam pieces, various tapes and thin plywood sections and multiple bond breaker products and installation procedures. Shotcrete was applied over the mockup and allowed to cure prior to removal. While actual shotcrete removal from the mockup proved to be significantly more difficult than anticipated, it did result in a clean final lining surface. The solution settled upon relied on 3-mm (0.125-in.) plywood sections nailed over the bolt pockets and a double layer of bondbreaker applied over the full area of the propping and a single layer applied one ring either side of the propping to ease removal of overspray. It was determined that excessive adhesion to the radial and longitudinal joints was not a significant concern.

Equipment. In order to make use of the unique propping solution and progress cross passage excavation concurrent with TBM mining, a custom folding work deck and a scissor-car-based work deck delivery system were devised and fabricated. The work decks and scissor car were designed by Kelley Engineered Equipment (KEE) of Omaha, NE. KEE also fabricated the scissor car while Traylor Bros., Inc. equipment shop in Evansville, IN fabricated the work decks. The decks are illustrated in Fig. 3.

Work sequence. TBM mining was conducted 24 hours per day, five days per week with maintenance performed on the weekends, while cross passage works were 24 hours per day, six days per week. The initial plan was to commence cross passage excavation from the Southbound tunnel after the trailing gear of the Northbound TBM (which was trailing Southbound by one month) had cleared the third cross passage along the alignment; roughly four months after the start of TBM mining. In reality, it took much longer to get ready for cross passage excavation than anticipated and, thus, true excavation did not begin until seven months after the start of TBM mining.

Throughout the propping installation process, the basic reinforcing steel detail remained unchanged — the radial and longitudinal steel in the thinner shell section was shipped loose and installed piece by piece while the reinforcement for the thickened section around the cross passage opening was separated into four cages that were pre-assembled off site and set in place. A series of hangers and slab bolsters were used to provide appropriate clear cover against the segmental lining and adequate support to hang the cages. The completed reinforcement, platform and services are illustrated in Fig. 4.

In order to provide shotcrete at relatively short notice and avoid obstructing the tunnel, the dry mix method was required. Dry mix shotcrete was delivered to the job site in one-cubic-yard super sacks and transported to the cross passage work via flat car and locomotive, before being placed by hand to the required profile as shown in Fig. 5.

Coordination with cross passage pre-support requirements (including dewatering). The flexibility of the open-

FIG. 8

Conveyor side shell removal.

4300 armed with a 2,500 ft-lb hydraulic demolition hammer. A second excavator (Cat 304), with a hydraulic hammer, bucket and thumb was also used to assist with the breaking operations and perform debris load out, with an excavator situated on either side of the cross passage and appropriate protective devices in place around the utilities.

The demolition procedure begins by breaking out a 1.2-m (4-ft) wide swath of the shell section along the full 6.1-m (20-ft) length of the crown. This creates relief and allows the remaining demolition to occur rapidly. The excavators next break the bond between the shell and segmental lining shell section on the non-cross passage side of the tunnel and then pull the shell section off the wall in several large pieces, as illustrated in Fig. 7. The large pieces are processed, sorted and loaded out before additional demolition occurs. Next, a relief cut is made across the columns on the cross passage side roughly 0.6 m (2 ft) below the lintel cage, after which the large machine breaks the lintel cage free from the segmental lining and it falls off in one large section, as illustrated in Fig. 8. The two columns are broken down traditionally to the top of the sill beam, and the sill beam and invert portion of the propping are removed in a follow-on operation when there is good access for rapid completion of the invert concrete across the propping width.

A follow-on finishing operation is required to remove overspray, plywood covers and miscellaneous anchors and repair any surface damage inflicted during the demolition process. This work is performed by hand and is accessed off scissor lifts working on the tunnel invert.

ing support being shotcrete was realized in the following:

- Pre-support spiles installed through the segmental lining over the crown of the cross passage, which were installed prior to the installation of propping to avoid conflicts between the propping reinforcing steel and the spiles. This is illustrated in Fig. 6.
- Dewatering wells that were routed through the propping reinforcing cages and shotcrete without causing interference.
- Post-installed dewatering wells, which required core drilling 25-mm (6-in.) diameter holes through the propping sill beam and reinforcing cage.

Movements and monitoring results. Overall, the shotcrete propping performed admirably and did not exhibit large movements or deformations. In a limited number of instances, total movement approached the trigger levels identified by Halcrow in the design documents but never reached a level of real concern.

Method of demolition. The project schedule required that temporary propping be in place in tunnels and at all 16 cross passages until very late in the job, requiring an efficient demolition methodology be developed and implemented. This exercise was made more difficult due to the unknowns in how the shotcrete would behave during the demolition process. Despite this complexity, an effective methodology and sequence were arrived upon during the second demolition attempt. The primary demolition tool is a Gradall XL

Conclusion

The opening in the shotcrete shell behaves as a deep beam above and below the opening and, while a number of effects need to be considered in design, hand calculations will usually suffice. Finite element modeling is only likely to offer savings in reinforcement where torsion in the jambs is an issue.

Use of the shotcrete shell approach to temporarily support around cross passage openings permitted TFK to start cross passage work earlier and concurrently execute the work on more fronts than would have been possible with a more traditional method of temporary support. Without these advantages the project could not have been completed within the tight schedule demands outlined in the contract.

Finally, the project highlights the inescapable value of focused face-to-face discussion, without which it is doubtful if the solution described would have come to light. ■

FEATURE ARTICLE

UCA's North American Tunneling conference set for Los Angeles

The Underground Construction Association's (UCA) 2014 North American Tunneling (NAT) conference is expected to attract about 1,000 tunneling and underground construction professionals. With the theme "Mission Possible," attendees from around the world will hear the latest in tunneling and underground construction technology in the two-and-a-half days of technical sessions.

The meeting is scheduled for June 24-27 at the JW Marriott Los Angeles Live in Los Angeles, CA. In addition to the technical programming, the accompanying exhibit has attracted 143 exhibitors in 162 booths. And the conference will offer short courses and plenty of social activities that will provide attendees the opportunity to catch up with each other. In addition, a proceedings volume containing all of the 128 papers will be available.

An impressive lineup of sponsors will help attendees enjoy the conference. They include Brierley Associates, Kiewit Infrastructure Group, Parsons, Skanska, Traylor Bros., MWH and HNTB.

Short courses

Four one-day short courses are scheduled for Sunday, June 22. Seven professional development hours will be awarded for each. "Tunnel construction ventilation planning design" will be taught by Brian Prosser and J. Daniel Stinnett, both from Mine Ventilation Services. The first half of the workshop will be devoted to the fundamentals of ventilation, basic thermodynamics, fan selection and other parameters essential to the understanding of tunnel ventilation. The second half of the workshop will be devoted to the design of ventilation systems, selection of equipment and system simulation using standard simulation tools/programs.

This course will provide an outline of the elements of modern thinking involved in the planning, design and control of construction ventilation circuits. It will also discuss new technologies in ventilation monitoring and control systems.

"Surveying in the tunneling industry" will be presented by Peter DeKrom, Atkins; and Darrell Bartley, Subterranean Solutions. This course is designed for engineering interns or individuals with a strong mathematics background interested in putting math in motion. Tunnel surveying is frequently ignored or not considered as a key element in tunnel construction. Proper survey procedures should be implemented beginning at the design phase and continuing throughout all stages of construction. This course will cover survey datums: geodetic datums versus localized datums and surface control, precision surveying for tunnel boring machine (TBM) guidance, guidance systems, as-built surveys (scanning technologies) and latest technologies to implemented.

About 1,000 attendees are expected at NAT this year.

The third course is "Hyperbaric operation in earth pressure balance tunneling, current standards and operational requirements," presented by Kevan Corson, Poseidon Safety International. The application and utilization of alterations in atmospheric pressure dictate that the safety and operational personnel comprehend the beneficial and potentially hazardous aspects of this esoteric environment. Applicable gas laws and their role in hyperbaric operations will be reviewed. This course covers the safety issues with the use of hyperbaric oxygen in the prevention of decompression injuries in the compressed air worker. Objectives covered include compression barotraumas, oxygen seizure, decompression barotraumas, tender decompression, emergency egress and fire. Also discussed will be the current regulations that govern the

Steve Kral, Editor

operational and safety aspect of compressed air work.

"Grouting in underground construction" will be presented by Raymond Henn, Brierley Associates; and Paul Schmall, Moretrench. This course will provide an overview of the materials, equipment and various grouting methods used in association with underground construction and tunneling in soils and rock. Subjects covered will include cements and admixtures, grouting equipment and practices, chemical and cementitious permeation grouting, jet grouting, compaction grouting, pre-excavation grouting, backfill and contact grouting, and cellular grouts. Nine industry experts will give the lectures on these various grouting subjects and techniques. Attendees will also receive a course notebook containing all presentation material by the speakers. This course is recommended for contractors, engineers, owners and consultants involved in any aspect of underground design and construction.

Technical program

NAT 2014's technical program will feature 20 sessions discussing all aspects of the tunneling and underground construction industry. A few of the topics include case histories, planning, design and technology. Abstracts of the presentations will be provided in the pocket program that will be available at the meeting. In addition, short profiles of the exhibiting companies are provided in the NAT Showguide that is bound into this issue of Tunneling & Underground Construction.

Monday, June 23 — Eight sessions are planned for the day. Morning sessions include Case studies: Ground treatment/control, chaired by W. Dean, Frontier-Kemper; Design: Design of underground spaces, chaired by M. Torsiello, Jacobs Associates; Planning: Project delivery I – Design and management, chaired by I. Hee, Arup; and Technology: Operation monitoring and control, chaired by M. Bruen, MWH Global.

Afternoon sessions include Case studies: Water control/grouting, chaired by D. Penrice, Hatch Mott MacDonald; Design: Challenging design issues, chaired by D. Hamilton, Kiewit Infrastructure; Planning: Risk and cost management, chaired by B. Harris, Drill Tech Drilling and Shoring; and Technology: Ground support, final lining and design, chaired by H. Leindecker, Halcrow.

Tuesday, June 24 — The sessions scheduled for Tuesday morning include Case studies: NATM/SEM contracting methods, chaired by S. Rand, King Packaged Materials; Design: Ground movement and structures analysis, chaired by A. Nitschke, Gall Zeidler Consultants, and G. Davidson, Jacobs Associates; Planning: Geotechnical and third party planning, chaired by S. Harvey, Brierley Associates; and Technology: TBM technology and selection, chaired by B. Robinson, Traylor Brothers.

Afternoon sessions include Case studies: Rock tunnels, caverns and shafts, chaired by M. Stokes, Skanska USA Civil NE; Design: Water and waste water conveyance, chaired by J. Bednarski, MWD; Planning: Project deliver II — design/build, chaired by M. McKenna, LACMTA; and Technology: Innovative toolbox, chaired by C. Fleming, Michels.

Wednesday, June 25 — The NAT technical program concludes Wednesday morning with four sessions. They include Case studies: Mechanical excavation, chaired by B. Zelenko, Parsons Brinckerhoff; Design: Design of transit tunnels, chaired by J. Theodore, Sound Transit; Planning: Future projects and industry trends, chaired by D. Haug, LASCD; and Technology: Fresh approach on performance, chaired by J. Wonnenberg, EPC Consultants.

Social events, awards

Monday's NAT luncheon speaker will be Char Miller, Director, Environmental Analysis Program and W.M. Kreck Professor of Environmental Analysis, Pomona College. The UCA of SME/ITA breakfast will be held Tuesday morning. Its program includes presentations from the winners of the Student Paper Contest. An exhibit hall luncheon on Tuesday and a reception later that afternoon are scheduled.

The UCA of SME Awards Banquet will take place Wednesday evening. Three industry professionals will be honored at the banquet, along with the UCA's Project of the Year (see pages 28-30 of this issue).

Herbert H. Einstein, professor at the Massachusetts Institute of Technolgy, will receive the UCA's Outstanding Educator Award. In underground construction, he developed several analysis and design approaches for tunneling in swelling rock. He and is co-workers also developed the Decision Aids for Tunnels, with which cost, time and resources subject to uncertainties can be estimated.

The Lifetime Achievement Award will be presented to Ronald E. Heuer, a geotechnical consultant. He has worked on more than 1,000 underground projects in the United States, Canada and several foreign countries. While working on Colorado's Eisenhower Tunnel in 1970, he helped develop concept drawings and geotechnical analysis for multiple drift methods used to complete tunnel excavation.

Lok Home, president of the Robbins Co., will receive the Outstanding Individual Award from the UCA. Prior to joining Robbins as a field service manager, he worked as a project manager for several Canadian mines. Home also founded Boretec Inc. He was instrumental in merging Boretec and Robbins in 1998 and remains its president.

The Project of the Year Award will go to the Tom Lantos project in San Mateo, CA. HNTB was chosen as the lead designer of the project, also known as the Devil's Slide project. The New Austrian Tunneling Method was used throughout the project to build the twin tunnels beneath San Pedro Mountain, greatly reducing commuter travel times and increased safety.

RETC is next year

While it is still a year away, make plans to attend the Rapid Excavation and Tunneling Conference (RETC) June 7-10, 2015, scheduled to be held in New Orleans, LA. ■

FEATURE ARTICLE

Risk related to PPP tunneling projects for design professionals

Tunnels and underground projects are inherently more risky than vertical projects, which typically utilize more conventional design and construction approaches and are undertaken in the context of relatively ascertained and defined conditions. On tunnel and underground projects, there are a host of special risk factors, including unknowns and uncertainties as to the physical and behavioral characteristics of the ground, the inextricable interdependence and necessary interaction of design decisions and construction means and methods with those ground conditions as well as the manner in which risks are allocated among project participants for unanticipated subsurface conditions. Public-private partnerships (PPP) projects, in their own respects (and independent of any major subsurface component), pose significant risk for all private sector participants. The main driver of owners to procure projects using PPP is financial, as often all, or substantially all, of the design and construction risk are transferred to the private sector consortium, including the design-build (D-B) team. For a concerning number of those public owners, that risk transfer regime includes rather onerous and aggressive contractual terms that allocate to the private sector participants substantially all risks associated with the encountering of unanticipated subsurface conditions. These aggressive risk allocation provisions, while directly impacting project participants upstream of the consulting engineer, have an indirect and corresponding risk intensifying effect upon consulting engineer professional liability exposure.

Tunnel fabrication at the Elizabeth River Tunnels project, a public-private partnership in Virginia. Photo courtesy of the Elizabeth River Tunnels Project.

There are many factors that result in increased professional liability exposure for consulting engineers involved in PPP projects. The more prominent and prevalent of those factors fall into the following categories:

Subsurface conditions risk allocation: Increasingly, project owners on major D-B and PPP subsurface projects are seeking to transfer substantial risk for subsurface conditions to the private sector participants (i.e. the concessionaire and the design-builder). Subsurface conditions, beyond any doubt, are a significant source of risk exposure, disappointed expectations, default and claims. For that reason, it is generally recognized that in order to ameliorate those concerns, the principles of fairness and balance in risk allocation should be adopted and implemented in the specific context of subsurface conditions.

Unfair risk allocation between the project owner and the concessionaire and/or design-builder will increase the risk of professional liability exposure for the consulting engineer. There appears to be no published empirical data conclusively establishing that use of these types of aggressive risk allocation provisions and related contracting practices in D-B and PPP agreements increases the risk of professional liability exposure for the consulting engineer. However, logic (and the experience of the authors) supports the conclusion that a design-builder is more likely to transform what would have been a contractual differing site conditions claim against the project owner into such a third-party professional liability claim – to recover costs incurred by the design-builder but not recoverable against the project owner due to aggressive risk allocation and disclaimer provisions in its prime contract.

Design development risk: For the consulting engineer, design development in D-B and PPP projects moves at an accelerated pace, and this schedule compression may often lead to liability exposures. The schedule compression of the design process of tunnels

David J. Hatem and Nasri Munfah

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and underground projects places special pressure on the geotechnical design discipline on which the design depends. The consulting engineer may be under significant pressure to produce work product resulting in insufficient data or inadequate levels of completion or coordination with other aspects of the design, thereby creating the risk of redesign during post-award or construction and the attendant increased costs and delays experienced in the construction process.

In addition, prior to contract award, the design-builder may look to the consulting engineer to provide quantity estimates and may seek to hold the consulting engineer accountable for overruns in cost or quantities. Although the concessionaire and the design-builder each assume (directly, or ultimately, to the project owner) the contractual risk and financial obligations associated with cost overruns due to "excess" quantities or other consequences of the post-award design development process, in many instances those parties regard the consulting engineer as a de facto risk partner and pass down these obligations. There is a further risk that the public owner may attempt to dominate the design review process, thereby resulting in delay and in the imposition of owner design preferences beyond the contractual requirements. Owner domination and imposition of preferences and judgments in the design development process in PPP and D-B projects is especially problematic in tunneling and underground projects in which the ability of the consulting engineer to make appropriate judgments and exercise discretion are critically important.

In a related vein, it should be noted that statements or descriptions of anticipated or assumed subsurface conditions, characteristics, or parameters in a geotechnical baseline report (GBR), as a general matter, are provided for the purpose of facilitating the allocation of risk between the project owner and the concessionaire and/or the design-builder. These types of statements or descriptions should not be understood by the design engineer as constraining, defining, prescribing or otherwise limiting (or, worse yet, relieving or substituting for) the engineer's obligation to exercise sound and independent judgment in the development of the design.

D-B and PPP design optimization and value engineering typically allow for input and collaboration from various professionals (including owner, concessionaire and design-builder) with the design engineer in the design development process in order to reduce project cost and/or to facilitate the construction process. While those are salutary objectives, the design engineer should be careful not to allow such input or collaboration to intrude upon its exercise of independent and sound professional judgment in the design process.

Cost overrun risk: A potential major risk for consulting engineers in D-B and PPP projects arises out of cost growth (above the guaranteed maximum price) due to the design development process. Typically, this type of claim arises when there are material differences between the design-builder's pre-award bid estimate assumptions (bid estimate) and the actual cost of designing and constructing the project. As a general observation, the design-builder's professional liability claims against the consulting engineer often seek recovery for some or all of its cost overrun.

A typical cost overrun involves some or all of the following factors:

- Aggressive, unrealistic and opportunistic preaward cost estimating or bidding.
- Inadequate information or design definition prior to the submission of the bid.
- Imposition of the project owner's design preferences that exceed contractually mandated design criteria or standards.
- Project owner's unwarranted intrusion into, or restriction of, the design-build team's discretion, judgment, or innovation or design responsibility (as engineer of record).
- Unanticipated or unreasonable application or enforcement of code or other public regulatory requirements or standards in the design development process.
- Inadequate design-builder contingency for cost growth due to design development.

Most of these factors have nothing to do with deficient service performance of the consulting engineer. Depending upon the terms of the prime design-build agreement, the design-builder may have limited, or no, opportunity to obtain an equitable cost or time adjustment from the project owner when some or all of these factors occurs. This situation often leads to a professional liability claim by the design-builder against the consulting engineer.

The bottom line is that unless the design-builder plans for, and is prepared to fund contingency for design development, in tunnel and underground projects there will often be gaps between pricing or bid assumptions and available financial resources required to address cost growth due to design development. The consulting engineer potentially will be exposed to significantly increased risk in D-B and PPP projects due to design development cost growth than in design-bid-build. In the contractual negotiation process, the design-builder may "flow down" various terms, the effect of which would be to transfer design development risk to the consulting engineer. These terms typically provide that:

- The design-builder has the right to rely upon the "accuracy" or "completeness" of conceptual or preliminary design and any quantity surveys, cost estimates or other work product prepared by the consulting engineer during the preaward phase.
- The consulting engineer will share in cost growth due to variations between pre-bid cost and quantity estimates and post-award actual costs and quantities based on the final design.
- The design-builder has the opportunity to influ-

ence or constrain design development cost through "design to cost," "design optimization," "collaborative design processes" and "value engineering" approaches.

The consulting engineer certainly should endeavor to manage its liability risk exposure for design development cost growth through provisions in its subconsultant agreement with the design-builder, such as those excluding or limiting responsibility for cost or quantity estimates. While these provisions, if contractually accepted, will likely provide the basis for an effective defense to professional liability claims arising out of cost overrun risk, the reality is that many design-builders, especially in current economic conditions and competitive market, do not agree to such provisions.

An alternative approach to managing design development risk is for project owners and design-builders (and/or concessionaires) to each carry adequate contingency for cost growth due to design development and prudent risk sharing including the utilization of GBR and contingency funding plan as was demonstrated by the Port of Miami and the Alaskan Way (SR99) tunnels.

Heightened performance standards: On most projects, a consulting engineer is required to perform its services in accordance with reasonable skill and care required under the circumstances. However, in many PPP projects, the design-builder and, by extension, its consulting engineer are obligated to provide certain services in accordance with a "fitness for purpose" obligation. Under the latter obligation, the engineer is required to produce a design that meets specific client requirements, and adherence to reasonable skill and care will not necessarily provide a defense or justification for failing to meet those requirements. In addition, "fitness for purpose" performance standards raise issues as to whether liability determined to exist under such a standard falls within the scope of coverage afforded under standard professional liability insurance policies.

Conclusion

PPP of tunneling and underground projects represent the potential for substantial risks for consulting engineers. The same salutary principles of fairness and balance in risk allocation should apply in the context of PPP projects. ■

COMING EVENTS

Colorado School of Mines to host shotcrete course

Shotcrete, a comprehensive three-day short course, will be held Sept. 3-5, 2014 at the Colorado School of Mines (CSM) in Golden, CO. The course director is Raymond Henn, adjunct professor at CSM. Attendees will explore effective and sustainable uses of shotcrete. Economical and expedient, shotcrete is increasingly used for the support of excavation, geotechnical retaining walls, soil nails, underground construction and tunneling, mining, new structural walls and wall repair.

Attendees will receive two continuing education units upon completion of the course. Registration is now open online. Enrollment is limited and applications will be accepted in the order received. The course fee is $1,585 through July 29, 2014 and $1,685 thereafter. Opportunities to become course sponsors at various levels are available online as well. For more information, registration forms and a detailed course outline, visit www.csmspace.com/events/shotcrete. ■

T&UC TUNNEL DEMAND

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Gateway Tunnel	Amtrak	Newark	NJ	Subway	14,600	24.5	2016	Under study
2nd Ave. Phase 2-4	NYC-MTA	New York	NY	Subway	105,600	20	2015-20	Under study
Water Tunnel #3 bypass tunnel	NYC-DEP	New York	NY	Water	20,000	22	2015	Under design
Water Tunnel #3 Stage 3 Kensico	NYC-DEP	New York	NY	Water	84,000	20	2017	Under design
Cross Harbor Freight Tunnel	NYC Reg. Develop. Authority	New York	NY	Highway	25,000	30	2016	Under study
Silver Line Extension	Boston Transit Authority	Boston	MA	Subway	8,400	22	2018	Under design
South Conveyance Tunnel	City of Hartford	Hartford	CT	CSO	16,000	26	2015	Under design
Red Line Tunnel - Cooks Lane Tunnel	MD Transit Administration	Baltimore	MD	Subway	14,000	22	2015	Under design
Red Line Tunnel - Downtown Tunnel	MD Transit Administration	Baltimore	MD	Subway	36,000	22	2015	Under design
Purple Line - Plymouth Tunnel	MD Transit Administration	Baltimore	MD	Subway	1,000	30x40	2015	PPP - RFQ 10/22/14
Northeast Branch Tunnel Northeast Boundary Tunnel	DC Water and Sewer Authority	Washington	DC	CSO CSO	11,300 17,500	15 23	2018 2021	Under design Under design
Olentangy Relief Sewer Tunnel	City of Columbus	Columbus	OH	Sewer	58,000	14	2016	Under design
Blacklick Creek San. Interceptor Tunnel	City of Columbus	Columbus	OH	Sewer	24,000	10	2015	Under design
Alum Creek Relief Tunnel Phase 1 Phase 2	City of Columbus	Columbus	OH	Sewer	30,000 21,000	18 14	2016 2017	Under design Under design
Dugway Storage Tunnel	NEORSD	Cleveland	OH	CSO	16,000	24	2014	Under design
Doan Valley Storage Tunnel	NEORSD	Cleveland	OH	CSO	9,700	17	2017	Under design
Westerly Main Storage Tunnel	NEORSD	Cleveland	OH	CSO	12,300	24	2020	Under design
Shoreline Storage Tunnel	NEORSD	Cleveland	OH	CSO	16,100	21	2021	Under design
Southerly Storage Tunnel	NEORSD	Cleveland	OH	CSO	17,600	23	2024	Under design
Big Creek Storage Tunnel	NEORSD	Cleveland	OH	CSO	19,500	20	2026	Under design
Ohio Canal Interceptor Tunnel	City of Akron	Akron	OH	CSO	6,170	27	2015	Under design
Northside Interceptor Tunnel	City of Akron	Akron	OH	CSO	6,850	24	2021	Under design
Continental Rail Gateway	CRG Consortium	Detroit	MI	Rail	10,000	28	2015	Under design
ALCOSAN CSO Program	Allegheny Co. Sanitary Authority	Pittsburgh	PA	CSO	35,000	20	2016	Under design

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Lower Pogues Run	Indianapolis DPW	Indianapolis	IN	CSO	9,700	18	2018	Under design
Fall Creek	Indianapolis DPW	Indianapolis	IN	CSO	19,600	18	2016	Under design
White River Tunnel	Indianapolis DPW	Indianapolis	IN	CSO	27,800	18	2016	Under design
St. Louis CSO Expansion	St. Louis MSD	St. Louis	MO	CSO	47,500	30	2014	Under design
KCMO Overflow Control Program	City of Kansas City, MO	Kansas City	MO	CSO	62,000	14	2014	Under design
Mill Creek Peaks Branch Tunnel	City of Dallas	Dallas	TX	CSO	5,500	26	2014	Under design
East Link Light Rail Extension	Sound Transit	Seattle	WA	Transit	30,000	22	2016	RFQ underway
L.A. Metro Regional Connector	Los Angeles MTA	Los Angeles	CA	Subway	20,000	20	2014	Skanska-Traylor JV Awarded
L.A. Metro Westside Extension Phase 1 Phase 2 Phase 3	Los Angeles MTA	Los Angeles	CA	Subway	42,000 26,500 26,500	20 20 20	2014 2015 2017	Awaiting award Under design Under design
Speulvada Pass Corridor	Los Angeles MTA	Los Angeles	CA	High/Trans.	55,500	60	2017	Under study
Northeast Interceptor Sewer 2A	LA Dept. of Water and Power	Los Angeles	CA	Sewer	18,500	18	2014	RFQ underway
River Supply Conduit - Units 5 and 6	LA Dept. of Water and Power	Los Angeles	CA	Water	8,608	12	2014	W.A. Rasic low bidder
River Supply Conduit - Unit 7	LA Dept. of Water and Power	Los Angeles	CA	Water	13,500	12	2015	Under design
JWPCP Effluent Outfall Tunnel project	Sanitation Districts of LA	Los Angeles	CA	Sewer	37,000	18	2015	Under design
Freeway 710 Tunnel	CALTRANS	Long Beach	CA	Highway	26,400	38	2016	Under design
SVRT BART	Santa Clara Valley Trans. Authority	San Jose	CA	Subway	22,700	20	2014	Under design/ delayed
BDCP Tunnel #1 BDCP Tunnel # 2	Bay Delta Conservation Plan	Sacramento	CA	Water	26,000 369,600	29 35	2017 2018	Under design Under design
Iowa Hill pumped storage project	Sacramento Muni. Utilities District	Sacremento	CA	Water	3,500	20	2018	Under design
Coxwell Bypass Tunnel program	City of Toronto	Toronto	ON	CSO	35,000	12	2015	Under design
Yonge St. Extension	Toronto Transit Commission	Toronto	ON	Subway	15,000	18	2016	Under study
Combined Sewer Storgage - East-West	City of Ottawa	Ottawa	ON	CSO	14,400	10	2015	Under design
Combined Sewer Storgage - North-South	City of Ottawa	Ottawa	ON	CSO	5,300	10	2015	Under design
Second Narrows Tunnel	City of Vancouver	Vancouver	BC	CSO	3,600	14	2013	Under design
UBC Line project	Trans Link	Vancouver	BC	Subway	12,000	18	2015	Under design
Northern Gateway Clore Tunnel Hoult Tunnel	Enbridge Northern	Kitimat	BC	 Oil Oil	 23,000 23,000	 20 20	 2014 2014	 Under design Under design

The UCA of SME wishes to thank its Corporate and Sustaining Member companies.

Their support for the underground construction industry and its professionals is sincerely appreciated.

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Black & Veatch Corp	Hatch Mott MacDonald	Parsons
Bradshaw Construction Corp	HNTB Corporation	Parsons Brinckerhoff
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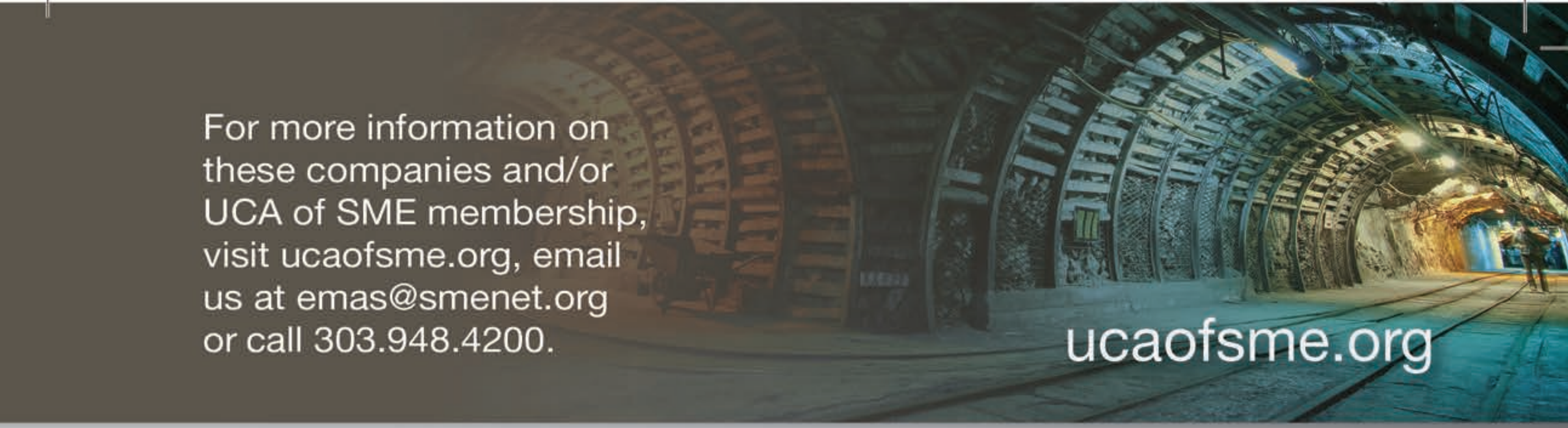

For more information on these companies and/or UCA of SME membership, visit ucaofsme.org, email us at emas@smenet.org or call 303.948.4200.

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EXECUTIVE COMMITTEE

Four members join the UCA Executive Committee at NAT

Four members of the UCA Division of SME will join the division's Executive Commttee during the North American Tunneling Conference June 23-25, 2014. They are Leon (Lonnie) Jacobs, Colin Lawrence, Michael Mooney and Michael Rispin. They will serve until June 2018.

Leon Jacobs

Leon (Lonnie) Jacobs has more than 30 years of experience in heavy civil and underground construction in the New York metropolitan area.

Jacobs earned a B.S. cum laude in civil engineering from Northeastern University, Boston, MA, in 1985, and an M.S. in construction management from Brooklyn Polytechnic University in 1988.

After graduation, Jacobs held several engineering positions on the New York City Third Water Tunnel project. In 1988, he worked for Perini as a project engineer on transit and waste water projects in the New York City region until joining Frontier-Kemper in 1995.

Some of the projects Jacobs has constructed with Frontier-Kemper during the past 19 years include: the New York City Department of Environmental Protection Water Tunnel Shaft 26B, the 26th Ward Water Pollution Control Plant Pilot Program, the New Croton Aqueduct Rehabilitation Project, the TBTA Queens Midtown Tunnel Rehabilitation Project and the New Jersey Transit Hudson Bergen Light Rail Weehawken Tunnel/Bergen Line Avenue Station Project.


JACOBS

Jacob's professional responsibilities at Frontier-Kemper have covered all facets of heavy construction, from project management to engineering, and include experience in design, scheduling, cash flow, insurance, safety, accounts payable and receivable, payroll, estimating, budget production, risk management, quality control, change-order negotiation, customization of equipment, design of specialized equipment, value engineering, human resources and strategic planning.

Jacobs has served on the George A. Fox Conference Committee since 2007 and was chair in 2008 and 2009. He has just begun a second, two-year term as the Fox Conference chair. He is a member of the UCA's North American Tunneling Conference (NAT) planning committee and helped organize NAT in 2012 and 2014. He will be vice chair of the NAT in 2016 when it is held in conjunction with the World Tunneling Conference. He is a licensed professional engineer in New York, New Jersey, Maryland and Virginia. He is also a member of Chi Epsilon, The Moles, the New York State Society of Professional Engineers and the American Society of Civil Engineers.

Colin Lawrence

Colin Lawrence is Hatch Mott MacDonald's tunnels practice leader for North America and a senior vice president with the firm. He has more than 34 years of specialized experience in all types of tunneling for transportation, water and wastewater projects through a variety of challenging ground conditions. He resides and has worked in the United States for the last 15 years.

Having worked for an owner and consultants, Lawrence has experience in all aspects of underground project implementation, from planning, design and project management to construction management and project completion.


LAWRENCE

He was fortunate to be involved in some of the more technically challenging and high-risk tunnel projects around the world. These included all types of tunnel projects for transportation, water, wastewater, oil and mining in a variety of challenging ground conditions in soil, rock and mixed face conditions.

Mike Mooney

Mike Mooney is a professor and the Grewcock chair in underground construction and tunneling (UC&T) at the Colorado School of Mines. He leads the university-wide interdisciplinary Center of Excellence in Underground Construction & Tunneling and serves as director of the UC&T graduate degree program at Mines.

Mooney is a licensed professional engineer and has 20 years of academic and consulting experience in civil engineering and construction.

(Continued on page 30)

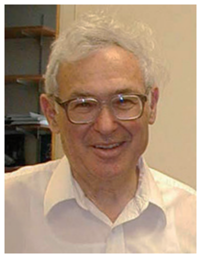
UCA AWARDS

UCA presents four awards at NAT

Outstanding Educator Award to Herbert H. Einstein

The UCA of SME's Outstanding Educator Award is presented by the UCA Executive Committee to professors and teachers who have had an exceptional career in academia and education in the areas of underground design and construction. These individuals also have made significant contributions to the industry through their academic interests, as well as through the introduction of many student graduates into the industry. They are nominated by their peers.

Herbert H. Einstein, a professor civil and environmental engineering at the Massachusetts Institute of Technology, received his Dipl. Ing. and Sc.D. in civil engineering from ETH-Zürich. His teaching and research areas are in underground construction, rock mechanics and engineering geology. Einstein has been involved as an advisor, consultant and researcher in issues related to underground construction, rock mechanics and rock engineering and natural hazards, notably landslides and in waste repository problems. He has been and is member of a number of national and international technical-scientific committees and advisory boards.



EINSTEIN

Einstein is also co-editor of the journal, *Rock Mechanics and Rock Engineering* and member of the editorial boards of *Tunnelling and Underground Space Technology* and of *Engineering Geology*. Einstein is the author or co-author of more than 240 publications in his area of expertise. He received the Müller lecture award from the International Society for Rock Mechanics and received the Outstanding Contributions to Rock Mechanics award from the American Rock Mechanics Association. He has also received several teaching awards from his department and from the School of Engineering.

In underground construction, Einstein developed several analysis and design approaches for tunneling in general and tunnels in swelling rock specifically. In addition, he and his co-workers developed the Decision Aids for Tunnels, with which cost, time and resources subject to uncertainties can be estimated. These analysis, design and construction management tools have been applied to a number of tunnels worldwide, ranging from transportation tunnels to underground-waste storage facilities.

Lifetime Achievement Award to Ronald E. Heuer

The UCA Lifetime Achievement Award recognizes outstanding achievements in the underground design and construction industry. The outstanding achievements recognized have been accomplished through the design or construction of civil underground facilities.

Ronald E. Heuer is an independent geotechnical consultant who works almost exclusively on underground projects. He received a B.S. degree in civil engineering (1963), an M.S. in geology (1965), and a Ph.D. in civil geotechnical (1971) from the University of Illinois, Champaign-Urbana (UI).

Upon graduation, he joined A.A. Mathews Inc., a construction engineering firm in the Los Angeles, CA and Washington D.C. areas. He returned to UI for three years to teach undergraduate and graduate courses in geotechnical engineering, while continuing to work part-time consulting on tunnel projects.

HEUER

Since 1978, he has worked full time as an independent consultant, about three-fourths of the time for contractors and one-fourth of the time for owners and engineers. Prior to construction, his work involves the study of available geologic information to interpret expected ground behavior and potential water problems and evaluating the suitability of alternative construction methods. During construction, he gets involved in interpreting the cause of problem behavior of ground and water and developing solutions.

Heuer has worked on more than 1,000 underground projects and tunnels throughout the United States, Canada and in a number of foreign countries. He has witnessed the transition from conventional drill-blast excavation in rock and compressed air hand mined shields in soft ground to today's hard rock TBMs and pressurized face soft ground machines. He has seen the introduction of precast concrete segments, shotcrete, and SEM methods into the United States.

Some special projects include Colorado's Straight Creek Tunnel in 1970, the Eisenhower Tunnel first bore. There, under Al Mathews' guidance, Heuer developed concept drawings and geotechnical analysis for the multiple drift methods used to complete tunnel excavation through the squeezing Loveland Fault Zone at 305 m (1,000 ft) depth. Other projects were the Point Lepreau cooling water intake shaft in New Brunswick, Canada in 1977, where a 6.4 m (21 ft-) diameter shaft excavation in rock was raised to within 4.3 m (14 ft) of the ocean bottom under the Bay of Fundy and the Crosstown Tunnel in Milwaukee, WI in 1986, where a 9.6-m (32-ft) diameter TBM using rock dowel support was driven with only 5.5 m (18 ft) of poor rock cover below a buried valley full of waterbearing sand and gravel under a 76-m (250-ft) water head.

Heuer served as chair of the second Dispute Resolution Board in North America on the Seattle Mt. Baker Ridge Tunnel in late 1980s. He also worked on the Big Walnut Augmentation/Rickenbacker Interceptor Tunnel in Columbus, OH in 1999, where earth-pressure-balance tunnel excavation was successfully completed through boulder ground; the Arrowhead Tunnels near Los Angeles, which were completed in waterbearing faulted ground adjacent to the San Andreas Fault under water heads up to 305 m (1,000 ft); and the recently completed Queens soft-ground tunnels excavated by slurry TBM methods at shallow depth under a railroad switchyard. On some of these he was actively involved in design or construction. On others, his contribution was to review proposed methods.

Outstanding Individual Award to Lok Home

The Outstanding Individual Award recognizes those individuals who have made significant contributions to the field of tunneling and underground construction and to UCA.

Lok Home is president of The Robbins Company in Solon, OH. He began his more-than-45-year career in the tunneling and mining industry after graduating with a degree in mining technology from the Haileybury School of Mines in Ontario, Canada. Between 1965 and 1968, he worked as a project manager at several Canadian mines, before joining The Robbins Company as a field service manager.

HOME

Home served as president of Atlas Copco Jarva from 1980 to 1985, then founded Boretec Inc. Boretec later acquired Robbins in 1998 and unified the two companies under the Robbins name. Today, The Robbins Company is a worldwide manufacturer of tunnel boring machines and underground equipment with 12 international subsidiaries and representation in more than 35 countries.

Project of the Year Award to the Tom Lantos Tunnel project, San Mateo County, California

The Project of the Year Award recognizes an individual or a group that has shown insight and understanding of underground construction in a significant project, which may include a practice, developing concepts, theories or technologies to overcome unusual problems within a project.

For more than 30 years, land slippages and rockslides plagued the narrow, cliff-side stretch of U.S. Highway 101, aptly named as Devil's Slide. After a heavy winter rain, residents of Pacifica and Half Moon Bay, CA, would wake up wondering if the highway they depended on daily still would be there, or if it had slid once again into the Pacific Ocean. Notorious for rock slides and collapse, a section of scenic State Route Highway 1 was closed nine times in the past 28 years, with the longest closure lasting 158 days.

UCA AWARDS

After years of public input and careful evaluation, HNTB was chosen as the lead designer on the project for the California Department of Transportation. Constructed beneath San Pedro Mountain using the New Austrian Tunneling Method, the project lies along the active San Andreas Fault, with four inactive faults crossing the tunnels.

The tunnels feature HNTB's innovative double lining — an initial layer strengthened with synthetic shotcrete to meet deflection requirements and a final layer that accommodates potential movements. The design meets some of the toughest seismic specifications in the world.

The twin tunnels are 9 m (30 ft) wide by 6.8 m (22.3 ft) high and 1.3 k (4,200 ft) long. The $430 million project includes the two tunnels, a 305-m (1,000-ft) bridge that spans the valley at Shamrock Ranch, and an intelligent transportation system that carefully monitors and reports road conditions and environmental changes in the region. The Tom Lantos Tunnels are named after the late Congressman Tom Lantos, who was instrumental in securing funding for the project. The tunnels opened on March 26, 2013. The county plans to open the old highway to hikers and bicycles in 2014. ■

EXECUTIVE COMMITTEE

(Continued from page 27)

He received a B.S. in civil engineering from Washington University in St. Louis, an M.S. in civil-structural engineering from the University of California-Irvine and a Ph.D. in civil-geotechnical engineering from Northwestern University. His expertise lies in soft-ground tunnel design and construction, instrumentation/monitoring of construction systems and equipment, nondestructive imaging techniques and intelligent geoconstruction processes. He has been the principal investigator for more than 30 geoconstruction-related research projects and has written more than 100 technical publications.

MOONEY

Mooney teaches courses in tunnel design and construction, support of excavations/earth retaining structures, instrumentation and monitoring, nondestructive evaluation, and intelligent geosystems. He has mentored more than 25 M.S. and Ph.D. students to completion of their theses and currently advises graduate and undergraduate students pursuing industry-focused, applied research projects.

In addition to the UCA Executive Committee, Mooney serves on the American Society of Civil Engineers' underground engineering committee, the ISSMGE underground construction in soft ground committee and the International Tunneling Association committee on education and training.

Michael Rispin

Michael Rispin was born in Montreal, Canada in 1961. He received his bachelors degree, B.Eng. Mining, in 1985, along with a minor in management.

Rispin began his career as a technical representative in the field of explosives application and, during the next 12 years, worked his way into various management positions. Throughout this period, he was primarily involved with underground applications in mining and tunneling construction.

In 1996, Rispin shifted his focus to construction chemicals. He began by propagating the benefits of sprayed concrete (wet mix shotcrete) technology to North American mining. He progressed through various positions in his company, Master Builders, which was subsequently acquired by BASF. He accepted an assignment in Switzerland with BASF and focused almost exclusively tunneling and underground mining, domestic and international.

RISPIN

Since 2009, Rispin has been part of the Normet Group and is currently senior vice president with a portfolio of responsibilities. Normet is a leading manufacturer and supplier of equipment, construction chemicals and rock reinforcement for tunneling and underground mining. It is heavily invested in the processes of sprayed concrete and explosives charging.

In addition to the UCA of SME, Rispin is a member of Professional Engineers Ontario, the Canadian Institute of Mining, Metallurgy and Petroleum, the American Society of Civil Engineers and the American Concrete Institute. He previously served as chair of the Underground Committee of the American Shotcrete Association. He has published papers on explosives, sprayed concrete and equipment. ■

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