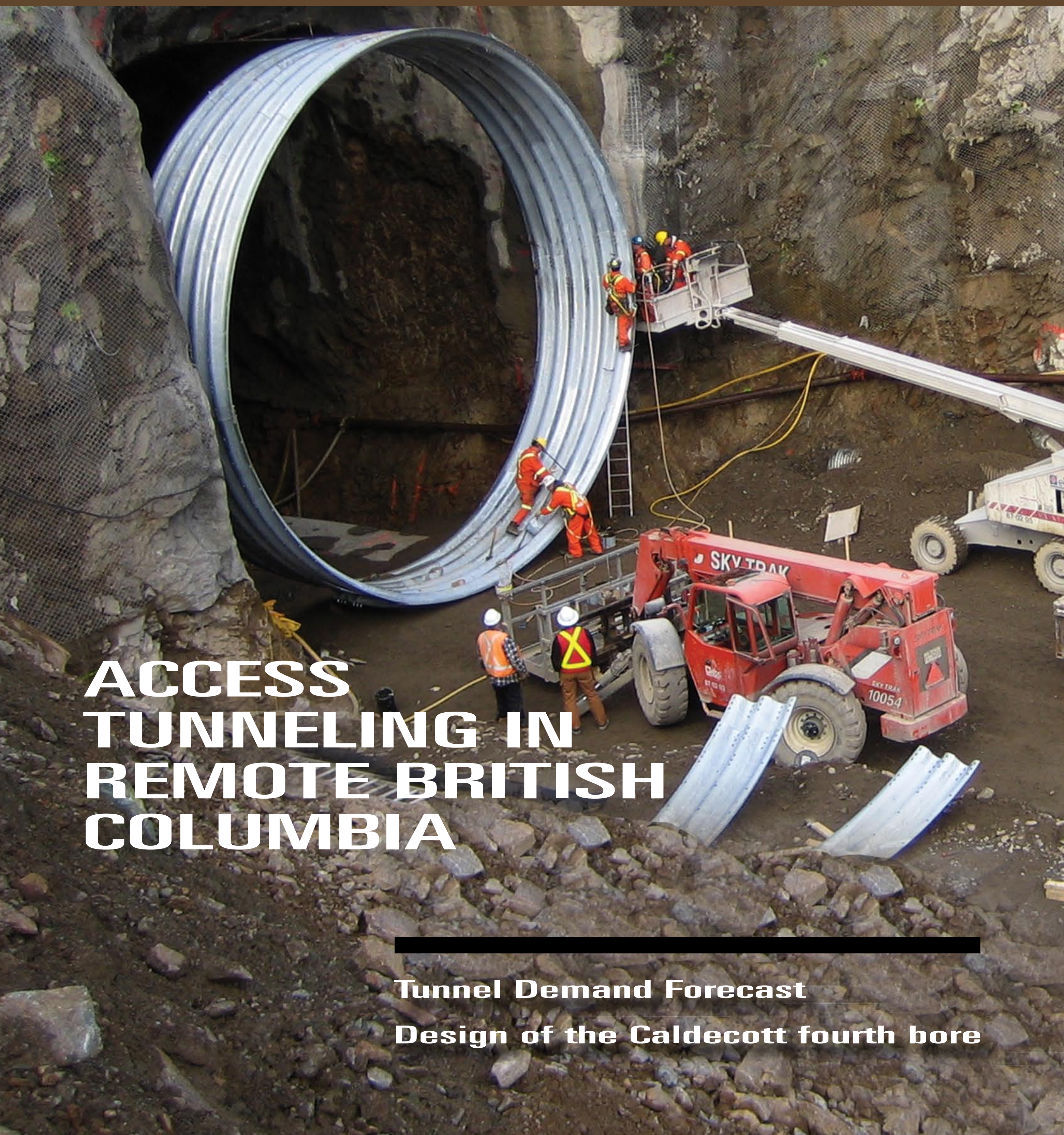
T&UC TUNNELING & UNDERGROUND CONSTRUCTION

THE OFFICIAL PUBLICATION OF UCA OF SME WWW.TUCMAGAZINE.COM VOLUME 1 NO 4 DECEMBER 2007



ACCESS TUNNELING IN REMOTE BRITISH COLUMBIA

Tunnel Demand Forecast

Design of the Caldecott fourth bore

T&UC

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COVER STORY

CONTENTS — NovaGold Resources and Teck Cominco are building the Galore Creek copper and gold mine in northwestern British Columbia. To access the proposed mine, a 120-km (75-mile) road is being built, including a 4.4-km (2.7-mile) tunnel. Details of this tunnel start on page 19. Also, registration is open for the 2008 George A. Fox Conference in New York in January, page 6.

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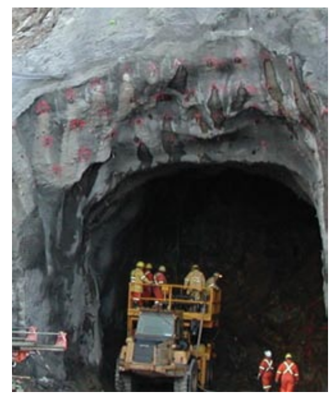

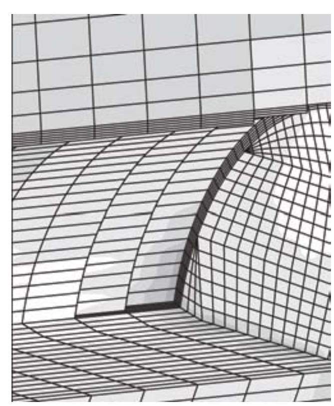

DEPARTMENTS

CHAIRMAN'S COLUMN

UCA becomes an SME division

The Underground Construction Association (UCA) was granted full division status in SME. The UCA Executive Committee made its request during the SME Board of Directors meeting in New Orleans, LA in September.

This is a win-win for SME and UCA and is the first step in developing a full partnership. UCA contributes about 20 percent of the meeting revenues and about 8 percent of the membership revenues, a percentage I expect to grow. SME contributes a strong organizational framework and staff that has already demonstrated its talents and continuous help to me and the rest of the UCA membership.

One of the first collaborative efforts, in addition to the traditional Rapid Excavation and Tunneling Conference, concerns the 2009 SME Annual Meeting in Denver, CO. The UCA of SME is working with the 2009 SME programming committee to organize one or more sessions. The topics will be underground construction and underground ventilation.

Recently, the UCA Executive Committee solicited nominees for a number of awards to be presented at the North American Tunneling Conference. Please take a moment and send us a recommendation for one or more of the following: the Lifetime Achievement Award, the Outstanding Individual of the Year and the Project of the Year. Nominations can be submitted to me at ucachair@smenet.org, or Mary O'Shea, oshea@smenet.org. The Executive Committee will evaluate the candidates and vote on the nominees during its winter meeting at the end of January.

Lonnie Jacobs and his Fox Conference planning committee has been hard at work and have an excellent program focused on mechanized tunneling. This one-day conference is scheduled for Jan. 29, 2008. And, as in past years, it is the day before the Moles Banquet. I encourage everyone to attend to learn about the latest developments in the New York projects, as well as the state of the art advancements in mechanized tunneling.

Greg Raines and the NAT conference planning committee met to solidify the program and events for the San Francisco conference June 7-11, 2008.

UCA's Technical Program Committees are back in business, and are advancing their goals and short-term products for use by our members in the areas of:

Better Contracting Practices, chaired by Bill Edgerton, president, Jacobs Associates;

Benefits of Going Underground, chaired by Amanda Elioff, senior project manager, Parsons Brinckerhoff;

Education and Training, chaired by Bob Pond, vice president, Frontier Kemper;

Underground Security, chaired by Hugh Lacey, Mueser Rutledge Consulting;

Tunnel Rehabilitation, chaired by Henry Russell, vice president, Parsons Brinckerhoff and

New Austrian Tunneling Methods, chaired by Nick Chen, Jacobs Engineering.

Edgerton and his steering committee have done a yeomen's job of revising the draft of the *Better Contracting Practices for the Underground*. About 100 contributions and editorial comments were received by industry folks concerning the handbook's revision. An aggressive schedule to have the revised handbook published in 2008 is looking good due to the dedicated work from the standing committee members. Proposals have been received by the Executive Board from UCA members for other issues affecting the industry at large. These proposals will be vetted by the Executive Committee at its January meeting.

Brenda Bohlke,
UCA of SME Chairman

Registration is open for 2008 Fox Conference

More than 200 tunneling professionals are expected to join UCA of SME at the Graduate Center - City University of New York for the 2008 George A. Fox Conference on Jan. 29, 2008.

This year's theme is Mechanical Excavation Methods. The theme will be discussed in the afternoon session by professionals representing Herrenknecht, Lovat, Robbins and Wirth-Raisebore.

Drill and blast methods will also be discussed as will splitting and the use of roadheaders during the afternoon session of the long-running one-day underground construction conference.

Edward J. Cording, professor of civil engineering at the University of Illinois has been invited to be the keynote speaker.

Mike McHugh has been asked to give the annual Hometown Projects Update and Don Hickey will provide an update on the Eastside Access project.

That East Side Access project is a $6.3-billion project that will connect the Long Island Railroad's (LIRR) Main and Port Washington lines in Queens, NY to a new LIRR terminal beneath Grand Central Terminal in Manhattan. The new connection will increase the LIRR's capacity into Manhattan, and shorten travel time for Long Island and eastern Queens commuters traveling to the east side of Manhattan, provide a new commuter rail station in Sunnyside Queens and more.

On Nov. 5, U.S. Transportation Secretary Mary Peters announced that the federal government will provide $2.63 billion in funds to the project. This is the largest transit investment in American history. (See page 8)

Attendees of this year's Fox Conference are also scheduled to get an update on the Pittsburgh North Shore Connector from Paul Zick.

The North Shore Connector project will extend the Port Authority's Light Rail Transit system, the T, 1.9 km (1.2 miles) from the Gateway subway station underneath Stanwix Street and the Allegheny River — in twin bored tunnels below the river — to the North Shore.

The North Shore Connector is a significant regional investment that will support the revitalized downtown Pittsburgh and North Shore's residential areas, business districts, educational institutions, entertainment developments and cultural venues in addition to enhancing development opportunities. The North Shore Connector will also enable the Authority to construct future extensions of the T to other destinations within Allegheny County, thus making it a catalyst for future development opportunities throughout the region.

This year's George A. Fox Conference is being sponsored by Allentown Shotcrete Technology Inc.; American Commercial Inc.; Arup; Basf Construction Chemicals; Black and Veatch Corporation; Bradshaw Construction; Cellular Concrete Inc.; DMJM Harris; Donovan Hatem LLP; Frontier-Kemper Constructors Inc.; GZA GeoEnvironmental; Halcrow; Hatch Mott McDonald; Herrenknecht Tunneling Systems USA; Jacobs Associates; Kiewit Construction Company; LiRo Group; Lovat Inc.; Moretrench; Mueser Rutledge Consulting Engineers; PB; Sandvik Mining and Construction; Schiavone Construction Co.; Sika Corp.; Skanska USA Civil Norheast Inc.; David R. Klug & Associates Inc.; Gall Zeidler Consultants and ILF Consulting Engineers.

New to this years conference is group rate hotel accommodations at the Sheraton Manhattan at Times Square. These rooms are being secured by the SME Meetings staff. To reserve a room call 888-627-7068.

Registration for the conference is open and registration forms are available on-line at www.smenet.org, or by calling SME Meetings at 303-948-4234 or 800-763-3132. ■

East Side Access project gets funding boost

The East Side Access tunneling project that will give Long Island Railroad commuters easier access to Manhattan's East Side received the single largest transit investment in American history from the federal government in November.

"The federal government will deliver $2.63 billion in funds," said U.S. Transportation Secretary Mary Peters.

The funding is expected to all but guaranteed that East Side Access, a plan to bring Long Island Rail Road trains to Grand Central, will become reality.

Officials say it will shave as much as 40 minutes a day off the commute for thousands of Long Islanders.

Officials say city residents will benefit from less crosstown congestion, including on the subways and buses, not to mention the economic impact, including hundreds of construction jobs as the Metro Transit Authority drills a new tunnel beneath Park Avenue. That tunnel will allow trains coming from Queens to travel through an existing subway tunnel at 63rd Street, under Park and down into Grand Central.

"At 46 m (150 ft) deep, we are going to carve out a brand new terminal under this existing terminal. That's not like doing an addition on a house; this is a big project," said FTA Administrator James Simpson.

The total project cost of East Side Access is $6.3 billion, which means the federal government is picking up about 40 percent of the cost. The project is expected to be complete in the year 2013.

New York Mayor Michael Bloomberg also announced that the city will soon be breaking ground on an extension to the number seven subway line.

The long-planned expansion will take the subway further west from its current end point at Times Square, and move it along to a new terminal at 34th Street and 11th Avenue.

Mayor Bloomberg also said the city remains committed to the Fulton Transit Center downtown. That transit center has already been redesigned because of rising costs The agency reconsidered after an outcry among board members. ■


The Changing Face of Tunneling
2008
The 2008 North American Tunneling Conference will feature a full professional development program. The technical program will highlight ***"The Changing Face of Tunneling"*** and cover:
Tunnel Boring Machines
Ground Conditioning and Modification
Equipment Automation
Conventional Tunneling
NATM/SEM & Caverns
Small Diameter Tunneling
Shaft Construction
Emerging Technologies
Lining Design & Precast Segment Advances
Fire & Life Safety
Vulnerability & Security
Seismic Design
Updating Design Criteria
Tunnel Management/Inventory
Rehabilitation
Cost Estimating & Scheduling
Financing
Public Policy
Contracting & Payment
Alternative Delivery Methods
Insurance & Bonding
Third Party Liability
Labor Management & Training
Case Histories
The conference will also feature:
• ***Workshops***
• ***Field Trips***
• ***Social Functions***
• ***Sponsorship Opportunities***
• ***Comprehensive Exhibit***
UCA of SME
NORTH AMERICAN TUNNELING CONFERENCE
June 13-17, 2008
Hyatt Regency • San Francisco, California
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Tunneling begins at Devil's Slide in California

On Sept. 17 a Terex TE210 earthmover started drilling into the mountain along California Highway 1. This officially began the tunneling part of the Devil's Slide project. Tunneling will proceed nearly non-stop until completion in December 2010.

Highway 1 was carved out of steep cliff sides in the 1930s and hugs the coastline between Pacifica and Montara. It has been the site of landslides, rockslides, mudslides and weather-related troubles that have caused significant road closures. One of the longest road closures happened in 1995. It lasted 158 days, and cost almost $3 million to repair. When the road is closed, drivers are forced to take long, slow detours on Highway 92 to Interstate 280.

In 1996, voters approved the Devils Slide project, a twin-bore, nearly 1.3 km (1,400 ft) tunnel that will run through the mountain between Montara and Pacifica. It will allow drivers to bypass the dangerous bit of highway that is often closed.

At the northern end, a 305 m (1,000 ft) bridge will span the valley at Shamrock Ranch. A realignment of Route 1 at the southern end will provide a safe transition into and out of the tunnel. An earthen embankment and vegetation-covered roof will help the facility blend with natural surroundings.

The former route will become a trail overlooking the Pacific Ocean for hikers, cyclists and tourists.

Opponents who feared building a freeway would ruin the area's natural beauty and lead to more development in the coastal towns of Montara, Moss Beach and Half Moon Bay, first filed suit in 1972 to stop the freeway. The tunnel plan was heralded as a more environmentally sound choice.

Preliminary work on the project began in 2005 but the official digging of the tunnel began on Sept. 17, 2007 when a Terex TE210 earthmover started drilling.

Workers will employ the NATM sequential excavation technique, which relies on the surrounding rock to support the tunnel. Excavation of each tunnel will take place in stages, working from top to bottom, then carving out the sides. Diggers will move at a 2 percent uphill grade, hitting groundwater along the way.

The hardest rock must be fractured by small packs of explosives, slid into holes and ignited. Soft clay can be shoveled out with a backhoe. But the bulk of the work will be done by roadheaders.

Dig work includes installing a canopy over the bull's-eye to protect workers and passing motorists from falling rock. The tunnel project is split into six contracts and includes mitigation for environmental concerns, construction of a maintenance center and both northbound and southbound tunnels. Each bore will contain one lane of traffic, a cycling lane and will have emergency walkways and shoulders on either side.

A jet fan ventilation system will expel exhaust and keep the air in the tunnels fresh.

Kiewit Pacific will be using two 120 t (132 st) ATM 105 roadheader machines, one in each tunnel, made in Austria by Sandvik Group's Voest Alpine. Each machine is almost 15 m (50 ft) long and cost more than $3 million. Moving south to north, they will excavate a pair of 1,220 m- (4,000 ft-) long tunnels, each 9.15 m (30 ft) wide and 6.7 m (22 ft) high.

The debris will be carried by conveyor belts onto dump trucks. Because the properties of the rock vary, geologists will constantly monitor the site, alerting the crew about what lies ahead. The debris will be hauled away to nearby swales, then covered with topsoil and native plants.

The tunnel will be supported by a combination of steel rods, wire mesh, and thin, fiber-reinforced concrete, preventing collapse. Among the finishing touches will be a concrete lining for the ceiling and panels on the sides. ■

London's Crossrail receives approval

The 117.5 km (73 mile) rail link that would cut across London from Maidenhead and Berkshire to Shenfield in Essex that was originally proposed in the 1980's received approval from British Prime Minister Gordon Brown on Oct. 5, 2007.

Cross London Rail Links (Crossrail) is a joint venture company formed by Transport for London and the Department for Transport.

Crossrail was allocated a budget of £154m in 2001 by central Government to carry out feasibility work to acquire Parliamentary powers. It was given a further £100m in 2005 for development work.

There will be two 22.5-km (14-mile) tunnels beneath central London and spur lines to Heathrow Airport and Southeast London that will offer a suburban rail system through central London while reducing the number of stops.

Stops in central London will include Liverpool Street, Farringdon, Tottenham Court Road, Bond Street and Paddington.

The diameter of the tunnels will be 6 m (20 ft), compared to 3.4 m (11 ft). The larger tunnels will allow normal heavy rail vehicles to enter the tunnel and will increase the capacity drastically. Once built, it will relieve traffic off the century old metro system that uses short and narrow trains to transport its 3.4 million passengers. Crossrail will also use overhead wires instead of a third rail. Crossrail will have to dig deep below the surface to avoid any conflicts with the current tunnels.

Crossrail will run 24 trains per hour per direction in the tunnel at peak hours (one train every 2.5 minutes). 78,000 passengers per hour will be able to travel in the tunnel under central London. Platforms will measure up to 400 m (1,312 ft) long, meaning that two ticket halls will be needed at each station.

Analysts predict it will create 30,000 jobs and inject £20 billion a year into the economy as well as easing traffic congestion and overcrowding on the London Underground and trains.

Several hurdles still need to be cleared. Crossrail remains subject to the passage of a bill, now proceeding through Parliament, and is likely to receive Royal Assent by summer of 2008. This will enable detailed design and essential enabling works then to move forward, with full construction under way from 2010 and services commencing in 2017. ■

Design for Las Vegas pipeline has begun

Final design for the Systems Conveyance and Operations Program (SCOP) pipeline and tunnel project in the Las Vegas, NV region has begun. The projected is estimated to cost $750 million.

Black and Veatch has commenced design work for a major effluent system conveyance and operations project, redirecting flows from Las Vegas Bay, using a 12 km (7.5 mile) pipeline tunnel.

Under an engineering services contract awarded by the Clean Water Coalition (CWC) in Nevada, Black and Veatch is serving as the lead design engineer for the Systems Conveyance and Operations Program (SCOP) pipeline and tunnel project that will convey effluent from CWC member agencies wastewater treatment plants to a new discharge location in Lake Mead.

Removing the effluent from the Las Vegas Wash and redirecting the discharge location from Las Vegas Bay to a location near Boulder Island will protect the quality of the water in Lake Mead.

The need for a new discharge location is driven by increasingly stringent water quality regulations, increasing effluent flows, protection of a drinking water source, protection of the Las Vegas Wash and Bay — especially at the low lake levels caused by drought — and continued reliance on Colorado River system return-flow credits earned by returning water to the river.

Black and Veatch has responsibility for the 30 percent design of the entire SCOP system including the 12 km (7.5 mile) tunnel through the River Mountain.

Black and Veatch is also responsible for preparing the geotechnical program required for detailed design, conducting the subsurface investigation program, determining the right-of-way requirements and performing the project survey.

The Black and Veatch team will review the final designs of all the project elements and provide design support during construction.

The SCOP project is an important aspect of the southern Nevada water resources management strategy.

The CWC and the Southern Nevada Water Authority are coordinating the placement of a new potable water intake and the effluent discharge location to provide the best water quality while ensuring capacity for the future.

The tunnel contract is scheduled to bid in Fall 2008 with a construction start in 2009. The project is expected to be completed 2011. ■

Nancy Creek Tunnel wins award

The American Public Works Association (APWA) named the Nancy Creek Tunnel its Public Works Project of the Year.

Nancy Creek was completed on-time and under-budget, according to the federal consent decree guidelines. Nancy Creek is a 13 km (8.3-mile), 5 m (16-ft) diameter tunnel. It won in the Environment category for projects that exceeded $100 million. Nancy Creek Tunnel ranges from 34 to 92 m (110 to 300 ft) deep.

The tunnel has been in operation for a year and has significantly impacted the dramatic reduction of sanitary sewer overflows, which used to plague the Nancy Creek basin. The tunnel has reduced sanitary sewer overflows in the North Atlanta/Buckhead communities by as much as 60 percent, helping to avoid overflows by up to 2.3 ML (600,000 gal).

"The Nancy Creek Tunnel is an important step in our Clean Water Atlanta Program to ensure clean and safe drinking water for our children, grandchildren and downstream neighbors," said Atlanta Mayor Shirley Franklin. "We are very pleased that APWA has recognized the tunnel with this prestigious award." ■

Lawmakers push for national tunnel inspectors

A federal safety boards report on the 2006 fatal ceiling collapse in Boston's Big Dig project has boosted Massachusetts lawmakers' push for a national tunnel inspection program that has a goal of preventing future tragedies.

The lawmakers began pressing for congressional hearings on tunnel inspection legislation in Sept. 2007. They citied the safety board's finding that the lack of Big Dig tunnel inspections contributed to the concrete ceiling tile collapse that killed motorist Milena Del Valle on July 10, 2006.

The National Transportation Safety Board called for a mandatory federal tunnel inspection program similar to the one already used for the nation's bridges. That recommendation should help convince Congress to act swiftly, said Rep. Michael Capuano (D-MA). He is a member of the House Transportation and Infrastructure Committee that is leading the effort on Capitol Hill.

Massachusetts' two senators, John Kerry and Edward Kennedy, are teaming up to win Senate support.

Safety advocates said it makes no sense to have a federal program for bridge inspections while ignoring tunnels.

The NTSB's report said the use of the wrong glue to secure concrete ceiling slabs was the likely cause of the July 10, 2006 accident, 39. The report spread the blame among multiple Big Dig contractors and project overseers.

One of the report's major findings was that the Massachusetts Turnpike Authority failed to implement a timely tunnel inspection program. Such a program, the NTSB concluded, likely would have detected problems with the adhesive anchors and enabled them to be fixed before the accident.

Capuano said most people are not aware that tunnels, unlike bridges, are not covered by federal inspection programs.

There are no national standards or requirements for highway tunnel inspections. Tunnel owners are responsible for determining how their tunnels should be inspected, Capuano said.

Earlier this year, Capuano filed a bill that would require the U.S. Secretary of Transportation to set minimum inspection requirements for tunnels. It would also make inspections of all highway tunnels mandatory. Bridges are already subject to such standardized inspections.

Kerry and Kennedy announced they were filing highway safety legislation on the day the NTSB report was filed.

"This report will help build momentum to get this legislation enacted so we prevent future accidents and force accountability on new large federal projects," Kerry said in a statement.

The Kerry-Kennedy measure includes the Capuano bill's mandate for a national tunnel inspection program. It also calls for independent engineers to review construction methods on major federal highway projects. ■

Send us your news

Send your news, project updates and press releases to the editors of *Tunneling & Underground Construction*.

Steve Kral, e-mail: **kral@smenet.org**

William Gleason, e-mail: **gleason@smenet.org**

Robbins Hybrid provides solution for Instanbul sewer project

A 3.1 m (10.2 ft) diameter Robbins Hybrid EPBM in Istanbul, Turkey can bore in two different situations. The hybrid machine can switch between hard rock and EPB modes, making it ideal in mixed ground conditions. The bored tunnel will be used to help clean up a sewer system for more than 250,000 people living along Istanbul's Beykoz coastline. The Bosphorus. NTF Construction Company will bore two mixed ground tunnels of 4.1 km (2.5 miles) and 3.0 km (1.9 miles) in length with the hybrid machine.

The Kavacik-Beykoz Wastewater Tunnels are part of a larger scheme by the Istanbul Water and Sewerage Administration (ISKI) to modernize Istanbul's deteriorating sewers. The two tunnels will convey untreated water via gravity from coastal areas to a new water treatment plant. A 30 m (100 ft) deep shaft, lined with concrete segments, will allow water to be pumped from both the tunnels to the plant. Once the entire system is complete, it will treat approximately 575,000 m^3 (1.5 million gallons) of water per day.

Geological conditions in the tunnel are highly variable due to Istanbul's location in a seismically active zone. Multiple fault lines exist at the tunnel site, and ground varies from silty clay to shale to limestone (rock varies from 75 to 100 MPa/ 11,000 to 14,500 psi UCS). Coral limestone found in preliminary geological tests also showed karstic features.

The Robbins hybrid machine can switch from a standard hard rock mode to a non-slurry EPBM mode in soft ground.

Specialized for mixed ground tunneling, the hybrid EPBM began excavating the Beykoz Tunnel in the first quarter of 2007. The machine is capable of boring with either 355 mm (14-in.) diameter disc cutters in medium to hard rock, or with tungsten carbide drag bits in soft ground. In the hard rock mode, the machine operates using a standard TBM belt conveyor for muck removal. In soft ground, the machine operates as a non-slurry EPBM using a screw conveyor to transfer spoils to muck cars for removal.

The Robbins circular back-up system (2.6 m/ 8.5 ft in diameter) allows for maximum space of the muck hauling system, which consists of a single track running down the center of the back-up. The 60 m (200 ft) long, 17-gantry back-up contains the TBM power pack and electrical systems, as well as a foam generation system for use when the machine is converted from hard rock to soft ground mode.

A single-arm segment erector is used to line both tunnels with 200 mm (8 in.) thick reinforced concrete segments in a 5 + 1 arrangement. Sand and cement grout mixture is used to fill the annulus. Waterproof seals are also applied in between each segment. Once boring is complete a second concrete lining will be added, making the finished diameter of the tunnels 2.2 m (7.2 ft).

As of August 2007, the machine had bored 1.1 km (0.7 mile) of the 4.1 km (2.5 mile) long Beykoz Tunnel, scheduled for completion in December 2007. The machine will then be stopped for maintenance and transported to the Kavacik shaft. Both tunnels should be complete by December 2008. ■

Orange County project completed

The tunnel boring machine responsible for a 1.6 km (1-mile)-long tunnel as part of the Groundwater Replenishment (GWR) System that is a joint venture of the Orange County, CA Water District and Orange County Sanitation District was removed from the ground on Oct. 5.

The GWR is a groundwater replenishment system, that is expected to begin in January. The facility will process about 265 ML/d (70 million galpd). It will undergo various tests through December.

The groundwater replenishment system is designed to collect treated sewer water, purify it three more times and use it as a barrier between drinking water from the Santa Ana River and seawater.

The system is also expected to help replace up to 20 percent of the groundwater that supplies 50 to 70 percent of water for north-central Orange County.

The estimated cost of the project is $487 million and was paid for through federal and state grants and through the future sale of the water.

Construction included digging a mile-long tunnel along Ellis Avenue from the sanitation district facility near Pacific Street to Callens Circle. The next step in the project is the installation of fiber glass piping through the tunnel, which began on Oct. 17.

The hole will be filled in as the piping is installed and an underground train system will be used to carry the equipment from Pacific Street to the end of the tunnel.

The pipes will be used to pump sewer water to the sanitation district for treatment and then to the water district's groundwater replenishment system or discharged to the ocean.

About 416 ML (110 million gal) for the water will be pumped to the water district a day.

The sewer district will also build a "diversion structure" at Ellis and Callens Circle where the two of the sewer pipes will connect. The structure will allow the district to divert the sewer flow between its two treatment plants in Huntington Beach and Fountain Valley.

The entire project is expected to be completed by winter 2009. ■

TUNNEL NAME	OWNER	LOCATION	STATE	TUNNEL USE	LENGTH (FEET)	WIDTH (FEET)	BID YEAR	STATUS
Canal Street Wet Weather Relief	Milwaukee Metro Sewerage Dist.	Milwaukee	WI	Sewer	13,500	7	2007	Michels - Awarded
County Grounds Tunnel	Milwaukee Metro Sewerage Dist.	Milwaukee	WI	CSO	2,700	17	2007	Bidding in Aug., 2007
Mission Trails #1 #2	SDCWA	San Diego	CA	Water	2,000 2,875	11 11	2008 2008	Under design
Near Surface Interceptors	Narragansett Bay Commission	Providence	RI	Sewer	19,500 11,000	3-6 3-6	2010	Preliminary design
Detroit River Crossing	Detroit River	Detroit/ Windsor	MI	Rail	9,000	28	2012	Study
Alum Creek Relief Sewer (1st phase of 3)	City of Columbus	Columbus	OH	Sewer	26,000	10	2010	Under design
Mt. Olympus San Diego Six	MWDSC	San Diego	CA	Fresh water	33,000	11.5	2011	Planning stage
WASA CSO Potomac Tunnel	Washington DC Water & Sewer Authority	Washington	DC	Sewer CSO	8,000	20	2014	Planning stage
WASA CSO Rock Creek Tunnel	Washington DC Water and Sewer Authority	Washington	DC	Sewer CSO	2,600	12-15	2015	Planning stage
East Side Access Queens Tunnel	NYCTA (MTA)	New York	NY	Subway	10,500	20	2008	Advertise late 2007
Manhattan West Side to LaGuardia Airport	NYCTA (MTA)	New York	NY	Subway	15,000	20	2016	Preliminary Study
East Side Access Manhattan Tunnels	NYCTA (MTA)	New York	NY	Subway	30,000	19	2007-2010	Under construction
East Side Access GCT Caverns Project	NYCTA (MTA)	New York	NY	Station	5,000	Various	2007	Bid, July. 31, 2007
Second Ave. Subway	NYCTA (MTA)	New York	NY	Subway	42,280	19	2007-2012	Under construction
No. 7 Subway Line Extension	NYCTA (MTA)	New York	NY	Subway	7,800	20	2007	Bid, July. 24, 2007
Hudson River Freight Crossing	NYC Economic Development Corp.	New York	NY	Rail				Feasibility planning
Harbor Siphons Project	NYC-DEP	New York	NY	Water	10,000	10	2008	Design completed
North Shore Connector Extension	Port Authority of Allegheny County	Pittsburgh	PA	Light rail	8,500	22	2006-2008	Under construction
Water Tunnel #3 KCT Tunnel	NYC Dept. of Envir. Protection	New York	NY	Fresh water	24,000	20	2010	Under design
East Side Light Rail	MTA	Los Angeles	CA	Rail	13,944			Under construction

The editor's of Tunneling & Underground Construction encourage UCA of SME members to submit projects to the online Tunnel Demand Forecast at www.smenet.org, log in as a member. 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
Harbor Siphons Project	Milwaukee Metro Sewerage District	Milwaukee	WI	Sewer	13,000	16-17 OD	2006	Under construction
North Vancouver	Greater Vancouver Regional District	North Vancouver	BC	Fresh water	2 @ 25,000	11	2006	Under construction
North Dorchester Bay Conso. Conduit	MWRA	South Boston	MA	Sewer CSO	15,700	17	2007-2009	Under construction
Canada Line Rail Extension	Translink	Vancouver	BC	Light rail	33,800	19	2006-2008	Under construction
W. Corridor LRT Tunnel	FastTrack Regional Transportation District	Denver	CO	Light rail	2 @ 280	18	2009	Under design
Drumanard Tunnel	Kentucky DOT	Louisville	KY	Highway	2 @ 2,200	35	2009	Under design
Port of Miami Tunnel	Florida DOT	Miami	FL	Highway	4,000	36	2008	Bouygues - low bid
Middlesex Tunnel	Middlesex CUA	Middlesex	NJ	Sewer	3,900	13	2007	Kenny Construction - Awarded
New Irvington Tunnel	S.F. Public Utility Commission	San Francisco	CA	Water	18,200	10	2009	Under design
Bay Tunnel	S.F. Public Utility Commission	San Francisco	CA	Water	26,200	9	2009	Under design
New Crystal Sprs. Tunnel	S.F. Public Utility Commission	San Francisco	CA	Water	4,200	13	2008	Under design
Upper NW Interceptor	SRCSD	Sacramento	CA	Sewer	19,240	12	2007-2009	Bid, July 2007
BART to San Jose	SVRT	San Jose	CA	Subway	22,700	19	2008	Under design
Caldecott 4th Bore	CALTRANS	San Francisco	CA	Highway	5,000	50	2009	Under design
Lake Mead Tunnel #3	SNWA	Las Vegas	NV	Water	15,500	20	2007	Bids due Nov. 2, 2007
Upper Rouge River CSO North Segment South Segment	Detroit Water and Sanitation Authority	Detroit	MI	CSO sewer	 18,500 21,200	 20 35	 2008 2009	 Under design Under design
Northwest Side Relief Sewer	MILW MSD	Milwaukee	WI	Waste water	4,600 6,100	4-5 6	2007	Nov. 07 bid - Feb. 08 award
Northwest Side Relief Sewer	MILW MSD	Milwaukee	WI	Waste water	4,000	rehab	2007	Nov. 07 bid - Feb. 08 award
North 27th St.	MILW MSD	Milwaukee	WI	Waste water	10,000	21	2007	Under construction
Barclay/Forest Chase	MILW MSD	Milwaukee	WI	Waste water	10,000		2007	
No Business Creek WW Storage Tunnel	Gwinett Co. Dept. of Public Utilities	Buford	GA	Waste water storage	16,000	12	2007	Under construction

There is an extensive list of upcoming projects in the New York City area available on the Internet at www.mta.info under the Capital Construction, Procurement link. These are projects for the NYCT, MNR, LIRR, MTACC and B&T.
For more information see http://www.mta.info/mta/capital/eotf-allagency.htm.

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Symposium on Shotcrete and Waterproofing for Underground Structures
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2009

Rapid Excavation and Tunneling Conference (RETC)
June 14-17, 2009
Caesar's Palace • Las Vegas, Nevada

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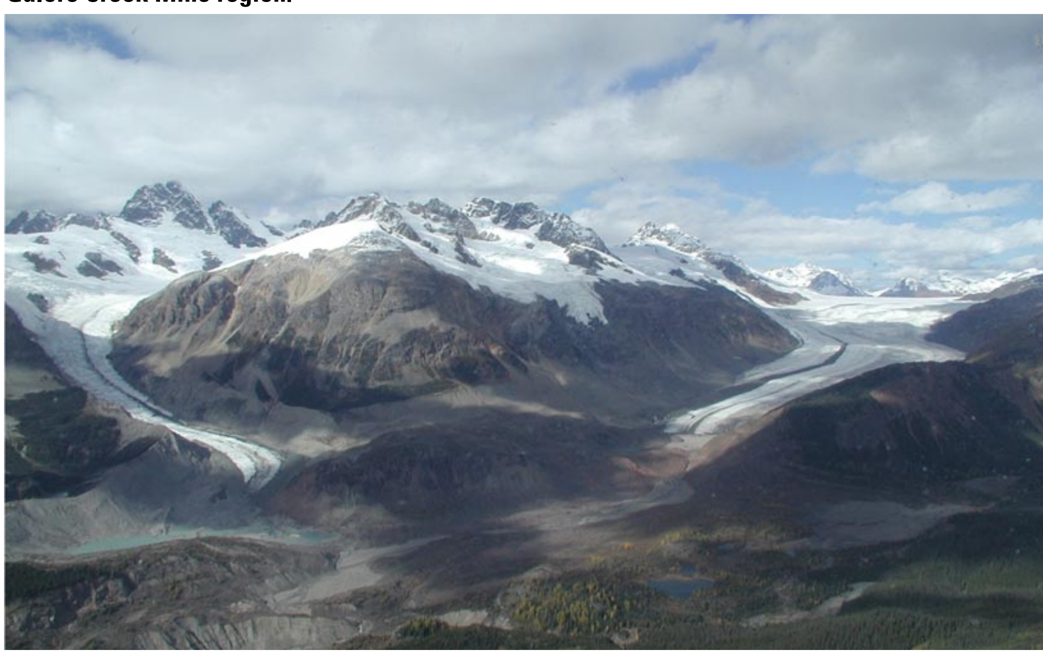
FEATURE ARTICLE

Tunneling under glaciers: Galore Creek Mine access tunnel, British Columbia

FIG. 1

Galore Creek Mine region.



The Galore Creek Mine project is one of the newest major mining projects in Canada. It is located in a remote area of northwestern British Columbia. The project is being developed by NovaGold Resources and Teck-Cominco of Vancouver, B.C.. The mine project comprises one of the largest and highest grade undeveloped porphyry-related gold-silver-copper deposits in North America. To access the mine site, a new 120-km (75-mile) road will be constructed including a 4.4-km (2.7-mile) road tunnel. The construction of the mine project commenced in mid-2007 with the main access road and access tunnel. When completed, it will be the longest private road tunnel in North America.

Detailed design for the mine access tunnel was completed in late 2006. The access road tunnel is about 50 m² (538 sq ft). It has been designed as a large, single-lane road tunnel to accommodate the transport of large size mining equipment. Key services for mining operations will be incorporated into the tunnel comprising diesel and power as well as the concentrate pipeline. The proposed tunnel will pass below two major glaciers with a maximum cover of more than 1,200 m (3,934 ft). A geotechnical investigation program commenced in the summer of 2006 with the excavation of overburden materials at the portals. Tunnel construction from both portals began in the spring of 2007.

The tunnel was tendered in late 2006 and awarded to EBC-Neilson Joint Venture. Notice to proceed was given in early 2007. Early mobilization required the removal of significant snow to gain access to the portal areas to commence tunnel excavation. Excavation is planned to be undertaken only from the North Portal and the overall project schedule duration is estimated to be about 24 months.

Project location, development and layout

The Galore Creek project is located in the historic Stikine Gold Belt. The mine property is approximately 75 km (48 miles) northwest of Barrick Gold's Eskay Creek gold-silver mine and lies 70 km (43 miles) west of Highway 37 and 150 km (93 miles) northeast of the town of

Dean Brox, Peter Procter, Claude Venne, Francois Groleau, Denis Lepinay, Alex Argus, Lorne Frost, Rick Anderson and Murph Miniely

Dean Brox, **Peter Procter** are with Hatch Mott MacDonald, Vancouver, BC. **Claude Venne**, **Francois Groleau**, **Denis Lepinay**, are with EBC-Neilsen Joint -Venture, Montreal, Quebec. **Alex Argus**, **Lorne Frost**, **Rick Anderson**, **Murph Miniely** are with Galore Creek Mining Corporation., Vancouver, BC, e-mail Dean.Brox@hatchmott.com.

FIG. 2

Galore Creek project location and layout.

Stewart, British Columbia that borders with Hyder, AK. The project area is characterized with steep sided valleys and glacier-covered high mountain peaks up to 2,000 m (6,561 ft) in elevation with high snow pack. Figure 1 shows the typical glacial terrain of the project area. Figure 2 shows the general project location.

The final feasibility study for the project was completed in October 2006. Estimated proven and probable reserves are 2.9 Mt (6.6 billion lbs) of copper, 165 t (5.3 million oz) of gold and 2.8 kt (92.6 million oz) of silver. Galore Creek also hosts estimated measured and indicated resources of 862 kt (1.9 billion lbs) of copper, 65 t (2.1 million oz) of gold and 762 t (24.5 million oz) of silver, with additional inferred resources of 1.1 Mt (2.4 billion lbs) of copper, 62 t (2 million oz) of gold and 1.1 kt (35.7 million oz) of silver. The ore deposit will be mined by openpit methods during a period of about 20 years at a typical production rate of 65 kt/d (71,000 stpd). The estimated capital cost of the project is $US2.2 billion.

The key infrastructure of the mine project comprises the 120-km (75-mile) access road from near the Iskut River west by the More Creek Valley, a 4.5-km (2.8-mile) mine access road tunnel, an openpit, one of the world's highest tailings dam at 260 m (853 ft) and a remotely located filtration plant.

The construction of a mine access road tunnel at such a remote location introduces logistical challenges for the efficient mobilization as well as supply of labor, materials and equipment during construction required to meet a critical path construction schedule to allow for construction of the mine site. The world's largest helicopter, the Mi26 from Russia has a payload capacity of 20,000 kg (44,000 lbs), transports the heavy tunneling equipment to the site (Fig. 3).

Tunnel alignment

The horizontal and vertical alignment for the mine access tunnel was defined by the selection of acceptable portal locations in terms of constructability. The tunnel portals were identified based on locations characterized with glacial overburden of shallow depth as indicated from seismic refraction surveys. The preferred location for the North Portal was at an elevation of about 960 m (3,100 ft) and out of the direct paths of potential rockfalls and avalanches from the overlying mountain slopes. The North Portal is located along the main north facing cirque slope surrounding the mine deposit. The portal slope extends from the base of the main Galore valley

FIG. 3

Helicopter transport of equipment to the Galore Creek Mine site.

at an elevation of about 900 m (3,000 ft) up to a glacier covered mountain ridge at elevation of about 1,200 m (4,000 ft). Figure 4 shows the general area of the North Portal.

The South Portal is located near the end of a major glacial valley upon the bench of a lateral glacial moraine at an elevation of about 1,080 m (3,500 ft). Figure 5 shows the general area of the South Portal. The exact position of the South Portal was revised during the detailed design within Scott Simpson Creek valley to a preferred location of minimum overburden that would facilitate rapid preparation of the portal laydown area and early excavation in bedrock for tunnel construction. Rockfall and avalanche hazards existed throughout the overall valley and no low risk locations were available to ideally site the South Portal.

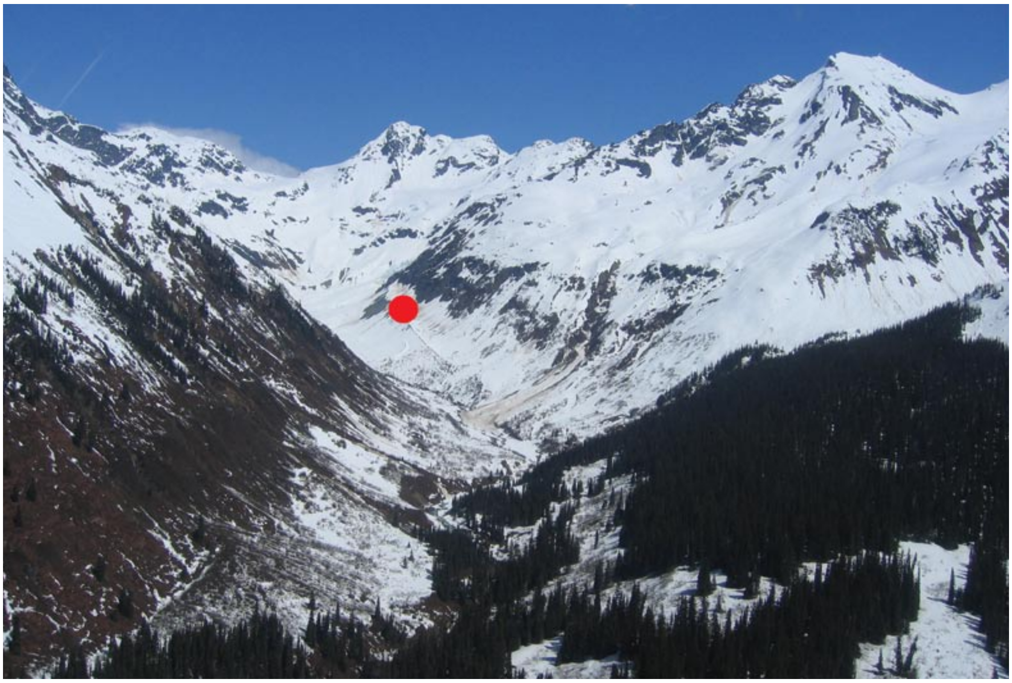
The portal locations result in a horizontal alignment with a length of about 4,400 m (14,400 ft) and an overall downgrade northward of 1 percent as shown in the plan and profile of Fig. 6. The maximum elevation along the tunnel alignment is about 2,100 m (6,900 ft) located approximately at midway and provides a maximum cover of about 1,200 m (4,000 ft). Approximately two-thirds of the tunnel alignment is covered by glaciers as can be seen in the orthophoto of the plan of Fig. 6. A vertical alignment with a downgrade into the mine site from the South Portal was preferred for mine closure where ground water inflows into the tunnel during operations would flow toward the main valley of the mine site and into the mine tailings area rather than require long-term treatment of such flows into open stream courses.

FIG. 4

North Portal area.

FIG. 5

South Portal area.

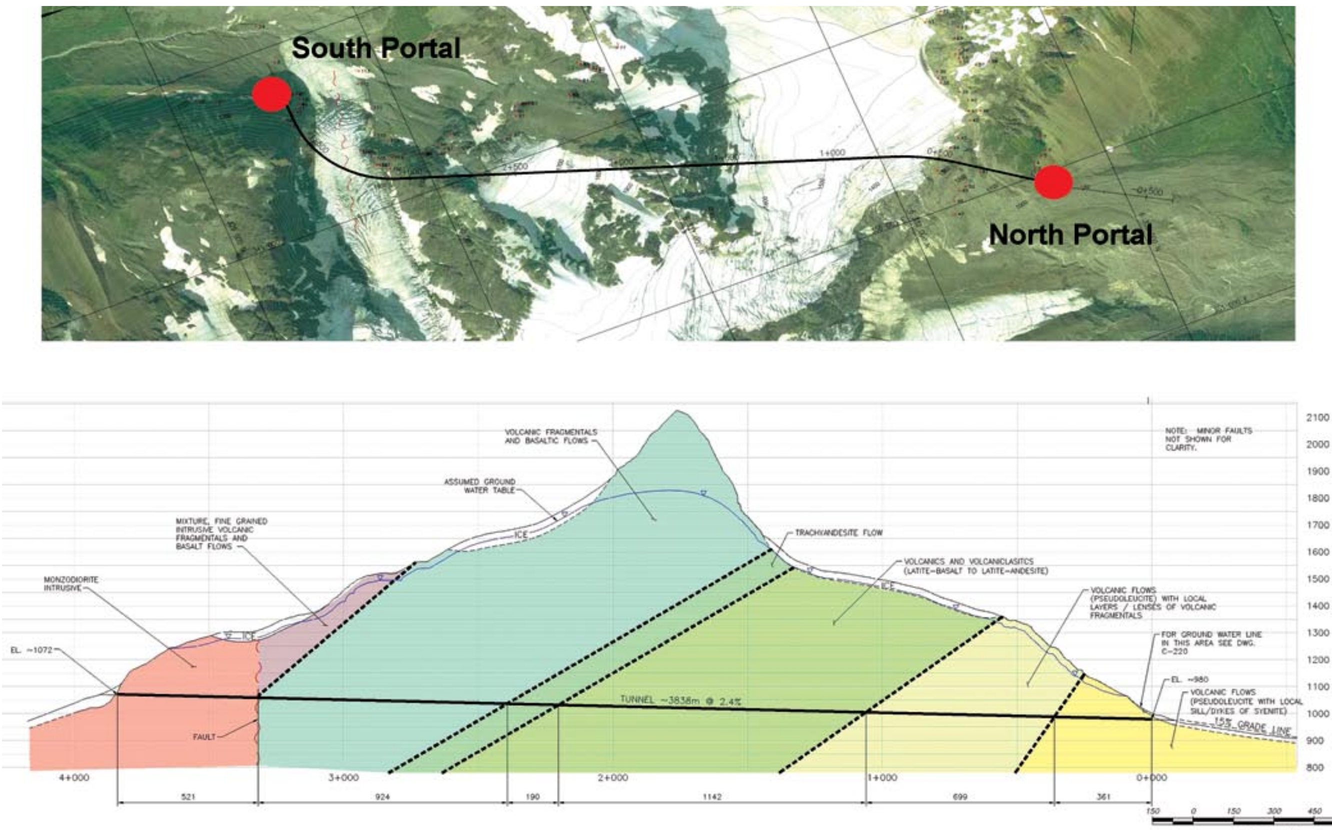


Mine access road tunnel cross section

The cross sectional size and shape was developed during the design based on providing internal vertical and horizontal clearances to allow for the passage of large size mining equipment for mine startup and subsequent operations. The dimensions of the largest envisaged mining equipment was 6 m (20 ft) wide x 4 m (13 ft) high. These dimensions in conjunction with allowances for

FIG. 6

Tunnel alignment plan and profile.



tunnel support, excavation alignment control and rock deformation yielded tunnel excavation dimensions of 8 m (26 ft) wide x 8 m (26 ft) high. The tunnel cross section is shown in Fig. 7.

A relatively flat arch shape was adopted for the tunnel roof in recognition of the hard rock environment and the expected ability to excavate and adequately stabilize the tunnel roof in a controlled manner without excessive overbreak. The floor of the tunnel incorporates a longitudinal side drain to convey expected ground water inflows. A nominal road base has also been accommodated to provide a safe and low maintenance traffic surface that can be easily graded during mining operations.

Table 1

Summary of rock mass quality.

Rock mass quality	Rock Mass rating range	Estimated percentage
Very good	80 – 100	25
Good	60 – 80	30
Fair	40 – 60	25
Poor	20 – 40	15
Very poor	0 - 20	5

Geotechnical conditions

Existing information and site investigations. Numerous exploration boreholes have been completed within and in close proximity to the openpit deposit. However, there were no boreholes previously completed near the portals or along the proposed tunnel alignment. Regional geological mapping was undertaken as part of previous studies. In particular, detailed mapping has been completed in the project including the tunnel alignment by the B.C. Provincial GIS Geological Survey and digital data files of this mapping were provided. This information allowed for the development of an original base geology map along the tunnel alignment for ground proofing. None of the regional faults that have been postulated in the area of the openpit deposit are believed to extend near or across the tunnel alignment.

Detailed field mapping was completed along the tunnel alignment. Bedrock exposures were inspected and mapped for lithology and fracture information at the portal areas as well as along the entire tunnel alignment. Limited exposures of representative bedrock existed along the northern section of the tunnel alignment due to the presence of glaciers. Access was not possible along the central section due to the steepness of the terrain. Following the field work, a comparison of the field collected data was made with the previously available base map to develop an updated geological plan and profile of the tunnel alignment (Fig. 6).

Seismic refraction surveys have been completed at each of the portals to assess the potential depth to and profile of the underlying bedrock. In view of the extensive outcrops of representative geology along the surface of the tunnel alignment and the absence of any foreseeable adverse geological formations along the tunnel alignment, it was not considered necessary to investigate the expected geotechnical conditions at tunnel elevation. Other geotechnical investigation work included petrographic analyses of selected rock samples and acid rock drainage (ARD) and metal leaching (ML) testing.

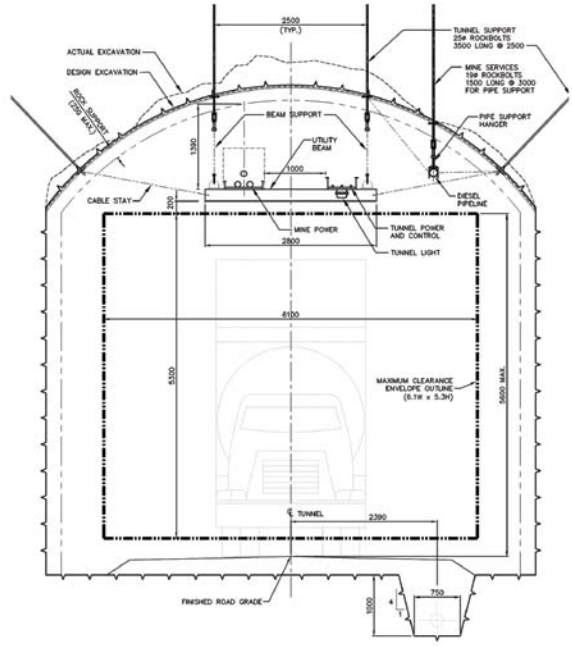
Site geology

The main rock types to be encountered along the tunnel alignment mainly comprise a repetitive package of moderately south-dipping volcanic/volcaniclastic bedrock while syenite porphyry will be encountered near the North Portal and monzodiorite along the southern most section. The volcanic and volcaniclastic rocks along most of the tunnel alignment mainly appear to comprise stratigraphically lowermost, plagioclase-bearing, dark green (chloritic) basalts with locally abundant bright yellow-green patches of epidote; overlying pyroxene-phyric basalts (rarely observed in the tunnel area) and an uppermost, thick, highly alkaline package composed of variably pseudoleucite-bearing flows and re-sedimented (volcaniclastic) rocks. However, along the proposed tunnel alignment, these units appear to be structurally repeated, presumably by folding and faulting, so that the basalts may occur at the highest elevations examined, and the volcaniclastic rocks at the lowest elevations examined as indicated in the geological profile of Fig. 6.

The main rock types along the mine access road tunnel are fractured and can be characterized with several sets of fractures with different orientations. These sets of fractures will combine to form potentially unstable wedge blocks along the crown, haunches and sidewalls of the tunnel that will be required to be supported to prevent fall-out. The spacing of the rock fractures within the volcanics and granodiorites varies typically from 0.2 m (0.7 ft) to 0.5 m (1.6 ft) and from 0.1 m (0.3 ft) to 0.4 m (1.3 ft), respectively, based on observations from surface outcrops. A total of five main fracture sets have been identified to be associated with the volcanics and four main fracture sets within the monzodiorites. Based on overall outcrop observations, the foliation/bedding (Fracture Set #1) is the most prominent fracture set within the volcanics. A limited number of faults are inferred to be present along the tunnel alignment. A single major fault with a width of 15 m (49 ft) has been inferred to be present below the glacier along the south section of the alignment (Fig 6).

FIG. 7

Tunnel cross section and key mine services.



Portal conditions

Overburden materials are present at both portals based on observations and the results of the seismic refraction surveys. These materials at the South Portal comprise glacial tills and mixed talus to an estimated depth of about 12 m (39 ft).

The North Portal is comprised of mixed talus material. The existing rock slope immediately above the portal location is very steep and relatively good quality rock mass conditions. There are a number of potentially loose rock blocks along the upper portion and crest of the rock slope that will require local scaling and pos-

FIG. 8

Portal canopy structure and portal house.

FIG. 9

North Portal excavation preparation.

sible stabilization works to provide a safe working area below for the excavation of the rock face to start tunnel excavation.

Rock mass quality and strength

Rock mass quality has been assessed using the Rock Mass Rating (RMR) rock mass classification system based on inspection of borehole core from the geotechnical drillholes completed along and nearby the tunnel alignment. The RMR rock mass classification system is based on five parameters describing rock conditions in terms of intact rock strength (UCS), rock quality designation (RQD), fracture spacing, fracture condition and ground water condition.

The rock mass quality of the main rock types along the tunnel alignment has been assessed based on outcrop mapping. Upon consideration of the rock mass quality data from the outcrops and recognition that additional minor faults and fracture zones can be expected, an overall summary of rock mass quality for the tunnel alignment is presented in Table 1. In general, most of the rock conditions expected to be encountered along the tunnel alignment can be described as fair to very good.

The strength of the various rock types to be encountered along the tunnel alignment has been evaluated from a limited number of UCS tests completed on block samples collected at site. The laboratory test results are within the typical range for the volcanics and granodiorites. Based on a review of these testing results and field observations, the rock strengths of the rock types are generally uniform and can be expected to vary only to a limited degree since there is no weakening effect due to significant alteration of the rock types along the tunnel alignment. It is particularly noted that the volcanic rocks can be generally characterized as extremely strong. The rock strength of the monzodiorite is estimated to be about 200 MPa and the rock strength of the volcanics about 260 MPa.

FIG. 10

South Portal excavation preparation.

Ground water conditions and predicted inflows

The ground water conditions and expected ground water inflows along the tunnel alignment have been assessed based on consideration of the site topography, tunnel alignment geology and overall geological environment. The depth to the ground water table is inferred to be relatively shallow along most of the tunnel alignment. Hydrostatic ground water pressures can, therefore, be expected to vary accordingly with topography increasing to an inferred maximum of about 900 m (3,000 ft) along the central section. The maximum hydrostatic ground water pressure below the glacier along the southern section may be as much as 275 m (900 ft).

Ground water inflows will emanate along open fractures and at major fault and/or fracture zones intersected along the tunnel alignment. Expected ground water inflows along the tunnel alignment have been evaluated using an established empirical approach for both nongrouted and grouted fault zones conditions and assumed rock mass permeabilities typical for the rock types. Notwithstanding the assumed rock mass permeabilities for the ground water inflow predictions, it is noted that higher rock mass permeabilities may exist within the rock conditions along the tunnel alignment due to the presence of open fractures at depth, which is not uncommon based on past experience in similar geological environments. The predicted ground water inflows along the entire tunnel alignment prior to breakthrough are 110 L/sec (1,740 gpm) without pre-excavation grouting and 55 L/sec (870 gpm) with pre-excavation grouting.

Rockfall and avalanche potential at portals and protection measures

The South Portal is located along the lateral moraine midway up along a major 300-m (984-ft) high slope. The existing slope comprises bedrock outcrops that have been subjected to alteration and weathering with the presence of some loose rock blocks. Rockfall and avalanche chutes are present along the slope, which restrict rockfalls and snow to these locations. However, rockfalls and avalanches may manifest from higher areas and occur over wider areas around the portal. Rockfalls of varying size have occurred in the past along this slope. Rockfall protection measures comprising scaling and slope fencing will be prudent to install as part of the portal works to protect workers and equipment during portal and tunnel excavation. Given the high snowpack of the project area, active full-time avalanche management is deemed necessary during portal and tunnel excavation to limit the extent of snow buildup for subsequent routine snow removal within a practical time frame.

FIG. 11

Starter tunnel excavation.

The North Portal is also located near the toe of a major rock slope where potentially unstable rock blocks can be observed along the upper portions of the slope. Scaling and cleaning of the rock slope are required as part of the portal works. And rockfall protection measures comprising slope protection fencing will be prudent to install as part of the portal works to protect workers and equipment during tunnel excavation.

Given the potential for avalanches and rockfalls at each of the portals, high capacity structural culverts, (double-shell, multi-plate culverts) have been adopted as protective canopies to be backfilled and buried with specific appropriate materials to absorb the impact energy associated with high speed avalanches and allow their deflection around the canopies.

Design and constructability issues

During detailed design the following issues were evaluated and addressed:

- Identification of preferred/acceptable portal locations.
- Tunnel excavation and support.
- Tunnel operations requirements – refuge bays and ventilation.
- Portal canopy requirements.
- Portal houses for transition of key services.
- Advanced construction of portals.

Preferred portal locations

The mine access tunnel provides the vital link connection from the Galore Creek valley at the mine site to the western end of the Scott Simpson valley. The western end of the Scott Simpson valley is characterized with steep-sided natural rock slopes above which are covered with significant snow pack throughout much of the year (Fig. 5). Several narrow gullies are present along the eastern side of the valley and extend from the upper high slope areas down to the bottom of the valley. Rockfalls and avalanches are typically channelled along these gullies and presented challenges for the siting of the South

FIG. 12

Installation of the North Portal canopy.

Portal at the end of this valley. The final location for the South Portal was selected based on consideration of the pathways of rockfalls and avalanches, rock quality and overall access road constructability restrictions. Similarly, the final location for the North Portal was selected based on consideration of the pathways of rockfalls and avalanches as well as the inferred shallowest depth of overburden materials.

Tunnel excavation and support

Given the relatively good quality, extremely strong rock conditions that are expected over most of the tunnel alignment, the mine access tunnel is being excavated by full-face, drill-and-blast methods. The tunnel cross section is approximately 50 m^2 (583 sq ft) and represents a moderately large cross section. However, this size of tunnel face area can easily be excavated with standard and modern tunneling equipment. The owner elected to pre-purchase four twin-boom Tamrock Axera T8 drilling jumbos. The tunnel geometry may be modified from the current tunnel cross section subject to the availability and selection of the tunnel contractor's equipment and the preferred methods of tunnel construction.

Tunnel excavation is proceeding from only the North Portal for logistical reasons. However, excavation from the South Portal may occur if required to meet the project schedule. The Tamrock jumbos have been fitted with 6-m (20-ft) long slides to allow for large blast rounds to maximum advance. Progress rates of 12 m/d (39 ft/d) are expected to be achieved with the selected equipment.

Based on the expected rock conditions along the tunnel alignment and the assessment of tunnel stability, and in accordance with standard industry practice, an appropriate level of tunnel support will be required to be installed to maintain the long-term stability and safety of the tunnel given the operating requirements of the mine access tunnel and to minimize maintenance disruptions during operations.

With the fast-track nature of the overall project and critical schedule for the mine access tunnel, it is suggested that initial tunnel support systems comprising rock bolts, mesh, shotcrete and lattice girders be installed as required concurrently with tunnel excavation. And final tunnel support comprising any additional rock bolts and any necessary shotcrete lining should be installed after breakthrough and removal of the ventilation duct and all services. This tunnel excavation and support approach is considered to result in the shortest overall construction schedule without jeopardizing the integrity of the tunnel.

With the expected variable rock conditions to be encountered along the tunnel, a series of tunnel support classes will be required to be installed during excavation to cater for these conditions. They will be comprised of combinations of pattern rock bolts, mesh and variable thicknesses of shotcrete. Tunnel support classes will be related to rock conditions as encountered defined in terms of rock mass quality using a recognized rock mass classification system. Rock mass quality data is collected as part of tunnel mapping during excavation. The required tunnel support for each excavation advance is evaluated based on consideration of the rock mass quality and geological mapping data as well as practical experience.

Tunnel operations requirements – refuge bays, ventilation jet fans and sealed doors

The mine access road tunnel will be operated as a private use tunnel. The design incident scenario for the mine access road tunnel comprises a vehicle fire and the escape of maintenance workers dictates a fundamental requirement for emergency egress to fresh air. For a single tube tunnel, this requirement is most commonly provided by self-contained refuge stations/safehouses located along the tunnel at appropriate intervals. The purpose of the refuge stations/safehouses is to provide a safe haven of breathable air and first aid supplies to any incident victims. The size of the refuge stations must be sufficient for the maximum number of expected people that could be impacted by a possible incident in the tunnel.

FIG. 13

Backfill completion of the North Portal canopy.

There is no recognized applicable regulation for the spacing of refuge stations for this type of mine access tunnel. But it is deemed appropriate that the interval of the refuge stations can be greater than that required for normal underground mining operations where there are several workers located in close proximity (300 m or 984 ft), and greater than that required for a high traffic volume highway tunnel (250 m or 820 ft). For the selected representative safety design incident involving a major vehicle fire (20 MW), a medium duration travel time to the refuge station of no more than eight minutes is considered to be appropriate based on a normal walking speed of 4 km/h (2.5 mph). In comparison, the maximum allowed travel time (NFPA 130) to a place of safety due to transit train fire in an underground transit station is four minutes. The Inspectorate of Mines of British Columbia has endorsed this overall approach.

Refuge bays/safehouses have been designed to be constructed at intervals of 500 m (1,640 ft) along the tunnel to provide emergency shelter in the event of a fire within the tunnel. The refuge bays will incorporate sealed fireproof doors, oxygen cylinders, carbon dioxide absorbers, water supply, blankets, first aid materials, toilet, a collapsible injury cot, and telephone communications to shelter 12 people who may be traveling and/or completing maintenance work within the tunnel. Eight refuge bays will be required. The refuge bays will be separated from the tunnel by an airlock entry system with double doors in each bulkhead. The toilet will be located in the airlock.

During normal operations, the mine access road tunnel will be self-ventilating due to the difference in elevation of the portals. This natural ventilation may be affected by weather conditions at the portals. A mechanical ventilation system will be required to provide airflow when the natural ventilation is inadequate or in the event of a fire.

Three banks of three jet fans each will be positioned within the tunnel along the northern (downhill) section and near the tunnel portals. They will be activated in the event of unacceptable air quality as monitored by sensors and/or an incident/fire to regulate the air-flow and force/exhaust smoke out of the tunnel in the most appropriate direction depending on the location of the incident. In the event of a fire in the tunnel, the ventilation system will be activated from the mine dispatch office following a telephone or radio call to mine dispatch from a person involved in the incident or following an alarm signal from an array of air quality sensors.

Additional fire, life and safety components that will be incorporated into the tunnel include radio communications, fire extinguishers, air quality sensors, telephones, reflective signage and lighting. Finally, sealed mine-shop doors located inside each portal have been incorporated into the design of the tunnel that will be manually activated to allow passage through the tunnel. The doors will serve to prevent cold air entering the tunnel and causing freezing of ground water inflows along the walls of the tunnel and will facilitate ventilation under emergency conditions.

Key mine services

The key mine services comprising the mine diesel supply pipeline the slurry concentrate pipeline, and the high voltage power cables must all transcend through the mine access tunnel. Cost tradeoff studies were completed as part of the detailed design of the mechanical and electrical components for the mine access tunnel. It was concluded that all services but the slurry concentrate pipeline would be suspended from the tunnel roof. The design layout of the key mine services in the cross section of the tunnel is included in Fig. 7. The tradeoff study evaluated making use of the main tunnel support and the requirement for accurate installation of all support to provide adequate bracing of the required cable trays suspended from the roof. The alternative was to consider the installation of an additional series of low capacity rock bolts that would be installed either as a secondary operation behind the advancing face or after breakthrough. This option was not selected due to the challenges of installing the additional rock bolts within a lag distance behind the advancing face and ahead of the ventilation duct without posing a significant impact to the overall progress of the tunnel.

Portal canopy requirements

Rockfall and avalanche hazards will exist during operations of the mine access tunnel. Portal canopy protection structures have been included at each portal to provide adequate protection of the tunnel against these natural hazards.

The canopies have been designed at a diameter of 9 m (29 ft) and a length of 65 m (213 ft) to accommodate variable impact loads from rockfalls and avalanches along the length of the canopies. That has been adopted based on consideration of rockfall and avalanches runout analyses based on location-specific topographical and geotechnical parameters. Figure 8 shows a three-dimensional image of the final arrangement of a portal canopy that has been completely backfilled around the structure. The canopy structures selected for the portals comprise the SuperCor deep corrugated steel plate structure from Atlantic Industries Ltd.

Portal houses

Portal houses comprising large span steel frame cladded structures have been incorporated into the tunnel design. They allow for the transition of key mine services of the diesel pipeline, power cables and concentrate pipeline from outside the tunnel to the roof of the tunnel. The portal houses will also include portal doors to retain the heat within the tunnel during winter operations and a closed circuit television camera to monitor traffic entering and exiting the tunnel (Fig. 8).

Advanced construction of portals

In recognition of the critical path nature of the mine access road tunnel, the tunnel works started in the summer of 2006 for portal excavation with the removal of overburden material to expose bedrock. This work required the mobilization of large capacity earthworks equipment (D8 bulldozers and back-excavators) by a Chinook helicopter with a payload capacity of 10 t (11 st). Geotechnical investigation at the North Portal required removal of talus slope debris down to bedrock. Geotechnical work that was undertaken at the North Portal laydown is shown in Fig. 9.

Excavation at the South Portal comprised the establishment of temporary access up along the lateral moraine to the steep rock bluffs and the removal of glacial overburden material to confirm the depth profile of the bedrock. This work will assist in the mobilization of large tunnelling equipment by helicopter in the spring of 2007. Figure 10 shows the laydown area at the South Portal.

Construction status

Excavation of the North Portal commenced in July 2007 followed by completion of a 50-m-(164-ft-) long (Fig. 11) starter tunnel. This work facilitated the installation and backfilling of the 65-m- (213-ft-) long, 9-m- (29-ft-) diameter structural avalanche protection canopy at the North Portal (Fig. 12). Backfilling of this canopy was completed in October 2007 (Fig. 13). Tunnel excavation resumed immediately following completion of the canopy on a 24-hour, seven-day-a-week basis using 6 m (20 ft) slides on the Tamrock twin boom jumbos with a planned advance of two rounds per day. It will continue through the winter of 2007-2008 and 2008-2209 for an expected breakthrough in mid-July 2009. Following breakthrough, the first passage of traffic will be allowed only once a minimum amount of safety equipment is installed within the tunnel.

Conclusions

The Galore Creek mine access road tunnel comprises an interesting tunneling project located in a remote area to be entirely constructed by helicopter support. The remote location introduces logistical challenges for the efficient mobilization as well as supply of labor, materials and equipment during construction required to meet a critical path construction schedule to allow for construction of the mine site. If constructed, the mine access road tunnel will be the longest private road tunnel in North America. ■

Acknowledgments

The authors acknowledge the permission of Galore Creek Mining Corporation (GCMC) to publish this paper. GCMC is providing full-time, on-site construction management during tunnel excavation with technical assistance by Hatch Mott MacDonald.

FEATURE ARTICLE

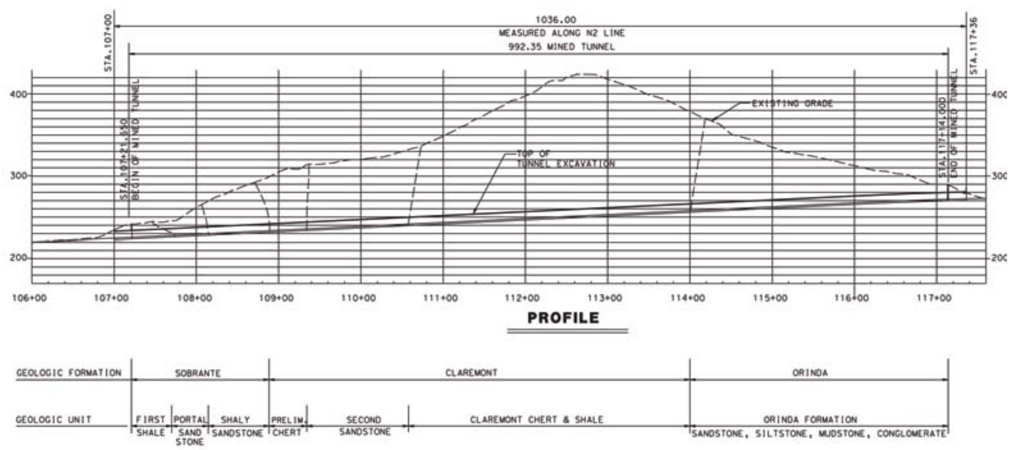
Preliminary design of the Caldecott fourth bore

Bhaskar B. Thapa, Michael T. McRae and Johannes V. Greunen

Bhaskar B. Thapa is an associate with Jacobs Associates; Michael T. McRae and Johannes V. Greunen, are principal and senior associate, respectively, at Jacobs Associates, e-mail thapa@jacobssf.com.

FIG. 1

Geologic formations and geologic units.



The existing Caldecott Tunnels consist of three bores along State Route 24 (SR 24) through the Berkeley Hills in Oakland, CA. The California Department of Transportation (Caltrans) and the Contra Costa Transportation Authority (CCTA) propose to address congestion on SR 24 near the existing Caldecott Tunnels by constructing a fourth bore that will provide two additional lanes. The length of the proposed fourth bore is 1,036 m (3,399 ft). The project will include short sections of cutand cover tunnel at each portal, seven cross-passageway tunnels between the fourth bore and the existing third bore, electrical substation buildings at either portal and a new operations and control building.

The fourth bore includes two 3.6-m (12-ft) traffic lanes and two shoulder areas that are 3 m and 0.6 m (10 ft and 2 ft) wide. The horseshoeshaped mined tunnel is 15 m (50 ft) wide and 9.7 m (32 ft) high. The tunnel includes a jet fan ventilation system, a wet standpipe fire protection system and various operation and control systems including CCTV monitoring, heat and pollutant sensors and traffic monitoring systems.

Geology

Major geologic formations and structure. The geology of the alignment is characterized by northwest-striking, steeply dipping and locally overturned marine and non-marine sedimentary rocks of the middle to late Miocene Age. The western end of the alignment traverses marine shale and sandstone of the Sobrante Formation. The Sobrante Formation includes the First Shale, Portal Sandstone and Shaly Sandstone geologic units as identified by Page (1950). The middle section of the alignment traverses chert, shale and sandstone of the Claremont Formation. The Claremont Formation includes the Preliminary Chert, Second Sandstone and Claremont Chert and Shale geologic units (Page, 1950). The eastern end of the alignment traverses non-marine claystone, siltstone, sandstone and conglomerate of the Orinda Formation. Major formations and geologic units within these formations are shown in Fig. 1.

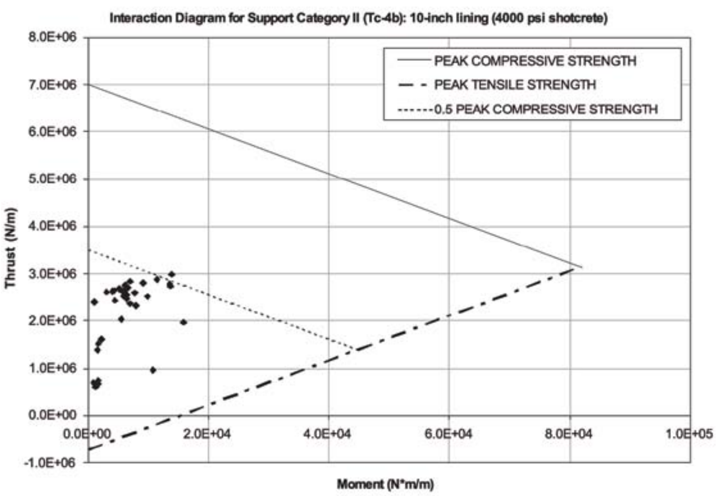
The regional geological structure of the project area has been characterized as part of the western, locally overturned limb of a broad northwest-trending syncline, the axis of which lies east of the project area. The fourth bore alignment will encounter four major inactive faults, which occur at the contacts between geologic units. These faults strike northwesterly and near perpendicular to the tunnel alignment. In addition to the major faults, many other weakness zones will be encountered away from the major faults, such as smaller-scale faults, shears and crushed zones.

West of the fault contact between the Preliminary Chert and Shale and the Second Sandstone, the bedding encountered in the fourth bore generally dips predominantly toward the northeast. East of this fault contact, the bedding dips to the southwest. Several joint sets occur within each geologic unit and random joints occur in almost any orientation in all geologic units. Intrusive sandstone dikes and volcanic dikes that are hydrothermally altered at some locations occur most frequently in the Claremont Chert and Shale, but may also be encountered less frequently in other geologic units.

The structure of the rock mass units along reaches of

FIG. 2

Moment — thrust diagram.



the alignment varies from being blocky in the best ground, down to a disintegrated or crushed condition in the poorest quality rock. Rock Mass Ratings (Bieniawski, 1989) and Q (Barton, 1988) at the tunnel scale vary between 20 and 65 and 0.006 and 10.5, respectively, along the alignment. Rock strength varies from weak to moderate along the alignment. Average values of measured unconfined compressive strengths varies from 5.2 MPa (750 psi) to 21.6 MPa (3,190 psi) in the various geologic units along the alignment. Mudstone, siltstone and shale in the Orinda and Claremont formations are expected to exhibit swelling behavior.

Seismicity

The San Francisco Bay region is considered one of the more seismically active regions of the world, based on its record of historical earthquakes and its position astride the tectonic boundary between the North American and Pacific plates. During the past 160 years, faults within this plate boundary zone have produced numerous small-magnitude (M<6), and more than a dozen moderate- to large-magnitude (M>6), earthquakes affecting the region. Major faults that comprise the 80-km- (49-mile-) wide plate boundary within the San Francisco Bay region include the San Gregorio, San Andreas, Hayward and Calaveras faults. The active Hayward fault, located 1.4 km (0.9 miles) west of the Caldecott Tunnel, is the closest regional fault to the project site.

Ground classification

The design and construction of the fourth bore is based on the sequential excavation method (SEM), also called the New Austrian Tunneling Method (NATM). The ground classification process was two-fold: identification and characterization of rock mass types (RMT) along the alignment having similar mechanical characteristics, and identification of ground classes based on similarity of anticipated ground behaviors of each RMT in response to excavation.

The identification of RMTs was based on the distribution of geological characteristics and relevant geotechnical parameters. The alignment was divided into RMTs based primarily on lithology, fracture density, discontinuity properties and unconfined compressive strength (UCS). Mechanical properties were determined for each of the RMTs along the alignment and ground behaviors were evaluated considering the identified boundary conditions. The RMTs were then grouped into four ground classes based on the similarity of anticipated ground behaviors in response to excavation. An appropriate support category was then developed for each ground class. For example, Ground Class 1 comprises all RMTs along the alignment that require Support Category I. Ground Class 2a correlates to Support Category IIA, and so on. Individually, the support categories address sets of similar ground behaviors and as a whole they address all anticipated ground behaviors along the alignment. The ground classes were the basis of design for the initial support categories.

Ground classes

The actual ground classes along the alignment will be determined during construction based on probe drilling ahead of the lead drift, geologic mapping of the tunnel and tunnel monitoring. The ground classes encompass a broad range of rock properties as shown in Table 1.

Table 1

Ground classes.

Ground Class	Rock Mass Description
1	Blocky rock masses with poor to good discontinuity conditions and weak to medium strong intact unconfined compressive strength
2	Very blocky to blocky/disturbed/seamy rock masses with poor to good discontinuity surface conditions and weak to medium strong intact rock unconfined compressive strength
3	Blocky/disturbed/seamy rock masses with poor discontinuity surfaces, or disintegrated rock with poor discontinuity conditions
4	Disintegrated First Shale rock mass at the west portal with poor to fair discontinuity conditions and weak to very weak intact rock strength.

Excavation and initial support

NATM excavation sequences and support designs were developed for the four support categories that correspond to the four ground classes described above. This section describes:

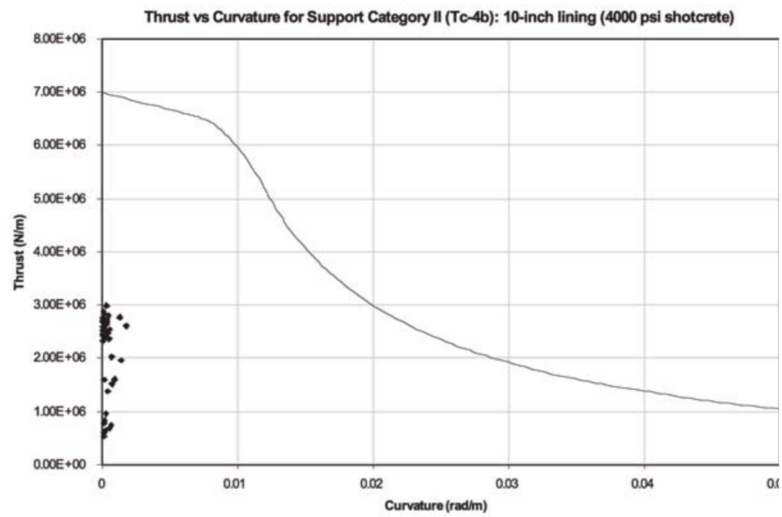
- The excavation sequence.
- The main analyses performed to determine support element requirements within each support category.
- The major support elements and support selection considerations for the support categories.
- Construction monitoring to be used during construction.

Excavation sequence

The overall excavation and support sequence consists of a top heading and bench. The top heading excavation will be accomplished using a single drift with a sloping core for face support. The bench excavation will be done in one or two stages depending on the support category and the lag maintained between the top heading and bench. A minimum lag between the top heading and bench is required to ensure equilibrium of the top heading under biaxial loading before additional loading is introduced as a result of the excavation of bench drifts. Drift advance length is primarily controlled by anticipated ground stand-up time and the size of the drift.

FIG. 3

Thrust — curvature diagram.



Analysis for determination of support requirements

Convergence-confinement analyses were performed using Fast Lagrangian Analysis of Continua (FLAC 5.0, Itasca, 2005) to determine the required thickness of shotcrete lining and the length of rock dowels in the four support categories. The FLAC analyses simulated the excavation sequence and installation of perimeter rock dowels and several lifts of shotcrete. In addition, the models simulated the strength/stiffness gain of the shotcrete with time. The models were used to estimate the moments and thrusts that develop in the shotcrete lining and these results were plotted on moment-thrust interaction diagrams to verify that the loads are less than the capacity of the lining (Fig. 2).

The FLAC models incorporated an elastic-plastic material model to simulate the inelastic behavior of FRS. Each beam element was assigned a tensile and compressive strength, which, along with the section geometry, defines an interaction diagram. At each time step, the axial forces and moments are computed for each beam element and these forces and moments are compared to the capacity envelope. If the axial forces and moments fall outside the interaction diagram, the axial forces and moments are adjusted to return the values to the capacity envelope. This approach effectively limits the tensile stress that will develop in the shotcrete lining and permits plastic rotations and deformations to develop if the tensile capacity is reached. To assure that the section remains structurally viable, rotations that develop in the lining are plotted on thrust-curvature diagrams to verify that they are within allowable limits (Fig. 3).

The elastic modulus of shotcrete used in the FLAC

FIG. 4

Face stability evaluation with FLAC3D.

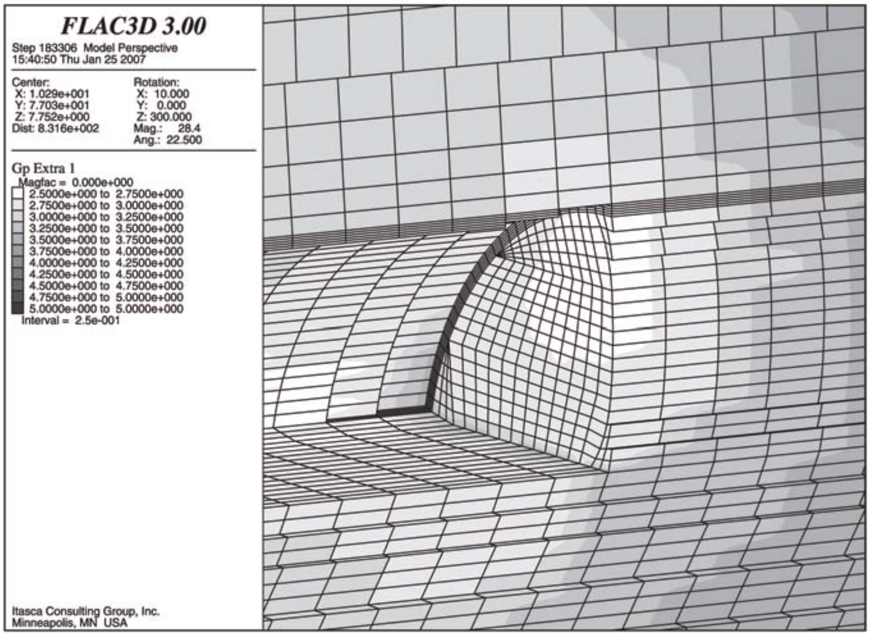
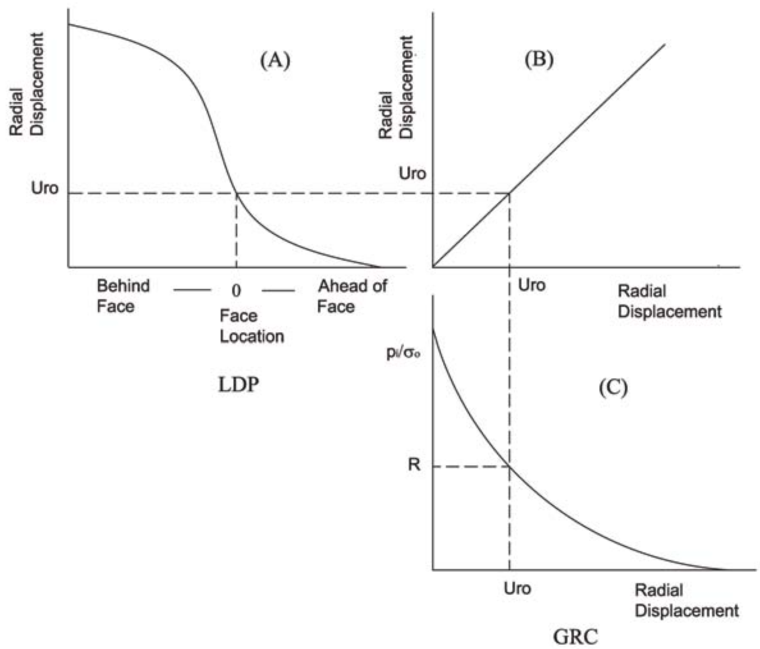


FIG. 5

Schematic illustration of estimation of ground relaxation factor using FLAC3D results.



analyses varied from 5,000 to 15,000 MPa (725 to 2,175 ksi) to account for creep in early age shotcrete (John and Mattle, 2003). The lining is initially assigned an elastic modulus of 5,000 MPa (725 ksi) immediately after installation. The elastic modulus is gradually increased to 15,000 MPa (2,175 ksi) for hardened shotcrete, as the excavation progresses, to simulate the stiffness increase of the shotcrete as it increases with time.

FLAC3D models of the full NATM excavation and support operation (Fig. 4) in each support category were used to estimate the amount of relaxation that occurs in the ground ahead of drift headings, evaluate face stability, estimate the required bench lags and evaluate spile performance. The methodology used to evaluate relaxation ahead of the face is shown in Fig. 5. Results from the FLAC3D analyses were also used to cross-check FLAC2D results. Finally, keyblock analyses were performed to determine support requirements to prevent block failure at the tunnel face and along the perimeter.

Initial support design

Support elements planned include fiber-reinforced shotcrete (FRS), lattice girders, fast-setting cement-grouted rock dowels, fiberglass rock dowels, self-drilling and grouted spiles and self-drilling grouted pipe spiles. The FRS will have a strength of 27 MPa (4,000 psi) in all support categories. Self-drilling spiles are used because drillholes are expected to be unstable where spiles are required.

Rock reinforcement, consisting of cement-grouted dowels, will be used in all support categories except Support Category IV. In some of the more adverse rock, self-drilling, cement-grouted dowels will be required. The top heading tunnel perimeter support will be installed within three rounds of the working face.

Spiles will be installed as part of Support Categories II and III to provide pre-support within the advance length. In Support Category IV, that includes a pipe canopy for presupport, the excavation profile is flared along the inclination of the pipe canopy, to provide adequate clearance for the drill boom used to install the pipes.

Drainage holes and probe holes will be drilled ahead of the top heading to control the impact of water inflows on the stability of the ground around the tunnel excavation, and to identify ground conditions ahead of the face. Shotcrete thicknesses for the four support categories range from 203 mm (8 in.) to 304 mm (12 in.). Rock reinforcement will consist of 4-m-long (13-ft-) rock dowels. A sloping core is used for face support in all support categories. Systematic pre-support and lattice girders will be required in Support Categories IIB, III and IV. Maximum advance lengths for the four support categories range from 1 m (3 ft) to 1.8 m (6 ft).

Monitoring

An initial support and ground response monitoring program will be implemented during construction to verify that the performance of the initial support systems is within the anticipated range. The monitoring data will also be used as supplemental information to facilitate the selection of appropriate support categories during construction and to help determine where additional support measures are needed. The monitoring instruments will measure displacements of the shotcrete lining at points around the perimeter of the tunnel and will monitor ground movements within the rock mass in the rock pillar between the third and fourth bores near the portals as well as within the slopes adjacent to the portals.

The tunnel monitoring program will use monitoring bolts to measure deflections of the shotcrete lining. Deflection measurement points will be installed at defined points around the circumference of the shotcrete lining. Six monitoring types, defining the instrument locations along the tunnel lining in a cross-sectional view, will be used for the range of support categories along the main tunnel alignment and in the cross-passageways.

Final lining and seismic design

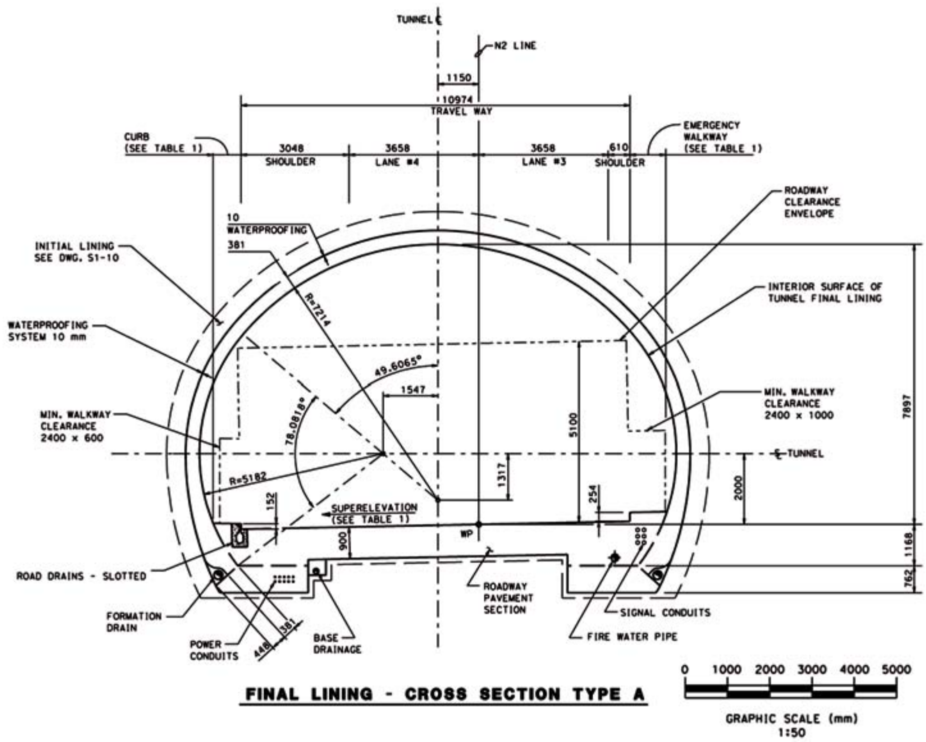
Final lining system. The Caldecott Fourth Bore uses a double lining system consisting of an initial support system (discussed above) and a cast-in-place reinforced concrete final lining (Fig. 6). A waterproofing membrane with a geotextile backing layer for drainage will be installed between the initial support and the final lining. The initial support system is designed to carry the ground loads that develop during construction while the cast-in-place reinforced concrete final lining is designed to carry long-term ground loads and any additional loads due to interior finishes or equipment anchored to it. The final lining will also accommodate seismic deformations and provide a durable and sound tunnel lining.

Loads and load combinations

The final lining will support its own dead load, ground loads from load sharing with the initial support system, rock wedge loads supported by the initial supports during construction and seismic deformations. Two critical load conditions have been identified. The first load combination could occur during the first few years after completion of construction before any ground loads are imposed on the final lining. This load combination consists of the final lining dead load and seismic deformations. The second critical load combination combines maximum ground loads with seismic deformations.

FIG. 6

Final lining.



Ground loads from load sharing

The initial and final linings will function as a combined support system in the long term. Over time, after the completion of construction, a portion of the ground load carried by the initial support system will be transferred to the final lining due to deterioration of the initial support system rock dowels and shotcrete. Analyses were performed to assess the effect of the degradation of the initial support and to determine the part of the ground load that will be transferred to the final lining. The analyses assumed the dowels deteriorate completely in the long-term and that the modulus and strength of the shotcrete degrade to approximately 60 percent of the original design values. The initial shotcrete lining is also assumed to have no flexural capacity in the long-term due to possible deterioration of any reinforcing embedded therein. The results indicate that the final lining will attract a maximum of approximately 50 percent of the ground load supported by the initial lining. The final lining was conservatively designed to support two-thirds of the ground load supported by the initial lining.

Seismic demand

General performance requirements. In accordance with general Caltrans practice for "important" facilities on lifeline routes such as SR 24, the seismic design for the tunnel is based on the Safety Evaluation Earthquake (SEE) and a lower-level Functional Evaluation Earthquake (FEE). The project uses a 1,500-year return period for the SEE event and a 300-year return period for the FEE event.

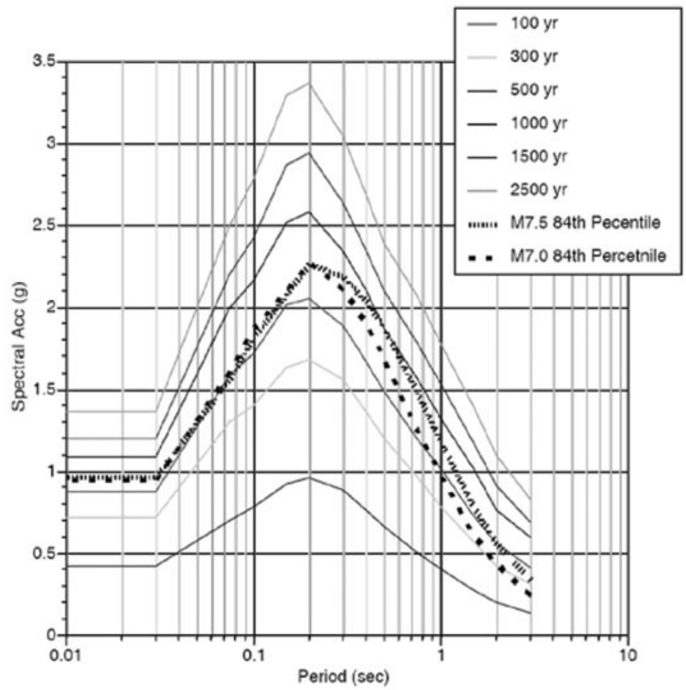
The performance requirements for the SEE are that the fourth bore will be open to emergency vehicle traffic within 72 hours following an SEE. Performance requirements for the FEE are that the fourth bore remains fully operational and experiences minimal, if any, damage.

Seismic hazard analysis. Deterministic seismic hazard analysis (DSHA) and a probabilistic seismic hazard analysis (PSHA) were used to characterize the seismic hazard at the project site (EMI, 2005). While numerous faults have been identified in the Bay Area, the Hayward fault was found to be the controlling fault because of its close proximity to the Caldecott Tunnels. Figure 7 shows uniform risk equal hazard spectra developed from the results of the PSHA and DSHA analyses.

Ground motion characterization and wave scattering analysis. Based on site specific rock acceleration spectra, three sets of time histories were developed for each of the ground motion events (SEE and FEE). Wave scattering analyses using these time histories were performed to

FIG. 7

Uniform risk equal hazard spectra and MCE 84th Percentile Spectra at the Cladecott Fourth Bore.



evaluate the effects of seismic wave propagation and to estimate the ground distortion around the tunnel lining for each time step of the input motion. These displacement time histories were used as input for the pseudo-static time history analysis described as follows.

Tunnel final lining seismic analysis. Ground shaking and the associated ground deformations are the primary seismic design issue for the fourth bore. Three types of lining deformation were evaluated due to ground strains caused by wave propagation: longitudinal axial compression and tension, longitudinal bending and ovaling or racking of the cross section. Two types of analyses were used to assess the behavior of the fourth bore lining due to longitudinal and racking seismic deformations. The first method uses closed-form solutions (Hashash et al., 2001 and Penzien, 1998 & 2000). The second is a state-of-the-art numerical method that uses beam-spring and beam-continuum models to perform pseudo-static time history analyses using the results of the scattering analyses described above. Two types of numerical models were used to calculate lining strains, stresses, and forces: 2-D SAP2000 (CSI, 2005) beam-spring models with nonlinear support springs (gap elements) to model ground behavior; and 2-D beam-continuum models using both FLAC (ITASCA, 2005) and ADINA (ADINA R&D Inc.) with elastic continuum elements to model ground behavior. Both methods were used to calculate strains, stresses, and forces in the fourth bore lining and cut-and-cover structures, and to ensure that the results were within acceptable stress and ductility limits.

Final lining design

Critical cross-sections in each support category were evaluated to determine the ability of the final lining to support the load combinations referenced above. Results of the analyses indicate that a 381 mm (15-in.) final lining with 35 MPa (5,000 psi) concrete can support the ground loads and accommodate the seismic deformations. This final lining thickness was selected for constructability and is controlled by the thrust resulting from the ground loads in the high cover section of the alignment. Two layers of reinforcing will be used for the final lining to meet Caltrans criteria. The seismic demands, although very high, do not control the thickness of the final lining.

Conclusions

Preliminary design of the 15-m-(49-ft-)wide two-lane Caldecott fourth bore included identification of four ground classes that are expected along the alignment. Four corresponding excavation and initial support categories have been developed for NATM construction of the mined tunnel. Support elements include fiber-reinforced shotcrete, lattice girders, fast-setting cement-grouted rock dowels, fiberglass rock dowels, self-drilling and grouted spiles and self-drilling grouted pipe spiles. Shotcrete lining thickness in the four support categories ranges from 200 mm (8 in.) to 300 mm (12 in.).

The final lining will support dead load, ground loads, rock wedge loads, and seismic deformations. The design analysis shows that a 381 mm (15 in.) final lining with 35 MPa (5,000 psi) concrete can support the ground loads and accommodate the seismic deformations. Seismic demands do not control the thickness of the final lining, despite the close proximity of the project to a major active fault and seismic design criteria corresponding to an earthquake with a 1,500-year return period and a peak ground acceleration of 1.2g. ■ (References are available from the authors.)

Acknowledgments

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One accident, three deaths, two friends gone

In late spring 2007, I had a discussion with Galyn "Rip" Rippentrop, chief executive officer and president of Frontier-Kemper Constructors Inc. (FKCI). in Evansville, IN. He said that the company was having an open house and celebration to commemorate the 100th year anniversary of the founding of Kemper Construction Co., a founding partner in FKCI. I was advised that, due to my long working relationship with the company (30 years in 2007), I would be requested to give a speech at the celebration dinner that was to be held on Aug. 10, 2007 in Evansville.

My involvement with FKCI began in 1977 when I was hired as an outside sales representative for the Underground Supports Division of Commercial Shearing Inc. of Youngstown, OH. The company was the leading national supplier of steel support systems to the underground civil and mining industries. The company manufactured steel tunnel supports in five plants across the United States at the time, and supplied numerous products to the mine construction industry. I was responsible for mining and mine construction project sales east of the Mississippi River. Thus, when I started work for Commercial in 1977, one of my first sales trips was to Evansville, IN to meet with FKCI. The company had numerous mine construction contracts in my sales territory at the time.

On my first visit to FKCI in Evansville, I met the "management troika" of Dyke Howell, president/partner, Dan McFadden, executive vice president/partner and Bob Pond, general manager. Because of the high regard FKCI personnel had for the Commercial Shearing people who proceeded me, I was treated in a professional manner and I made every effort to maintain this professional and most appreciated business relationship during the many years.

Frontier-Kemper Constructors Inc's. ownership structure at the time consisted of three people, Dyke Howell, Dan McFadden and Bruce Kemper. Bruce Kemper was the third generation owner of Kemper Construction Co. and was located in Los Angeles, CA. From the first time I met the owners, each treated me with respect and dignity even when it was evident that they were much more knowledgeable about the industry. Each helped me during my career.

As the many mine construction projects flourished during the late 1970s and early 1980s, I got to know the three members of the management troika quite well. I worked closely with Dan McFadden. He was the manager in charge of all field operations so he made the decisions on the type of steel supports to be used on the various projects, such as the Mapco shaft project, Turris coal project, the Consol O'Donnell slope project and many other mine construction projects.

One day during the early 1980s, I was in a meeting with Dan McFadden in the Evansville office. Dyke Howell stuck his head in the door and said, "Klug, you're buying lunch as we want to talk to you." Many things never changed over the years. I never had a first name and I always bought lunch. If someone's wife was not home that evening or if there was a special project meeting, I bought dinner at the Haub Steak House, but this could be an article of its own. The Haub Steak House is a famous local restaurant located in the nearby German community of Haubstadt, IN. At that time, the restaurant did not take credit cards. One gave them a business card and they mailed you a bill for which you sent them a check. A man was expected to meet his moral obligation to pay, how Midwestern.

The purpose of our luncheon meeting with Dyke, Dan and Bob was to discuss the future of Frontier-Kemper Constructors. The mining work for which they had been dependent and built a good business was slowing and there were not sufficient projects on the horizon to sustain the organization they had built. They were evaluating whether to shrink the business to a core group of people or expand the group into other areas, such as civil tunnel construction.

I had recently been part of a planning committee for the Underground Supports Division of Commercial Shearing. Our group had defined that the mining activity that had been so strong during the 1970s and early 1980s was going into a downturn. However, civil tunnel construction opportunities were going

David R. Klug

David R. Klug, member UCA of SME, is president, David R. Klug & Associates Inc., Pittsburgh, PA. He is also vice chair of the UCA of SME, e-mail dklug@drklug.com.

to improve as the U.S. economy was improving and more money would be spent on water, sewer and transportation projects. So I recommended that FKCI expand more heavily into civil tunnel work on a general contractor basis. Dyke said that the management team had similar input from other individuals. FKCI did not retreat. Instead, it advanced into the heavy civil market and the rest is history. I was most honored that they solicited my opinion on this very crucial business decision.

I worked with the management troika on many mining and civil projects until 1995 when Dyke Howell and Dan McFadden sold their shares in the business. Bruce Kemper's interest had been purchased earlier. By 1995, FKCI had become an industry leader in the heavy Civil tunnel market after successfully completing highway tunnels in Colorado and Hawaii and was then building a light rail tunnel in Portland, OR. Dyke Howell retired to a house on the water in Florida and Dan retired to a ranch in Wyoming. Both had become good friends and I would continue to see them on occasion at FKCI and at various FKCI functions after their retirement.

When Dan McFadden retired, the mining division became ruled — a Freudian slip — I mean managed by Del Brock. Del had worked on numerous mining and civil projects for FKCI during his career. He is a dedicated man who expects quality work and products to be executed or delivered in a timely and professional manner. Del is one of those people who likes to drill holes and blow things up. He is the type of person that keeps our industry functioning.

I started my own company, David R. Klug & Associates Inc., in 1998 and continued to work with FKCI on numerous civil and mining projects. When Galyn "Rip" Rippentrop became president, one of his tasks was to have every division manager select and groom his respective replacement. Some division managers had an easier job than Del Brock. This was because the coal mining projects had progressed into the purest form of design/build construction ongoing in North America today, as the mining companies had eliminated their mine/shaft design personnel in cost cutting measures. Del is frequently given a minimal amount of information and is expected to negotiate the project with the mining company, provide constructability oversight to the FKCI Engineering Department, consult on the building of special equipment in the Evansville shop to meet specific project requirements while all the time having to travel by SUV to such ideal travel destinations as Grundy, VA and Hazard, KY, plus keep his wife, Fay, happy at the ranch.

FKCI had one individual who rose to meet the Mining Division challenge. His name was Todd Richardson. Todd started as a worker and progressed up the ranks to Assistant Mining Division Manager. In August of 2005, he was promoted to Mining Division Manager when Del retired from the position. Del stayed on as a consultant to FKCI to "supervise" the development of the new blind hole drilling business unit.

I had worked closely with Todd Richardson on various projects during the past seven years. He demonstrated the same character and drive as Del and was poised to keep FKCI the industry leader in coal mine shaft and slope construction in the eastern and midwestern coal fields. In August 2007, I was working with him on four different mine construction projects. Throughout the years, Todd had become a very good friend.

On Aug. 9, 2007, my son Jonathan, who has now entered my business with me, drove from Pittsburgh to Evansville, IN to attend a lobster cookout and barbeque to be held that evening. This event preceded the events of Aug. 10. The fresh lobsters were coordinated and prepared by the people of HarMac Rebar and Steel of Fryeburg, ME. It was a special event. The lobster cookout and barbeque was attended by invited guests consisting of retired or former FKCI management personnel and invited industry guests. It was nice to renew old friendships with people I had not seen in some years and I introduced them to my son. There was plenty of good food, adult beverages and camaraderie that carried back to the Executive Inn that evening.

It was a distinct pleasure to see Dyke Howell, Dan McFadden and Bruce Kemper again. On Friday, Aug. 10, there was to be an open house of the offices and plant and a tour of the Gibson County coal airshaft in nearby Princeton, IN. A formal dinner was planned for that evening and I was to be a scheduled speaker. I had my speech prepared.

During the course of the Thursday evening festivities, Todd Richardson talked business for a short period of time and we set up a time on Friday afternoon to review some outstanding issues on the River View #1 slope project located in Waverly, KY. Todd said that he was to take Dan McFadden on a private tour of the Gibson County shaft bottom station before the visitors arrived. He was very proud of this project and requested that my son and I accompany them to the special visit down the shaft. We could then return after lunch to his office and have our meeting. I respectfully declined because I needed to meet with Peter Hanke of the estimating department and Neal Wedding of the engineering department. This would give Todd and I sufficient time to review the various project issues when he returned to the Evansville office after the site visit.

On Friday morning, Aug. 10, a young project engineer named Jarred Ashmore joined Dan McFadden and Todd Richardson as each climbed into the 6 ft deep x 8 ft diameter muck bucket that is designed to safely lower them the 545 vertical feet to the shaft bottom. Shortly after they started their descent, the large bucket overturned and all three men fell to their death at approximately 10:30 am on Aug. 10, 2007. Dan McFadden, Todd Richardson and Jarred Ashmore never returned to the Evansville office.

I did not really know the young project engineer, Jarred Ashmore. I met him at the Gibson County shaft project site in the summer of 2007. But we only exchanged pleasantries as I then had a meeting with the project manager regarding the design and supply of the shaft reinforcement. Jarred had graduated from the University of Evansville in 2006 with a degree in civil engineering and was planning a career in underground construction with Frontier-Kemper Constructors Inc. Jarred was a man of substantial character. He knew the risks of the mining and underground industry because his father died in an methane explosion at the Pyro Mining Co. when Jarred was only six years old.

Back at the Evansville office, information started to be dispensed. In a meeting with Peter Hanke, I was advised that there was an accident at the site. In a later meeting with Neal Wedding, we were advised there were three deaths but no names were given. At a lunch in a tent set up in the parking lot for the open house, we were given the names of two of the individuals. Within the next two hours, we were given the third name.

By this time, numerous industry personnel had arrived. The morning tour group was on site at the Gibson County shaft having a safety orientation when the accident occurred. The group promptly returned to the Evansville office. All visitors soon left the FKCI complex and we returned to the Executive Inn hotel where most were staying. When I walked into the lobby of the hotel, I observed many industry friends and colleagues standing there in stunned disbelief. After an exchange of pleasantries we all just stood there doing our obligatory duty to inform the people arriving for the dinner of the tragedy that had occurred.

When such events occur, people rise to the occasion and do what is right and proper. By mid-afternoon, an announcement was made by FKCI management that there would be a memorial service for the three individuals at the hotel on Friday evening. People milled in the lobby or returned to their rooms. I went to my room as I needed to do some work but I could not. I thought I could take a short nap but I could not. I later put on my coat and tie and went to the memorial service. It was well done and appropriate. The people who spoke were very eloquent under the circumstances of the day.

After the ceremony, I went to the Haub Steak House in Haubstadt with friends Josef Arnold, chief executive officer of Beton-und-Monierbau, a sister company to FKCI from Austria; Bill Edgerton, president of Jacobs Associate; John Farley, executive vice president of Ahern & Associates; Paul Schmall, vice president with Moretrench America Inc. and my son Jonathan.

It was comforting to be with good friends in familiar surroundings at such times. We did what most men in such circumstances should do. We shared some good food, good wine and discussed other more worldly matters. I continued the tradition and Klug bought dinner. We returned to the hotel and we all departed Evansville on Saturday morning.

We went back to our families, our homes and our careers. Unfortunately, the three victims were not able to do so. They will be remembered as fine individuals that were dedicated to our industry. One of the best memorials to the three individuals would be to define the cause of the accident and make sure that this type of accident does not occur in the future.

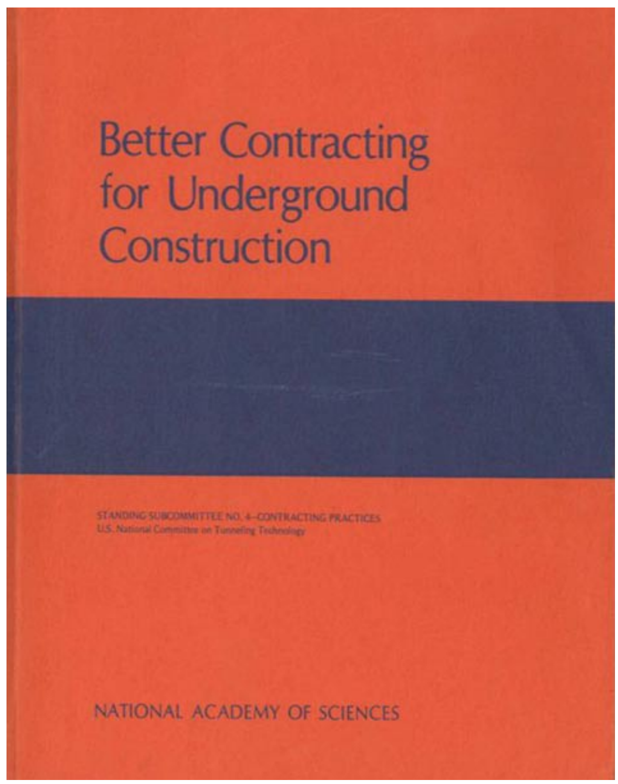
The underground heavy civil and mine construction industry is a very special industry. For most of us, the job is our life as we frequently work extended hours, forego our family, our spare time and other normal activities to advance the project. Some would say we are not normal. This could be argued and I have some good examples. But the major reason is that we have a passion for the industry. The three men who died all had a passion for the industry. Dan had a passion to observe and learn even after he had retired. Todd was driven to excel in his new management position and demonstrated a passion to show others the successful work completed by the people in the mining division. Jarred had a passion to learn and was enthusiastic about his work and the future. All were special men in a special industry. They gave their lives to the industry and they will be missed.

One accident, three deaths, two friends gone but the industry will continue. ■

Note: Dan McFadden, Dyke Howell and Bob Pond were school mates at the Colorado School of Mines. A memorial fund has been created in the name of Daniel McFadden at the Colorado School of Mines. Readers wishing to make a contribution should contact the school or FKCI's human resources department, phone 812-426-2741.

Better Contracting for Underground Construction scheduled for release in June

Note: This is an excerpt from the Preface of the new *Better Contracting for Underground Construction*, currently scheduled to be available in June 2008. It is currently being reviewed by the UCA of SME's Better Contracting Practices Committee.



Over the past 30 years a number of factors in combination have contributed to a marked increase in the use of underground space. One obvious factor is an increase in transportation needs around the globe. We have also seen an increase in the number of people living in dense urban environments and desert climates that make the use of underground space particularly practical. Along with an increase in the use of using underground space have come advances that have made it possible to build underground in ways that would not have been feasible even 10 or 15 years ago. Engineering advances in areas such as rock mechanics, concrete technology, geotechnical investigation, and numerical analysis have been notable, but the most significant change in underground construction may be from advances in construction technology, such as the development of tunnel boring machines, machinery for drilling large-diameter shafts, new methods of excavation support, new waterproofing materials, and advanced guidance systems.

Rather than keeping pace with these challenges and further promoting the health of our industry, our contracting practices have stagnated. Standard contract provisions have grown ever more restrictive, increasing economic and legislative pressures on all parties. The pressures put most of our national tunneling contractors out of business – either because of project losses or because their anticipated profits didn't justify the risks – and the shortage of qualified firms has owners paying higher costs in the bid prices. In addition to being restrictive, standard contracting practices often allocate risk in ways that stifle the development of innovative new technologies.

To correct the course of our industry, we need a set of contracting practices that more fairly allocate risk and reward. More than 30 years ago, our predecessors in the heavy-civil construction industry identified a similar need when they recognized that the system for procuring underground projects in this county was in need of major overhaul. As examples of the anemic condition of the industry, they pointed to owners' increasingly harsh, one-sided contract provisions, and the contracting community's reluctant acceptance of these provisions. They noted how eager contractors bid for projects based on unrealistic, overly optimistic assumptions. The result was a system characterized by a wide gulf between owner and contractor expectations, with neither party having incentive to work with the other to narrow the gulf. Both sides considered it a foregone conclusion that any significant disputes would be resolved by litigation.

In response, the U.S. National Committee on Tunneling Technology, acting through the National Academy of Sciences, published Better Contracting for Underground Construction. The group conducted several years of studies, an industry survey, and subsequent workshop-conference, and then, in 1974, published a 143-page document setting forth recommendations for improved contracting. The recommendations were in 17 key areas.

The 1974 report was originally available from NTIS in Springfield, VA, but is currently out of print, although copies are available for use at some technical libraries.

The objective of the 1974 report was to develop the practices, procedures and tools that would "foster a cooperative atmosphere in which there will be incentive for both the owner and the contractor to stimulate the use of advanced technologies and innovative construction techniques" and improve the state of the practice. Many beneficial new contracting approaches were developed from the original report. Nonetheless, some of the issues identified in the original report are still problems, and new problems have arisen.

Recognizing that 30 years of experience is no insignificant block of knowledge, and knowing that there is still room for improvement in contracting practices, the American Underground Construction Association undertook in 2004 to prepare an update to the original manual. In early 2005, the Underground Construction Association of the Society for Mining and Metallurgical Engineers (UCA of SME) assumed the sponsorship of the effort, and this document is the result.

Drawing upon the experience and talent of 28 industry veterans, and a number of industry reviewers, the new edition offers a comprehensive review of the key aspects of underground construction pertaining to contracting practices. The semi-chronological approach begins with a discussion of Project Planning, and how decisions made therein can affect subsequent contract provisions. The chapter on Relationships between the parties then sets the stage for many of the following chapters, which are organized around disciplines commonly involved in underground projects: Subsurface Conditions, Risk Analysis, Insurance, Design Development, Engineer's Estimates, and Schedules. Following these are three chapters that address the preparation of contract documents, particularly focused on payment mechanisms: Pricing Provisions, Contracts, and Changes. Then there is a chapter that discusses various methods of Dispute Resolution. The last chapter summarizes all of the recommendations set forth in the body of the text, and the appendices provide supplemental material that is referenced in individual chapters.

This new edition of Better Contracting for Underground Construction is intended to provide owner agencies and their engineers with a set of best contracting practices, to be considered during the development of contract documents and the administration of construction contracts. Contractors will benefit from the manual by gaining a better understanding of the rationale behind contract provisions. In each chapter, the authors have endeavored to provide relevant historical background and to document the advantages and disadvantages of current approaches. The recommendations contained herein reflect the contributors' years of industry experience and industry consensus on best practices (where consensus exists).

Although we recognize that in many organizations change is not easy, we know that an awareness of how underground contracting must differ can enable all parties to adopt changes that will make projects more cost-effective for owners and more profitable for contractors, while contributing to the growth and advancement of the industry. Accordingly, it is our hope that this manual continues the tradition of promoting fair and practical contracting that was embodied in the original report. ■

Robbins TBM resets record

A Robbins 7.2-m- (23.6-ft-) diameter tunnel boring maching (TBM) operating on the remote Kárahnjúkar hydroelectric project in Iceland has entered new territory. The machine, operated by contractor Impregilo SpA, beat its own world record for the second time when it bored 115.7 m (380 ft) in 24 hours on Aug. 25, 2007. It then set another record in its size class of 7 to 8 m (23 to 26 ft) by boring 428.8 m (1,400 ft) in one week.

The previous record was also held by a Robbins TBM that excavated the TARP project in Chicago, IL.

These feats are all the more remarkable considering the machine is on its second tunnel, having bored more than 15 km (9 miles) so far in very hard rock up to 300 MPa (43,500 psi) UCS. The machine previously bored an 11.1-km- (6.9-mile-) long section of the main headrace tunnel at Kárahnjúkar, breaking through in September 2006.

The machine's success highlights the longevity of all three TBMs used at Kárahnjúkar. Another machine (TBM #3), has successfully bored nearly 20 km (12 miles) on its two previous projects and will now be used on a third 15.3 -km- (9.5-mile) long tunnel in China. All three Kárahnjúkar machines are high performance TBMs, employing high capacity main bearings and 482 mm (19 in.) back-loading cutters to increase boring efficiency in hard rock over long distances.

"The Kárahnjúkar machines are a great example of what Robbins hard rock TBMs can accomplish if they are properly maintained. The TBMs have performed extremely well despite very hard rock and heavy water inflows encountered in the early stages of the project," said Joe Roby, vice president of the Robbins Company. ■

Liebherr unviels new tunnel excavator

The redesigned Liebherr tunnel excavator, the R 944 C Tunnel Litronic, will replace the R 934 B Tunnel excavator. Liebherr has provided specialist excavators for tunnel building for more than 20 years in the size category that the R 934 will fall. At around 41 t (45 st), the R 944 C Tunnel Litronic is much heavier than its predecessor, with an output of 190 kW (258 hp). It also offers 31 percent more engine power. However, the new excavator's dimensions have been kept compact to suit its purpose.

The R 944 C Tunnel Litronic is powered by a Liebherr six-cylinder, in-line engine that produces an output of 190 kW (258 hp) at a nominal speed of 1,800 rpm.

For protection, the tunnel cab on the tunnel excavator is equipped with FOPS and FGPS structures as standard. The windows on the right and to the rear are polycarbonate and, therefore, characterized by their high impact resistance and good visual qualities. The R 944 C Tunnel Litronic includes a slewing arm with 2 x 45° slewing areas and a 4.5-m (15-ft) bucket stick. The optional mechanical quick-change system has been fitted with reinforced locking and wear protection at the rear.

www.liebherr.com

Liebherr 944 C Tunnel Litronic.

Pipe Ranger provides video inspection

The Compact Pipe Ranger (CPR) from CUES is a lightweight, compact and rugged steerable closed circuit television (CCTV) camera transporter that is used to inspect sanitary and storm sewers. It is made to traverse long distances and tough pipe conditions, and to facilitate ease of handling during insertion and retrieval.

The CPR is designed to operate on a minimum of 305 m (1,000 ft) of multi-conductor television cable to inspect 152 mm (6 in.) relined pipe through 762-mm-(30-in.-) diameter pipe. Its two-speed transmission doubles the torque of the unit to produce maximum pulling power in the larger diameter pipes.

The CPR includes full-proportional steering to traverse meandering pipe and 45° and 90° turns. When assembled with the CUES OZIII zoom pan and tilt camera, the compact length enables the unit to negotiate difficult entry conditions and standard sweeps.

The pulling power of the CPR, combined with the optics and directional lighting of the compact OZ III zoom pan and tilt camera (with the ability to rotate in a 102-mm or 4-in. circle), creates video inspection quality that is unsurpassed in the industry. CPR operates most efficiently with the new CUES lightweight/high strength, multi-conductor video cable.

Multiple wheel sets are available to maximize bottom clearance, traction and optimum camera position. Ease of operation is accomplished with one joystick control for all transporter and camera movements.

www.cuesinc.com

Envirolink adds level of safety to tunneling operations

Envirolink from Trolex is a versatile environmental monitoring system that brings new levels of safety to tunneling operations.

Flexibility is the key to the system. This allows any combination of sensors from a single channel to eight channels.

The system includes alpha numeric channel identification, continuous display of all inputs, signal bargraph indication and RS232/485 communications.

Trolex tunneling products offer complete monitoring, data acquisition and data transmission systems for use at the construction and completion stages. SCADA, installation and commissioning services are also available.

Other features of the Envirolink system are data logging, assignable alarm relays, alarm accept and reset facility, battery backup option and 85 - 264V ac supply.

The system can be linked to leaky feeder systems, incorporating radio/telephone communications. And it can be supplied as EEx ia I certified for hazardous areas. ■

www.trolex.com

January 2008

29, 2008 George A. Fox Conference, City University of New York, Graduate Center. Contact: SME Meetings Department, 8307 Shaffer Parkway, Littleton, CO 80127, phone 303-973-9550, fax 303-973-3845, e-mail sme@smenet.org, Web site www.smenet.org.

29-31, Underground Construction Technology Conference and Exhibition, Cobb Galleria Centre, Atlanta, GA. Contact: Karen Francis, P.O. Box 941669, Houston, TX 77094-8669, phone 281-558-6930, ext. 222, fax 281-558-7029, e-mail kfrancis@oildom.com, Web site www.uctonline.com.

February 2008

- **4-7, 15th Annual Microtunneling Short Course,** Colorado School of Mines, Golden, CO. Contact: Office of Special Programs and Continuing Education, Colorado School of Mines, phone 303-273-3321, fax 303-273-3314, e-mail space@mines.edu, Web site www. mines.edu/outreach/cont_ed/econeval.shtml.

- **20-22, Viatec 2008,** Innsbruck Exhibition Centre, Bolzano, Italy. Contact: Maria Kostner, phone 43-0-512-59-36-111, fax 43-0-512-59-36-7, e-mail m.kostner@come-innsbruck.at, Web site www.viatec.org.

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

March 2008

- **12-14, 3rd International Symposium on Tunnel Safety and Security (ISTSS),** Foresta Hotel, Stockholm, Sweden. Contact: Margaret Simonson, SP Technical Research Institute of Sweden, Box 857, SE-501 15 Boras, phone 46-10-516-52-19, e-mail info@sp.se or marga-ret.simonson@sp.se, Web site www. sp.se/fire/istss2008.

- **20-22, International Symposium on Underground Freight Transportation (ISUFT 2008),** The University of Texas at Arlington, TX. Contact: Mohammad Najafi, University of Texas at Arlington, Box 19308, 438 Nedderman Hall, Arlington, TX 76019-0308, phone 817-272-0507, fax 817-272-2630, e-mail najafi@uta.edu, Web site www. isuft.com.

April 2008

- **10-12, The Sixth International Symposium Geotechnical Aspects of Underground Construction in Soft Ground,** Tongji University, Shanghai, China. Contact: Xiongyao Xie, Tongji University 1239 Siping Rd., Shanghai 200092, China, phone 0086-21-65982986, fax 0086-21-65982986, e-mail secretary@tc28-shanghai.org, Web site www.tc28-shanghai.org.

- **27- May 2, 2008 No-Dig Show,** Gaylord Texan Resort, Dallas, TX. Contact: Benjamin Media, P.O. Box 190, Peninsula, OH 44264, phone 330-467-7588, fax 330-468-2289, e-mail mmagyar@benjaminmedia.com, Web site www.nodigshow.com. ■

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BUSINESS OFFICE

SME - 8307 Shaffer Parkway
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Advertising: x243 • Direct: 303-948-4243
Fax: 303-973-3845
www.smenet.org

EDITOR
Steve Kral: kral@smenet.org

PRESS RELEASES
Steve Kral: kral@smenet.org

ASSOCIATE EDITOR
Bill Gleason
gleason@smenet.org

ADVERTISING AND PRODUCTION/ MEDIA MANAGER
Johanna McGinnis:mcginnis@smenet.org

ADVERTISING SALES OFFICES

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GUNTER SCHNEIDER • SCANDIN. / EUROPE
49 2131-511801 • 49 2131-4038973 • info@gsm-international.eu

JOHANNA MCGINNIS
ASIA, RUSSIA, UKRAINE, AFRICA, MIDDLE EAST, LATIN AMERICA, AUSTRALIA
303-948-4243 • Fax: 303-973-3845 • mcginnis@smenet.org

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