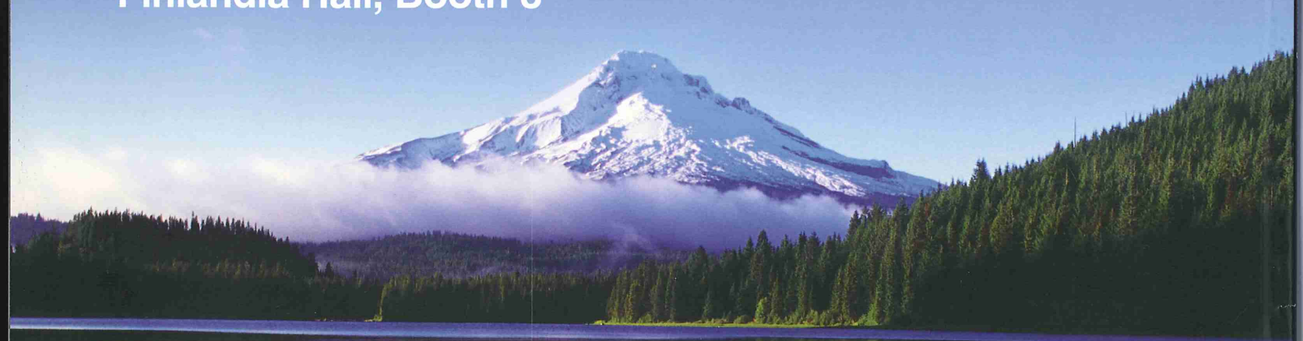
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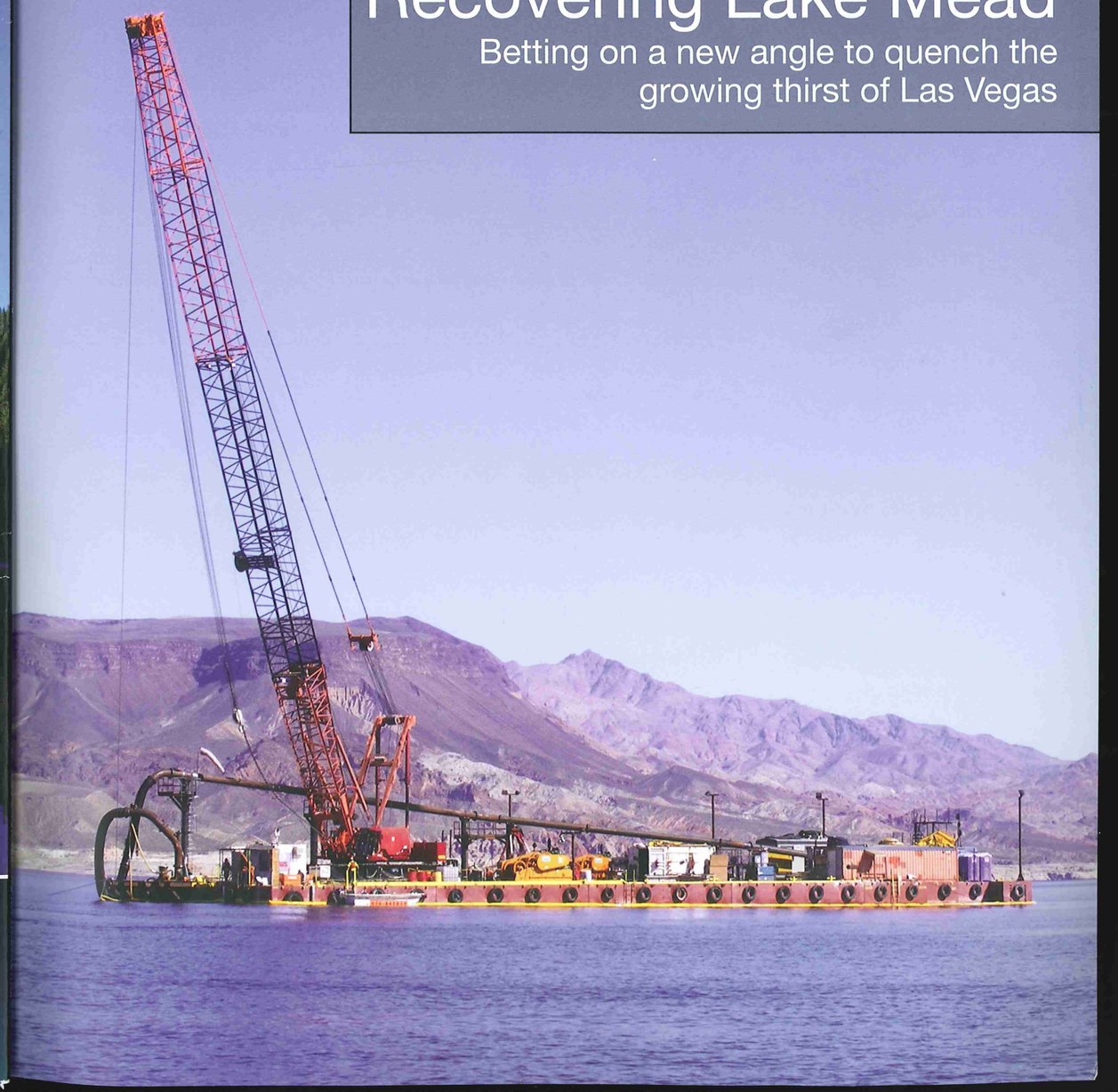
Focus: South East Asia
Diving in to booming Asia with a look at the region's longest drill and blast rail tunnel

Technical: Excavation methods
The first of a two-part exploration of the new parameters and choices

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Recovering Lake Mead

Betting on a new angle to quench the growing thirst of Las Vegas





SOCHI: FIRST OLYMPIC SUCCESS.

The infrastructure necessary for the 2014 Olympic Winter Games is now rapidly being built between the Caucasian Black Sea coast and the Alpika-Servis ski resort. The tight time schedule poses great technical and operational challenges for the commissioned companies and the project coordination. With the EPB Shield (Ø 10.63m) for railway tunnel No. 5 and the Single Shield TBM (Ø 13.21m) for road tunnel No. 3, Herrenknecht delivered the full range solution which allows the customer high production performances using tightly coordinated construction site solutions. The customized conveyor systems from H+E Logistik ensure a rapid transport of the excavated material and the world's largest lining segment production plant from Herrenknecht Formwork Technology secures the just-in-time delivery of lining segments. However, not only portal cranes, multi-service vehicles, cooling towers and concrete-mixing plants, but also the service personnel were provided by Herrenknecht.

After more than 2.8 challenging tunnel kilometers, breakthrough by the Herrenknecht TBM S-517 Single Shield could already be celebrated on February 9. Currently, the tunnel constructors in road tunnel No. 3 are managing the challenges of the construction ground with the S-534 Single Shield TBM. This means that the scheduled taking-into-operation of the Olympic infrastructure is on a winning course.

SOCHI | RUSSIA

PROJECT DATA	CONTRACTOR
S-517, EPB Shield Diameter: 10.630mm Installed power: 2.800kW Tunnel length: 2.814m Geology: sandstone, marl	OAO Bamtonnelstroy
S-534, Single Shield TBM Diameter: 13.210mm Installed power: 3.520kW Tunnel length: 3.100m Geology: limestone	OAO Usk Most





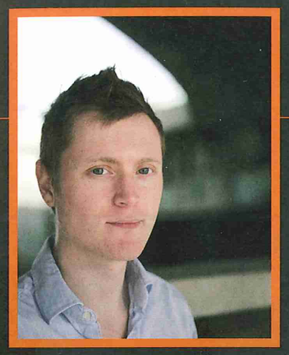


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Democracy's death grip

There is much debate in the UK surrounding this month's referendum on the voting system used to elect parliament. The referendum is to decide between keeping the existing 'first-past-the-post' or replace it with the 'alternative vote' electoral system. Not least among the issues being debated is the question: should there be a referendum? In other words: should the general public be asked to form a decision on an issue many do not fully understand.

The opinion of this editor is no, they should not.

Democracy is a commodity that should be limited, in both the issues it is applied to and the people allowed to participate.

When democracy is applied to heavy engineering projects it is disruptive and costly with few, if any, obvious benefits. Projects in the Land of the Free, the US, are frequently under fire from pressure groups and campaigners.

Making headlines on a regular basis is Seattle's Alaskan Way Viaduct Replacement Scheme, which earlier this year narrowly avoided a public vote after activists failed to garner enough signatures to table the referendum. The argument is set to continue in the courts, with legal grounds still under debate. The contracts to design and build the tunnel have already been let; a cancellation of the project at this stage would be a massive waste of tax payers' money.

Elsewhere, in India, the Kolkata metro has stalled over land acquisition issues. The local government has been reluctant to evict residents from sites needed for metro construction for fear of losing votes – Kolkata is facing local elections this month.

And back in the UK it took no time local interest groups and objectors to launch their No HS2 (High Speed Two) campaign, claiming the project threatens to disrupt the peace of the Chiltern countryside.

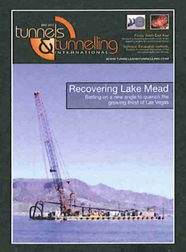
But that is not to say there should not be discussions around the scope of a project. When developing its Land Transport Masterplan, which includes the doubling of its underground metro network, the Singapore government charged two departments with the task: the Land Transport Authority (LTA) and the Urban Development Authority (UDA).

Senior technical executives from the two departments hammered out the tunnel alignments and station locations to fit with plans for other infrastructure and utility developments and with the growth needs of the city.

As a result Singapore is on target to construct 140km by 2020, just 12 years from the publication of the Masterplan and 14 years from the start of discussions.

Short of giving over the entire democratic process to a benevolent dictator, more needs to be done to eradicate the damaging effects of NIMBYism and minority pressure groups.

Jon Young



On the cover:

T&TI visits the Lake Mead Intake Three tunnel as the contractor attempts a new alignment

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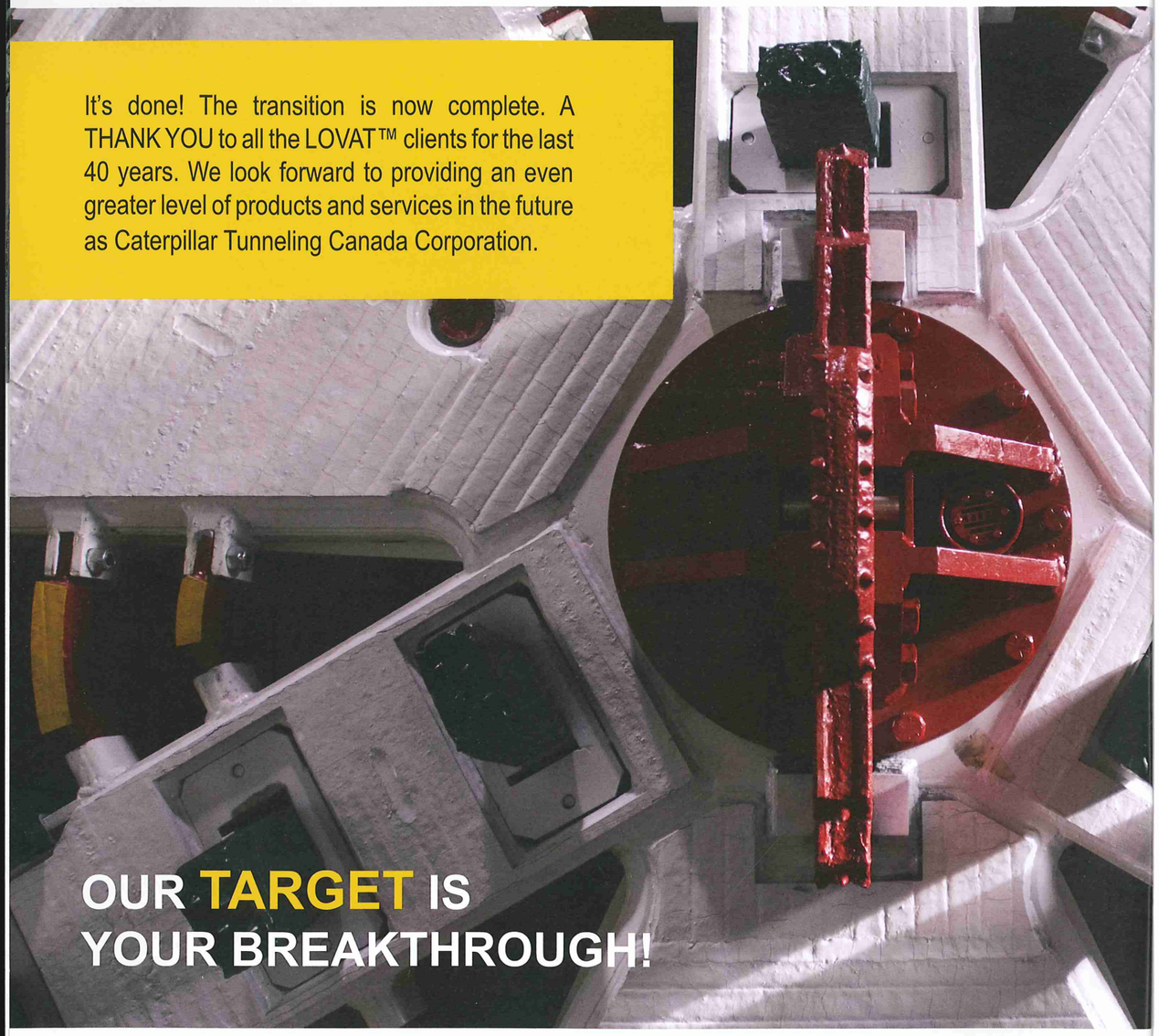
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Final Crossrail tunnel contracts

GREAT BRITAIN

Crossrail last month awarded the final tunnelling contracts for the central London rail line. Combined, the contracts were worth some GBP 225M (USD 367.0M).

C310 – 'Thames Tunnel' between Plumstead and North Woolwich (Drive H) was awarded to a joint venture of Hochtief Construction and J Murphy & Sons. The contract is worth GBP 190M (USD 310.0M). This contract included the tunnel portals for these drives, with TBM launch in late 2012.

C315 – Connaught Tunnel refurbishment was awarded to Vinci Construction UK and was worth GBP 35M (USD 57.1M).

In addition Crossrail also awarded a contract to Morgan Sindall for construction of the Pudding Mill Lane tunnel portal, valued at GBP 50M (USD 81.5M).

Construction will commence mid-2011. Two TBMs on 'Drive Z' from Stepney Green to Pudding Mill Lane will be recovered from this portal in the third quarter of 2014. It was one of five new portals to be constructed.

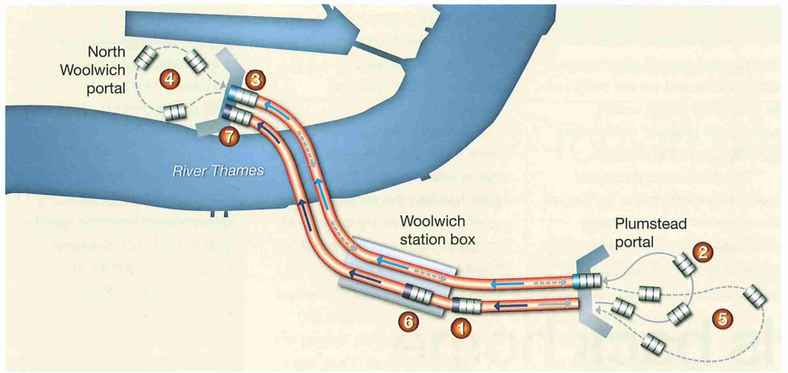
The first TBM on the Thames Tunnel will be launched from the Plumstead portal in late 2012 following construction of the portal starting later this year.

The new awards completed the contracts required to construct a total of 42km of bored tunnels (21km twin-bore), including portals, at depths of up to 40m.

Crossrail also confirmed that selected TBM manufacturers would be announced in late April, to be purchased by the main running tunnel contractors. There will be at least seven TBMs used for the ten drives, according to Crossrail.

The contract for construction of a portal at Victoria Dock, east London, will be awarded this year.

Below: **Tunnelling sequence for the Thames Tunnel (see box, right)**



Thames Tunnel

The plan for C310, the Thames Tunnel, is to use one back-up system and two cutterheads:

1. The TBM on the westbound drive will halt here just before the Woolwich station box. The cutterhead will be detached and the back-up withdrawn to the Plumstead portal;
2. The back-up will be turned and relaunched with a new cutterhead for the second (eastbound) drive;
3. On the north bank the cutterhead will be recovered with the back-up;
4. The back-up will be turned and taken back through the bore drive;
5. The back-up will be again turned around at Plumstead, taken into the first bore, and reconnected to the cutterhead previously left;
6. By this time the Woolwich Station box will be completed, so the westbound drive will continue;
7. The westbound tunnel will be completed on arrival of the TBM at North Woolwich.

Toronto transit plan backs subways

USA

Toronto mayor Rob Ford and Premier of Ontario Dalton McGuinty announced on 31 March a revised, CAD 12.4bn (USD 12.9bn) transit plan for the city of Toronto that favoured underground solutions over the previously planned surface options.

Ontario, through Metrolinx, will be responsible for building the Eglinton-Scarborough Crosstown LRT, a single line running 25km. The LRT line will have up to 26 station stops and will operate largely below ground along Eglinton and along the existing Scarborough Rapid Transit right-of-way.

The previous plan called for a tunnel only between Keele Street and Laird Drive, of around 10km. The province would contribute CAD 8.4bn (USD 8.7bn) to the revised plan.

The city of Toronto will rely on private sector financing to fund the remaining CAD 4bn (USD 4.2bn) Sheppard Subway extension.

Under the new plan, Toronto would extend the Sheppard Subway to Downsview station in the west and Scarborough City Centre in the east, incorporating the project into the TTC subway system. The Sheppard Subway extension will be 13km in length and have nine new stations.

"This plan means that we can move forward with our top regional priority, the Eglinton-Scarborough Crosstown LRT," said Kathleen Wynne, minister of transportation. Wynne added, "It will be built as a continuous line that gives riders a new east-west link across Toronto and connects them to the Yonge-University-Spadina subway."

Ford, elected in autumn 2010, ran on a platform to build more subways. He secured 47 per cent of the vote.

Blast kills four

CHINA

An explosion in a Chinese expressway tunnel that killed four last month was caused by a collision between two oil tankers, reported state-run news agency Xinhua.

Damage to the tunnel has not yet been assessed. Rescue work was hampered by high temperatures.

The tunnel is in northwest China on the Lanzhou City to Linxia Hua region link. The expressway remained closed to traffic last month.

Three vehicles were 'mangled'.

Sinkhole spotted in Seattle

USA

A sinkhole roughly 30ft (9m) wide and at least 15ft (4.5m) deep has been found near the alignment of the Brightwater tunnel in Bothell near Seattle, Washington. It was not clear how long the hole had existed.

"It's so close to the Brightwater alignment that it's pretty reasonable to assume that it's related to Brightwater," said a spokesperson from King County's Wastewater Treatment Division.

The 13-mile (21km) conveyance tunnel was part of the county's project to build a new regional wastewater treatment plant called Brightwater.

Originally a joint venture of Vinci/Parsons/Frontier-Kemper had been working on the tunnel with Herrenknecht TBMs, which were both damaged, and operations shut down in 2009. One machine was repaired and completed the excavation from Kenmore to Bothell.

Two years ago, a sinkhole with similar dimensions formed under a Kenmore resident's driveway.

A Jay Dee/Coluccio JV replaced the original contractor for the remaining 1.9-mile (3.1km) segment using a Lovat TBM.

King County is waiting on a permit to fill the sinkhole.

Mott MacDonald joins Jaipur metro project

INDIA

Mott MacDonald announced this month that it had been made the technical and general consultant for the Jaipur metro project in India. The INR 100bn (USD 2.2bn) project will run for 35km, divided between two corridors: north-south and east-west.

Mott MacDonald will prepare technical documents and review existing work during the bid process. Completion of the project has been scheduled for mid-2013.

"The city of Jaipur is one of India's most sought after tourist destinations and we are delighted to play a key role in such a prestigious project," said project director Gaurav Srivastava.

"This project continues our association with metro development in India, having previously been involved in metro projects in Bangalore, Chennai, Delhi and Kolkata. This project will be quite challenging as we aim to provide innovative solutions to the interchange of the two corridors between underground and elevated stations."

The metro was proposed to relieve traffic and make the city more environmentally friendly. Jaipur has had the second fastest growth rate of any city in India, its population has been projected to hit eight million by 2031.

Pub crawls back home

NEW ZEALAND

The Birdcage Tavern was last week returned to its original site after being moved in 2010 to accommodate the construction of the new Victoria Park motorway tunnel in Auckland, New Zealand. The 600-tonne hotel was shifted 44m by a series of hydraulic jacks.

The 450m long Victoria Park Tunnel Project is one of the seven roads of national significance. Construction of the tunnel will eliminate the last serious traffic bottleneck on the central motorway junction between the Auckland Harbour Bridge and the Newmarket Viaduct.

The tunnel will take three northbound traffic lanes and two of the three tunnel lanes should be ready for use early, in November.



Above: The Birdcage was moved 44m to accommodate tunnel works

News in brief

Second breakthrough at Song Giang 2
Last month Cavico Hydropower broke through a second, 2.44m diameter tunnel to connect the water intake gate with an adit sub-tunnel on the Vietnamese hydropower project.

Koralm tunnel gets underway in Austria
Government officials and provincial governors attended the groundbreaking ceremony for a 20km-long section of the Koralm tunnel.

Explosives conference
The European Federation of Explosives Engineers (EFFE) announced its sixth world conference last month, to be held at the Corinthia Hotel, Lisbon, Portugal on 18 Sept.

Soil testing begins on Chennai metro project
Government-ordained special purpose vehicle, Chennai Metro Rail began the tests to check for soil strength and erosion capacity.

Chinese workers rescued
All 19 workers trapped in a collapsed tunnel in Yunnan Province were rescued after a 28-hour ordeal. Early reports on the disaster highlighted unstable geology.

Aktor's Albanian win
Ellaktor's subsidiary Aktor won the tender for the construction of the tunnel part of the Albania's new Tirana-Elbasan highway. The project was a government priority.

Segment expansion
CBE Group announced two new major contracts for the supply of segment moulds and precast facilities in China. Some 12 sets of moulds will be delivered to the subway construction site in Fuzhou.

Murphy in box-jack pilot drives

GREAT BRITAIN

J Murphy & Sons last month completed two pilot tunnels for a sub-highway box-jack project in Kent, England. The project used precast concrete lining segments from new supplier F P McCann.

The work was part of Phase Two of Kent County Council's A-road improvement scheme that caters for over 20,000 vehicles a day near Kent Airport, and is due for completion in 2012.

The scheme includes the need for a 125m-long underpass beneath Foads Hill and a railway at Cliffsend. In an innovative design this required two parallel pilot tunnels within which the necessary rails for underpass box-jacking would be laid. Murphy used its TBM, named 'Doris' to make the drives through chalk either side of the drive line for the concrete box underpass to be jacked into and through the hill.

McCann supplied 268 concrete segment lining rings, each of 3.05m i.d. and 1.0m wide. These were delivered from Cadeby over a six week period.

Murphy's tunnel construction manager, Lee Aspden said, "We were extremely pleased with both the service F P McCann provided and the finished quality of the segments.

"Operating in some extreme weather conditions towards the end of the second drive was challenging for us the, contractor and our suppliers."



Above: Murphy engineers following breakthrough

MWAA revisions

USA

The Metropolitan Washington Airports Authority (MWAA) board of directors last month gave final approval to the underground location for the Metrorail station at Washington Dulles International Airport.

The new plan called for an underground station rather than an aerial alternative, but reduced tunnel depth and length from the original design, saving up to USD 330M, said MWAA.

Cost reductions would come from building the station using cut and cover excavation rather than tunnelling and moving an electric substation above ground.

The USD 3.83bn phase two of the Metrorail line would run through the Dulles Corridor from Wiehle Avenue to Route 772 in Loudoun County, with six stations and a tunnel and underground station at Dulles Airport.

This estimate was shared with the project partners in September of last year. The MWAA then directed staff to conduct further engineering studies to consider alternative alignments and station locations for the airport station to reduce the overall cost of phase two.

Preliminary engineering and preparation of phase two's design-build solicitation was scheduled to be completed in 2011.

The USD 2.7bn phase one of the Dulles Metrorail Project was originally scheduled to be completed in 2013.

News in brief

Alaskan Way contract
Hatch Mott MacDonald was awarded the USD 11M contract for construction management services.

Airport Link to make loss
Leighton Holdings wrote off AUD 430M (USD 451.8M) before tax on the Brisbane Airport Link. The project was originally expected to generate AUD 407M (USD 427.64M) in profit.

Toulon breakthrough

FRANCE

Miners in the Bouygues Construction-Colas-Screg-Soletance Bachy contracting joint venture equipped with a long-armed hydraulic breaker broke through in the second Toulon Tunnel in France this month, completing a total length of 1,818m. Permanent lining work then began, together with work on retaining walls and tunnel partition structure.

The tunnel was designed to relieve congestion on the busy east-west coastal highway, which was already served by one tunnel bore constructed in 2002 under the city. The road links Marseille with Nice. The project owner was the regional highways authority (Provence Alpes Cote d'Azur - PACA) with project management by Setec TPI and Terrasol, and technical consultancy from the Centre d'Etudes des Tunnels CETE Mediterranee.

Tunnelling began on 10 September 2007 and was due to complete at the end of last year, but ground conditions requiring stabilisation made progress difficult. The tunnelling benefitted from intermediate 'attack' points from shafts. Work continued on a 24-hour basis for six days a week, with most surface activities under an acoustic canopy to minimise disturbance to residents.

The construction cost was recently reported as EUR 292M (USD 411M). In addition to the mined tunnel there were cut-and-cover stretches of 210m length at the west end and 200m to the east. The whole tunnel, including other drives, measured 2.9km.

Excavation featured an unusual gantry rig known as the GTA. One was used at each of the two main faces. Designed in Germany, it has been in use since April 2008. It was equipped with two access baskets and two drills on articulated arms. It was fully automated under remote control by surveyors to ensure the accuracy of movement and to adapt to the geology encountered. The machine was suspended from two guide rails in the tunnel crown and was used for all face work except the excavation itself.

Second drive begins for Second Avenue Subway

USA

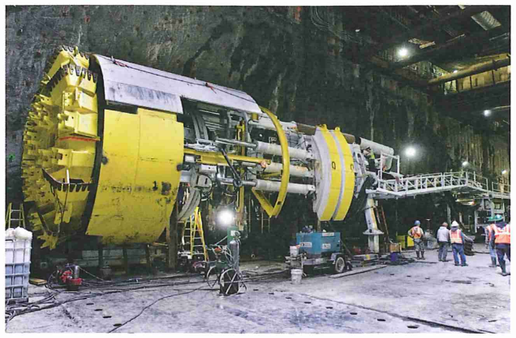
The Metropolitan Transportation Authority (MTA) last month announced that excavation had begun on the second tunnel for New York's Second Avenue Subway project.

Following completion of the 7,162ft (2.18km) initial eastern drive, the TBM was dismantled and returned to the launch chamber at 92nd Street to begin the second, 7,800ft (2.38km) western bore (see feature, p26).

The first 200ft (60.96m) of the drive will be through frozen ground. The alignment will curve sharply to the west into the existing 63rd Street Station with completion of the metro line due in December 2016.

"Phase One of the Second Avenue Subway will serve more than 200,000 people per day, reducing overcrowding on the Lexington Avenue Line and restoring a transit link to a neighbourhood that lost the Second Avenue Elevated in 1940," said a spokesman for the MTA.

"When Phase One is complete, it will decrease crowding on the adjacent Lexington Avenue Line by as much as 13 per cent, or 23,500 fewer riders on an average weekday. It will also reduce travel times by 10 minutes or more for those on the far east side or those travelling from the east side to west midtown."



Above: Excavation on the second tunnel began last month

Earthquake delays TBM

USA

Delivery of the Hitachi Zosen TBM for the five-mile (8km) Bay Tunnel in San Francisco was delayed by a month following the earthquake in Japan.

The contractor ordered an EPBM for the 15ft (4.57m) tunnel that will be excavated below the floor of the Bay (see feature, p19).

"While the TBM passed inspection, it is now awaiting container space as the aftermath of the earthquake has affected Japan's shipping business. The team now expects the TBM to arrive in late May after two weeks of travelling and approximately another two weeks in customs," said a spokesman for the San Francisco Public Utilities Commission. The TBM should launch in August.

Waller Creek tunnel project breaks ground in Texas

USA

Construction work last month started on the Waller Creek tunnel project, a storm water bypass tunnel located in Waterloo Park, Austin, Texas.

The plan for the storm water bypass tunnel includes an inlet structure in Waterloo Park and an outlet structure at Lady Bird Lake near Waller Beach and the Four Seasons Hotel.

The tunnel will measure a mile long and will vary between 22 and 26 feet (6.71 to 7.93m) in diameter. The project will be executed with an investment capital of USD 144M.

The project was expected to reduce the size of the 100-year floodplain of the lower Waller Creek watershed by an estimated 28 acres and allow denser development and redevelopment in a very desirable area of downtown Austin.

Initially, construction crews will excavate a 70-foot (21.34m) deep shaft straight down into the creek between Fourth and Fifth streets in downtown Austin, then tunnel towards Lady Bird Lake and Waterloo Park.

The project should be completed by 2014. The tunnel was expected to eliminate the threat of floods along the creek. It was hoped it would pave the way for future development.

News in brief

Warsaw wastewater
Some 16 pipejacked drives were completed using 3m diameter Herrenknecht hydroshields. Soil comprised coarse and fine sand, clay, loam, gravel and boulders.

Malta-Gozo link studied
Transport Malta has commissioned a pre-feasibility study for the construction of the proposed subsea tunnel between the islands Malta and Gozo.

Granite Construction wins USD 41M rail relocation project in US
Scope of the work included constructing multiple access tunnels for pedestrians and service vehicles.

Bilfinger Berger expands Polish infrastructure
Bilfinger Berger began carrying out two projects valued at USD 107.39M. Work included a 1.1km tram tunnel in Poznan as well as rail modernisation in Warsaw.

Fast pace set at Zhengzhou, China
Tunnelling through the soft ground achieved a record advance rate of 720m, machine manufacturer Robbins announced last month. Drives will run 3.6km.

Honduran hydropower
The Government of Honduras signed a USD 50.5M contract with Sinohydro last month for the preparatory phase of the Patuca Three plant. A mid-year start could be possible.

Finnish metro extension
Lansimetro of Finland signed a 30-year agreement with the European Investment Bank and the Nordic Investment Bank to fund the USD 1.16bn, 14km-long Westmetro project from Helsinki to Espoo.

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Brenner bash signals working resolve

AUSTRIA

A ceremony was held in Innsbruck last month to mark Austria and Italy's agreement to launch work on the 55km Brenner Base Tunnel. The decision was made following an agreement on cost and finance for the project, estimated at approximately USD 11.4bn, including risk provision.

Works will begin from Innsbruck, Austria, in the north and Fortezza, Italy, in the south. Construction on the main tunnel, running between Ahrental and Trens will begin in 2016 with completion scheduled for 2025. Excavation work on the exploratory and access tunnels started in 2008 and has made good progress.

"This decision marks an important step forward," said Siim Kallas, European commissioner for transport. "In these economically difficult times, investing in a sustainable European transport policy is more important than ever.

"In line with the objectives of the White Paper on the Future of Transport the Brenner Base Tunnel will deliver a crucial contribution for rail transport to play its part in more resource efficient and sustainable alpine transport."



Above: Work on the exploratory and access tunnels has progressed well since it started in 2008

The cross-border tunnel will remove a major bottleneck for both freight and passenger transit between Austria and Italy. It was part of the vision for Priority Project One, the Berlin, Germany to Palermo, Sicily section of the Trans-European Network (TEN).

"Today's decision reflects the progress made by Austria and Italy in recent months as well as by the Brenner Corridor Platform and other stakeholders since the start of this important TEN-T Priority Project," said Pat Cox, coordinator for Priority Project One. "It is a tribute to all those who have worked with such commitment to ensure the realisation of one of Europe's major future rail corridors."

News in brief

Skanska USA Civil announces new COO
Mike Cobelli has been promoted to chief operating officer, a newly-created position, for Skanska USA Civil. Cobelli will be responsible for the allocation and assignment of operational resources across all of Skanska USA Civil's offices.

Peab signs letter of intent to acquire K Nordang
Peab announced its intention last month to acquire 90.1 percent of Norwegian Vestlandet-focused construction firm K. Nordang.

URS movement
URS Corporation has named Bob Holt senior vice president and national director of program and construction management across all business lines.

Costain acquires majority share in oil and gas firm
Costain announced that it had acquired 75 per cent of the share capital of Aberdeen-based ClerkMaxwell, an oil and gas industry operations support provider. The firm could still buy the remainder.

Toronto airport tunnel bidders shortlisted

USA

The Toronto Port Authority (TPA) last month announced three consortia shortlisted to design, build, finance and maintain the proposed Billy Bishop Airport pedestrian tunnel.

Forum Infrastructure Partners (Forum Equity Partners/PCL/Arup/Trow/Technicore Underground/ZAS Architects), Elite Tunnel Group (Macquarie Capital Group Limited/McNally/Morrison Hershfield/Golder Associated/Scott Associates Architects/State Group) and City Airport Tunnel Partners (Aecon Concessions/Fengate Capital) were among the more than 50 private sector proponents that responded to TPA's request for qualification.

TPA will issue a request for proposals to the three consortia, which will have six months to make their submissions.

Northern Interceptor in Colombia signed

COLOMBIA

The CICE consortium, led by Mexican firm ICA with Colombian company Estyma, signed a USD 67M contract last month with Aguas Nacionales EPM to build a 7.7km tunnel in Medellin Colombia.

The 2.4m-diameter Northern Interceptor will be at depths between 3.3m and 21m below the surface. It will collect wastewater from the central and northern parts of Medellin and the Bello municipality and deliver to a future water treatment plant. The project will be constructed over 990 days, and is scheduled to begin in April.

"We believe that Colombia is one of the most attractive markets for infrastructure development," said Ruben Lopez, head of strategic planning and international operations for ICA. "The Northern Interceptor is an important element for the restoration of the [River] Medellin."

ATKINS

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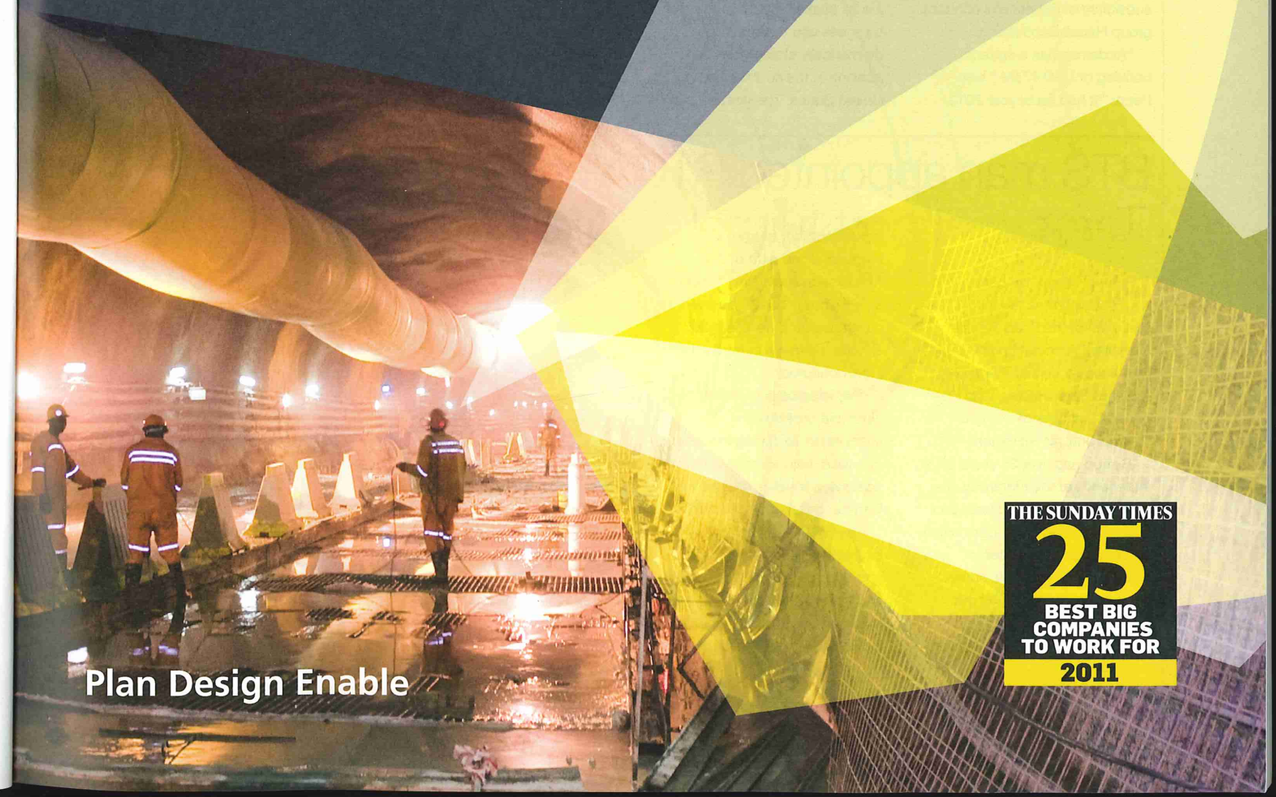
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New chief for Cavico

VIETNAM

Cavico last month appointed Tuyen Anh Hoang as the new president of its subsidiary, Cavico Vietnam. He replaces the former president Thanh Vu Tran.

Hoang was previously a supervising engineer for Kumagai Gumi, a Japanese contractor and affiliate of Cavico in Vietnam.

Employed by Cavico Vietnam in 2000 as a vice deputy of engineering and project development, he served in various positions including president of Cavico Infrastructure Development, to which he was appointed in 2003.

"Through his leadership, Mr. Hoang was able to guide and maintain steady growth for Cavico Infrastructure, especially during the years Vietnam experienced an economic crisis," said Ha Quang Bui, chairman and CEO of Cavico.

"With his experience, work ethic, and understanding of Cavico's business, I am confident that Mr. Hoang will effectively help us to accomplish our goals of better results and efficiency. He is committed to improving shareholder value through active involvement and coordination in Cavico's daily operations."

Hoang graduated from Hanoi University of Mining and Geology in 1996 with an engineering degree in mining and underground construction.



Above: **Tuyen Anh Hoang replaced Thanh Vu Tran.**

Tutor Perini acquires Anderson

USA

Tutor Perini announced last month that it had completed the acquisition of a 100 per cent stake in the Anderson Companies, subsidiary of the general contract group Harrell Contracting.

"Anderson has a current backlog of USD 475M," said Perini. "It had fiscal year 2010 revenues of approximately USD 287M and average annual revenues exceeding USD 400M over the last five years."

Ronald Tutor, Tutor Perini CEO, said, "The Anderson Companies are an ideal fit for our building business and this addition dramatically strengthens our position in the southeastern United States. They have a proven track record of delivering quality projects for their customers on time and under budget."

Anderson's traditional expertise lay in general contracting, design-build, preconstruction and construction management services in southeast USA.

Anderson will continue to be operated by its current senior management team.

BTS man appointed RTOA chairman

GREAT BRITAIN

Peter Bishop has been appointed as the third chairman of the Road Tunnel Operators Association (RTOA), it was announced last month. He replaces Peter Hedley, who was general manager of the Tyne Tunnels until his retirement.

Bishop has over 25 years of experience at the Kingsway and Queensway Mersey tunnels and was most recently principal officer for buildings and estates at Merseytravel, the organisation responsible for operating the Mersey tunnels.

"Accepting this office is a very proud moment for me, as I was involved at the birth of the Association some ten years ago," said Bishop. "I never believed my colleagues and peers would elevate me to my current position. I feel honoured.

"My mission is to further the aims and profile of the association, including the creation of a validated Operatives training scheme, and forge greater links with our colleagues in the BTS."

The RTOA represents the interests of road tunnel owners and operators throughout Britain and Ireland and has acted as a focus for best practice standards including training operatives.



Above: **Peter Bishop told *T&TI* he will strive to forge greater links with the BTS**

News in brief

Brenner works contract
The Swietelsky JV secured the EUR 20.6M (USD 29.9M) contract to excavate adit entrances, erect portal walls, and set up the landfill site.

New Berlin S-Bahn
Berlin works cover construction of concrete tunnels and workshop for the new S-Bahn S21. Contact Derek Scharwaechter +49 30297-551-04

Laermschutz retrofit open tender notice
Operational and structural retrofit of two-lane Laermschutz road tunnel. Contact Herrn Schmitz on +49 541 503-721.

Norwegian highway planning tender notice
Works include preparation of development and technical plan for 12km section of highway including two bridges and two tunnels of 2.7km and 650m. Contact Ane Fyksen on +47 8152 2000

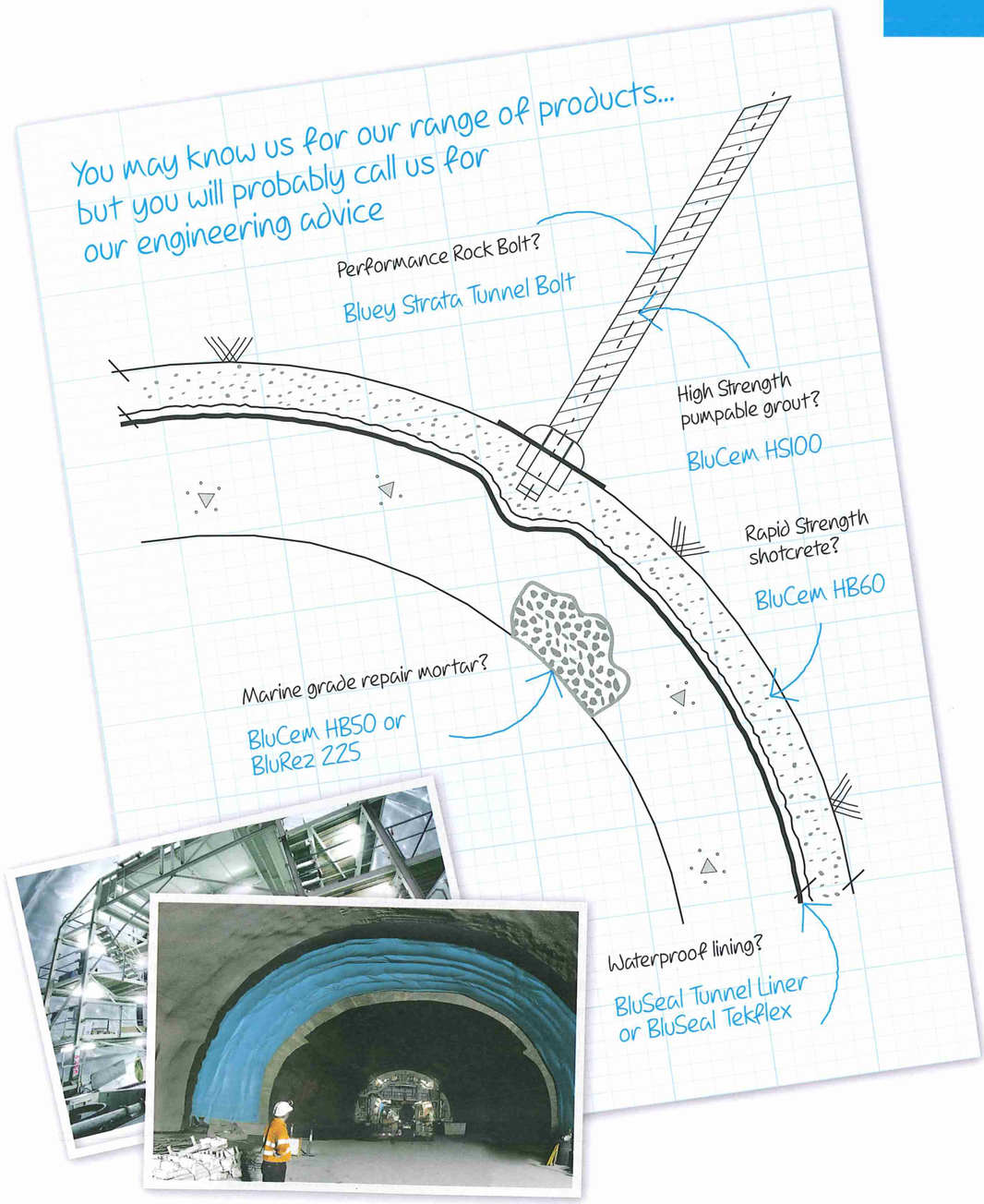
Serbian highway lot three tender announced
Construction of 750m-long twin-tunbe, two-lane Bancarevo tunnel. Contact Nenad Ivanisevic on +381 11-334 4174.

Channel tunnel fire detection systems
Invitation to negotiated tender for six lots of preventive and corrective maintenance of fire detection systems on French and English sides of the tunnel. Contact Peggy Gouverneur, +33 321 0043-28.

Poyry purchases HQ
Poyry has exercised its purchase option to buy its head office building in Vantaa, near Helsinki, Finland. The move ended Poyry's rent and lease obligations.

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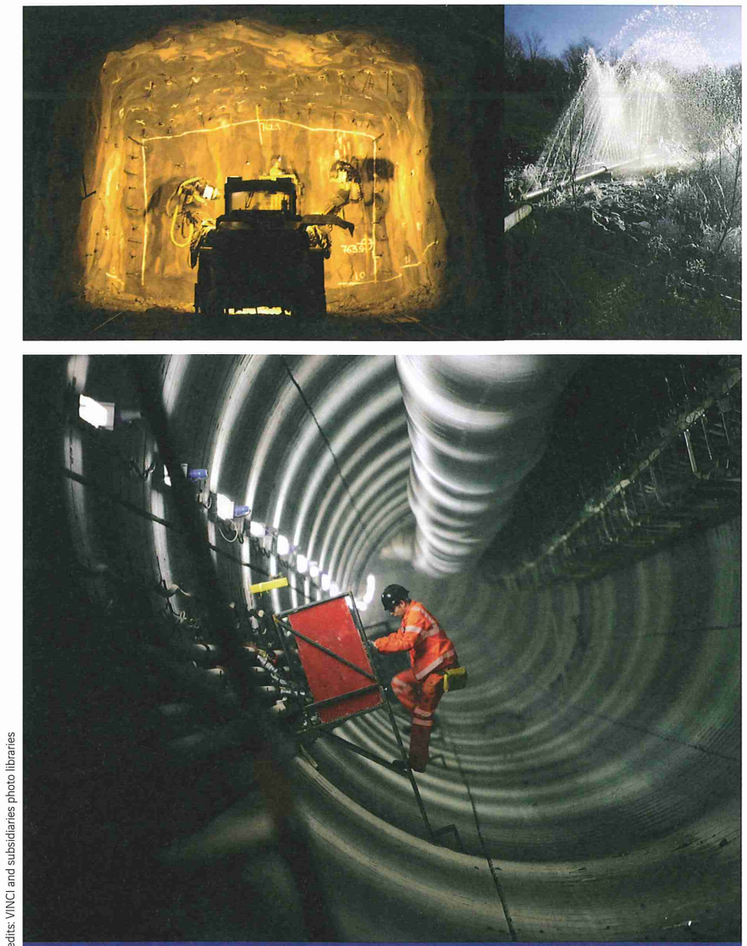
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Samoter reveals healthy plant market

TRADE SHOW

Despite a well-established three-yearly rotation with Bauma and Intermat, exhibitors at the 2011 Samoter trade show said that attendance suffered by calendar proximity to Conexpo and RETC.

Organisers claimed 98,000 visitors, of which 11,000 were from outside the host country Italy. There were 900 exhibitors listed, albeit with a high proportion through agents, representing 37 countries at the March show.

Although Samoter was a general construction equipment show, a high proportion of the exhibitors featured underground construction exhibits, added to which can be geotechnical drills and ground improvement systems in which Italy has been a leader, and which have often been found on cut-and-cover tunnelling projects. This reflected the importance of tunnelling to the Italian, and broader European construction market.

Exhibits with significant tunnelling content included Atlas Copco, Belloli with Rowa, Bauer group, CIFA, Herrenknecht Italia with TechniMetal Systemes, Mapei, Ocmer, Sandvik, and Techniwell. In addition, specialist agencies included Anbel for Aker Wirth, CFT, Condat Lubrifiants, GIA Industri, Scudi and Tunneltec; Colli Drill for American Augers and Astec Underground; and Geotunnel for Bauer and ABS Trenchless.

Conference

Perhaps in recognition of this the Italian tunnelling society, Societa Italiana Gallerie (SIG), in co-operation with the French tunnelling association: Association Francaise des Tunnels et de l'Espace Souterrain (AFTES), chose VeronaFiere and Samoter as the venue for the two-day conference, plus a combined display for members such as Geodata Engineering, Marti-Technik and Penetron Italia. Lead speakers at the conference included Giuseppe Lunardi of Rocksoil, Andrea Pigorini of Italferr and Piergiorgio Grasso, Geodata.

Another newer significant feature at Samoter was the influence of Chinese manufacturers and finance. Chinese manufacturer Sany displayed a 12m³ concrete mixer. Zoomlion showed a concrete pump, the ZL33, under its own name, and had a major presence through its subsidiary Cifa.

The firm focused on the Carbotech range of truck-mounted pumps, which were demonstrated in the designated area, as was the CSS3 step three sprayed concrete equipment. This includes a new Tier III/Stage IIIA diesel drive with catalytic silenced exhaust, improved safety features and new options to suit site requirements.

Cifa representatives were keen to point out that the Zoomlion purchase of Cifa has shown itself as a practical integration rather than a takeover, with Cifa being allowed to exploit and develop its own expertise further, whilst Cifa management was represented in the Zoomlion management.

Concrete spraying

Ocmer featured its range of rotary sprayed concrete dry and wet mix pump mixers and pumps. The same machines can be used for the pneumatic conveying of pea gravel for the annulus in TBM tunnelling and similar applications. The latest design used a hydraulic clamping system with two lubricated rubber gaskets for quick, efficient access whist maintaining integrity. The company has recently reached agreement with equipment manufacturer Putzmeister to utilise its piston pump. The new sprayed concrete applicator has been made available on a Dieci carrier, sold as a package, but other carriers can be used if the customer prefers. Ocmer supplied concrete sprayers for the Budapest Metro. Dott Bruno Messina explained to *T&TI* that the company had developed





Above, top: Prominent on the Atlas Copco stand was an XE3 Boomer tunnelling drill rig sold to Italian contractor CMC; Above, bottom: Rotary cutter excavator attachments from the Simex range on show at Samoter

units especially for the China market at lower prices than other international suppliers but which are more efficient and reliable than cheaper local makes.

Nonex introduced a non-explosive demolition system, imported from South Africa, which can be used for boulder splitting and specialist tunnelling applications. One such has been for work on the Josaphat rail tunnel in Brussels, Belgium, where, explained Paolo Pastuglia, it was used for demolishing bulkhead walls below the European Union offices for THV Leophat. Cartridges break rock and concrete with minimal fly rock, vibration and noise. They were made available in cartridges of 12, 28, 34 and 60mm diameter, and charge weights of 2-500g.

Specialist plant hire company Euromacchine Commerciale introduced its own design of mobile sprayed concrete applicator, the Spraymaster, including a new dosing control systems Franco Crescini told *T&TI* that the new machine incorporates many design improvements which take on board problems the company has discovered in operating units of other manufactures. The first units will, at first, be operated in the company's hire fleet before commercial introduction.

Maurice Jones



The tale of three cities

The market for tunnelling in North America is strong but also struggling due to political and financial pressures, and more recently public outcry. Nicole Robinson profiles tunnelling projects in New York, Seattle and Toronto

In the US, where politicians are in constant gridlock over the nation's budgets, tunnel projects are still moving ahead. Despite cancellations and anti-tunnel initiatives, there is plenty of demand for underground construction. In Canada, where politics can change more rapidly, in comparison to its southern neighbour, a new mayor may mean the industry will be busier in years to come.

New York

New York City has seen several milestones already this year on two subway projects. A Skanska/Schiavone/Shea joint venture completed the first of two bores for phase one of the Second Avenue Subway, and has started mining the second (see feature, p26). This particular phase for the two-track 8.5mile (13.7km) line running below Second Avenue, includes new stations at 96th, 86th and 72nd Streets. Phases two through four will complete the north-south running line, starting from 125th Street in Harlem, running to Hanover Square in Lower Manhattan, with 16 new stations in total.

The second project is the East Side Access for the Long Island Rail. Work is underway in both Queens and Manhattan to complete tunnels either side of an existing 2.6km long stretch at 63rd Street. On the Queens side of the project, a joint venture of Granite Construction Northeast/Traylor/Frontier-Kemper has just this spring started mining the 3.2km of tunnels using slurry TBMs. A joint venture of Dragados/Judlau is constructing the 2.2km Manhattan Approach Tunnels and caverns beneath Grand Central Station.

"There is an incredible amount of underground work in New York," says Greg Kelly, president of infrastructure at Parsons Brinckerhoff. There is always a need for expanding capacity and for rehabilitating tunnelling assets, whether that demand is coming from the water or transportation markets," he explains.

What was set to be another mega project for the area, the USD 8.7bn Access to the Region's Core (ARC) tunnel, met its demise though the (budgetary) axe-wielding New



Left: The Seattle seafront and Alaskan Way Viaduct; Right: One of the TBMs for the York Spadina extension

Jersey governor, Chris Christie. He cancelled the tunnel in October 2010 citing concerns of potential cost overruns. Other alternatives have been speculated, but nothing as concrete as Amtrak's February announcement of the Gateway Project. The rail operator will spend USD 50M on preliminary engineering and design for two new trans-Hudson rail tunnels from Penn Station in Newark, New Jersey, to an expansion at Penn Station in New York.

"While the governor of New Jersey made the decision to stop the project, the need to solve capacity across the Hudson River remains. And so it's interesting and, in a sense, reassuring to everyone—including the governor," Kelly says. "We need to still deal with these kind of issues. While ARC was stopped, it doesn't mean that those in political positions are not prepared to deal with it. They're just looking at different solutions to solving the problem of trans-Hudson capacity."

Seattle

In Seattle the end result isn't capacity, it's creating a replacement for the double-deck Alaskan Way Viaduct, which is deteriorating. But many of the arguments from those opposed to the bored tunnel solution are similar; fear of cost overruns, an aversion to spending while state and federal governments are strapped for cash and environmental concerns.

In January, a joint venture of Dragados/Tutor Perini signed a USD 1.35bn contract with the Washington State Department of Transportation (WSDOT) to design and build the two-level, 1.7-mile (2.7km) bored tunnel that will replaced the Alaskan Way Viaduct in Seattle. Following the project's environmental review expected this summer, the JV will begin final design and construction of the bored tunnel; or maybe not.

Two anti-tunnel groups have gathered enough signatures for their two separate initiatives to be on an August ballot. One would prohibit use of the city's right-of-way for the tunnel project. The other measure is a referendum for Seattle citizens to affirm or repeal the right-of-way agreements the city made with WSDOT. The city attorney, Pete Holmes, has declared this referendum illegal and is trying to put it before a judge. And a third group, supporting the tunnel, has retained a lawyer, Paul Lawrence, to support him.

Holmes and Lawrence say both initiatives are not legal because they are being applied to administrative actions, not policy decisions.

The rift between supporters and opponents has the pro-tunnel governor of Washington and Seattle City Council pitted against the anti-tunnel mayor of Seattle. It is safe to say the tension will continue to rise in Seattle as the year draws closer to August, which marks not only the votes but also the estimated start date for construction on the tunnel.

But it's not all bad news coming out of Seattle. Progress is being made on the 3.15 mile (5km) University Link light rail extension. These twin bore tunnels will run north from the city's downtown to the University of Washington. Three TBMs with 21ft (6.4m) diameters, will be delivered by May, for excavation to start this summer. A joint venture of Traylor/Frontier-Kemper is using two Herrenknecht TBMs, each doing an 11,300ft (3.4km) drive from the UW station to the Capitol Hill station. The JCM U-Link joint venture of Jay Dee/Coluccio/Michels is using one Hitachi-zosen machine for the tunnels between Capitol Hill Station and Pine Street Stub Tunnel, a distance of approximately 1.15 miles (1.85km).

Toronto

The tunnelling market in Canada is very vibrant and active, says Rick Staples, president of the Tunnelling Association of Canada. Large urban areas like Toronto require tunnels for rapid transit and utilities, while some other areas of the country are seeing an active market for hydroelectric power plants.

"There has always been a demand for tunnelling, but it varies with the economic and political climate," Staples says. "Right now we've got governments that have seen action is required so they're coming to the table and funding some of these things."

In Toronto, the 8.6km Toronto-York Spadina Subway extension with six stations is in the initial stages of construction. Contractor Aecon, with McNally and Kiewit, is getting ready to launch the first of the project's four Lovat EPBMs and start mining on the project's southern tunnels at the end of May.

Earlier this year, Toronto Transit City awarded OHL the northern tunnels package. There is also a series of LRT expansion programmes in various forms of design and a preparation for construction, which involves many kilometers of underground construction. Though that wasn't always the plan.

Elected in autumn 2010, the city's mayor, Rob Ford, ran on a campaign championing underground solutions. In March he announced a revised, CAD 12.4bn (USD 12.9bn) transit plan for Toronto that does just that.

The Eglinton-Scarborough Crosstown LRT, a single line running 25km, that was previously planned as mostly above ground, has been changed to one that will be largely below ground.

In addition to the transportation work, there are also large diameter sewer extensions in the works for Toronto, according to Staples. "Probably sometime next year we'll have in the order of 10 to 12 TBMs operating simultaneously on various tunnelling projects."

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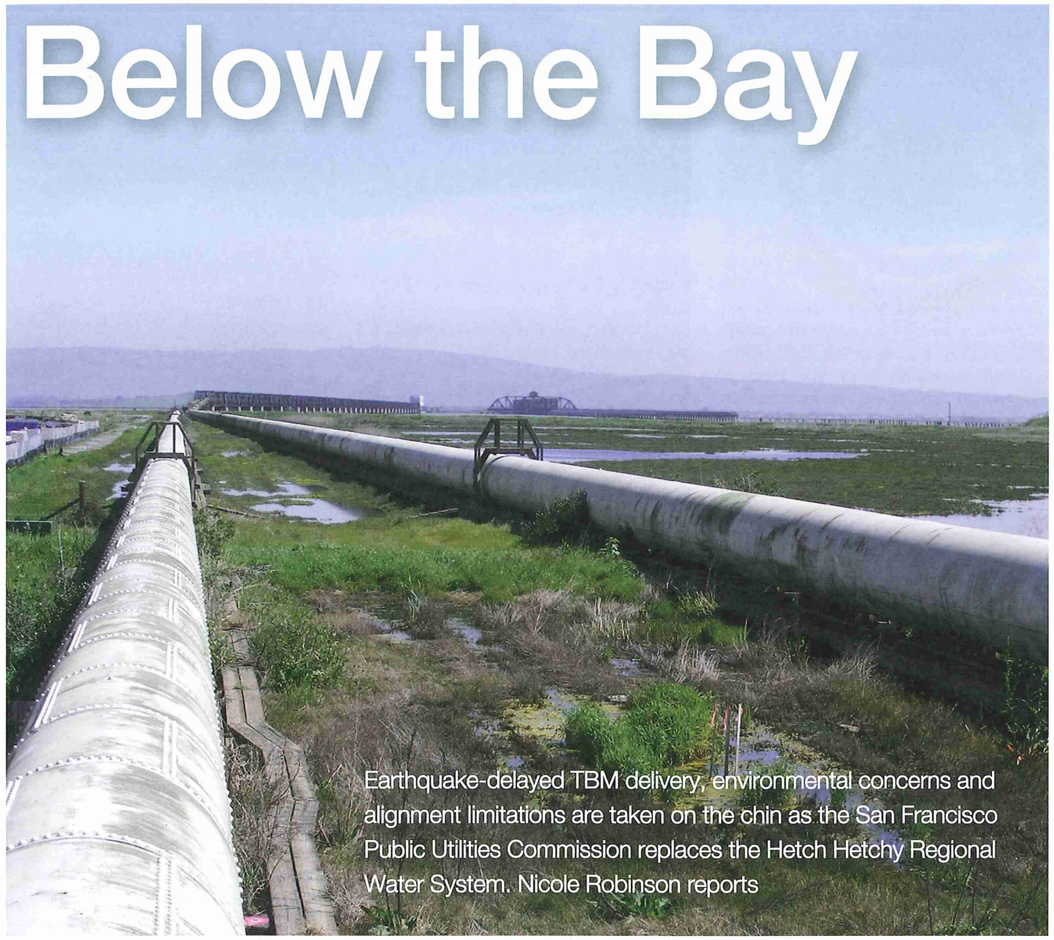
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Below the Bay



Earthquake-delayed TBM delivery, environmental concerns and alignment limitations are taken on the chin as the San Francisco Public Utilities Commission replaces the Hetch Hetchy Regional Water System. Nicole Robinson reports

There are 280 different species of migratory birds in the Don Edwards San Francisco Bay National Wildlife Refuge. Just a stone's throw away is the main work site for the five-mile (8km) Bay Tunnel; its perimeter outlined by special fencing that features a one-way valve, much like a 'doggy door' or 'cat flap' to allow the elusive Salt Marsh Harvest mouse to leave but not return.

"One of the challenges during design was choreographing the borings because if you get too close to the wildlife refuge area, the impacts to the species could lead us to a minor EIR, or what we call a mitigated negative declaration," explains Johanna Wong, project manager for the Bay Tunnel and regional project manager for all Bay Division regional projects for the San Francisco Public Utilities Commission (SFPUC). And if that were to happen, she says, the environmental assessment alone could take a whole year.

The alignment does go around the refuge, but will pass through environmentally sensitive salt ponds, marshlands and mudflats. Once the project is completed, in 2015, Bay area residents can be reassured in the event of an earthquake, they will have potable water—and that biological resources have been protected.

SFPUC is undertaking its USD 4.6bn Water System Improvement Project to repair and replace the Hetch Hetchy Regional Water System, which serves 2.5 million people. This program focuses specifically on seismic upgrades to ensure high-quality drinking water after an earthquake or during a drought. One element of this involves decommissioning older pipelines where they cross the San Francisco Bay and replacing them with the USD 313M Bay Tunnel.

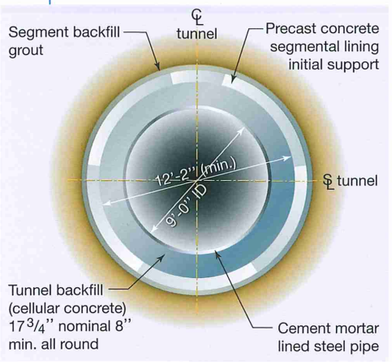
Above: **The existing pipelines crossing the San Francisco Bay**

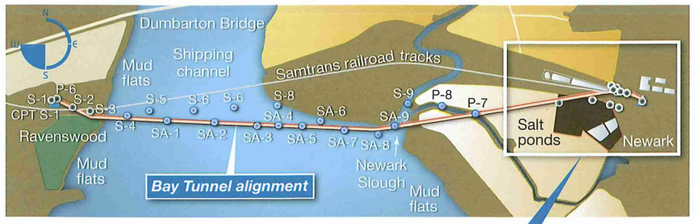
It's only a matter of months before the TBM will be launched to excavate the first tunnel under the San Francisco Bay—the Transbay Tube built in the late 1960s was immersed. A joint venture of Michels/Jay Dee/Coluccio must construct the 5-mile tunnel, 15ft (4.6m) in diameter, without any intermediate access shafts.

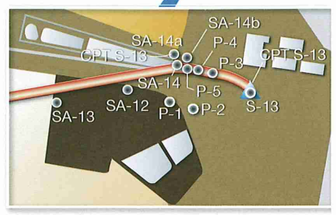
Late summer launch

Notice to proceed was issued to the contractor on 1 April 2010 and set-up on the 12 acre Ravenswood site is moving









Above: Figure 1, land and marine borings along the tunnel alignment and shafts
Left: Figure 2, the Bay Tunnel will have a two-pass lining;

along quickly, including the construction of a temporary electrical substation that will power the Hitachi Zosen earth pressure balance machine. Unfortunately with the March earthquake in Japan, shipping has been delayed by two weeks.

Members of the project team had been in Osaka, Japan, to inspect the fully-assembled machine when the earthquake struck. Everyone returned safely to California, and the TBM passed inspection. Delivery is expected in late May following two weeks of travel time and two weeks in customs. Despite the delay, the delivery still fits within the project's baseline and Jim Stevens, project manager for contractor Michels/Jay Dee/Coluccio, plans to launch the TBM in August.

An EPBM had been recommended to the contractor, though a slurry machine had been an option as well, to deal with the San Antonio formation, a silty clay with some sand. Toward the end of the alignment the tunnel is anticipated to encounter Francisco bedrock for roughly 700ft (213m), and for this the machine has the ability to be outfitted with a full set of 10in disc cutters.

Depths vary between 110ft (33.5m) on the western end of the alignment at Ravenswood where the TBM will start, and 86ft (26.2m) to the east at the second shaft (Figure 1). The tunnel will cross under two existing pipelines built in the 1920s and '30s. There is also an abandoned railroad near the Ravenswood shaft and a live railroad spur and a sewer main near the other shaft in Newark.

"We cross at a very far depth," says Isabelle Pawlik, senior project engineer, Jacobs Associates, the tunnel's designer. "We've done some extensive analysis and we believe they will handle it well, as long as we monitor the earth pressure."

Several alignments had been looked at and it was really the limitations on where borings could be done that determined the final option. Although Wong notes, "Even though this railroad is abandoned, there has always been a plan to reconnect that bridge as commuter rail. So we had to cross inland, and not where they're going to potentially be putting in deep piles."

Another notable challenge of the project is a gap in the borings along the alignment in the salt ponds. "They've got a mile or more of material out there we don't really know what it is. We think it's clay, but there is nothing to prove it right now," Stevens says. "We expect it to be the same, but in underground work you don't know."

One thing that is for certain is seismic activity. The tunnel is between the two most active fault zones in the Bay area. To the west is the San Andreas fault, and to the east is the Hayward fault.

Lining the tunnel

Subcontractor Bencor Corporation completed the 3ft (0.9m) thick diaphragm walls for the 58ft (17.7m) diameter Ravenswood shaft and the 28ft (8.5m) diameter Newark shaft. At the time of *T&TI's* visit to the Ravenswood site, the shaft had been excavated and dewatered—with the exception of sludge at the bottom, which was being mucked out with a crane and a skip box—and would be fully cleaned out just days later.

Because the tunnel doesn't actually cross a fault, along with the shafts, it has only been designed for shaking. "We basically had seismic parameters that were considered for the design. The maximum was 7.5 on San Andreas and 7.1 on the Hayward fault," explains Pawlik.

She adds, "the tunnel itself is not the problem. We designed the lining for internal/external pressures, as well as seismic stresses. But the key problem areas were the connection points to the, very rigid, shafts. We ran some three-dimensional analysis on these portions and we actually made adjustments to the design. We increased the steel strength of the pipe, and we encased these portions in higher strength concrete."

The Bay Tunnel will have a two-pass lining, with an initial segmental lining of sealed and gasketed concrete segments (Figure 2). The six-piece rings are being fabricated roughly 80 miles (129km) away by Traylor Shea Precast's plant in Stockton, California. Segments are 5ft (1.5m) long and reinforced with steel fibers. The secondary lining is the steel pipe required by the SFPUC. The tunnel will be backfilled with cellular concrete, the pipe installed and a 5/8in (127/203mm) cement mortar lining applied for corrosion protection—for a 9ft (2.7m) internal diameter.

Squeezing ground is an issue, and the TBM has features designed to handle this, including increased thrust, higher torque and ports on the outside of the boy to pump bentonite, if needed, explains Bob Mues, construction manager with US firm Jacobs Associates.

The TBM has also been designed to take two rings of the segmental lining at one time because of the project's limited access. All work must be done out of the Ravenswood shaft.

"The whole machine is processed and designed around the ability to deliver two rings at a time to the heading," Mues says. "That travel time is an issue on a five-mile tunnel. When you get out there over two and half miles, haul time is important and there are some limits to the speed you can haul in a tunnel."

Limited by length

A rail system will be set up for the whole length of the tunnel, strictly as a people





Above: An excavator hauls sludge from the Ravenwood shaft; Below: The conveyor belt can be extended by adding the 305m long rolls

mover. Michels/Jay Dee/Coluccio will be using electric-powered locomotives rather than diesel to more easily meet ventilation requirements of California, as well as saving money on fuel costs.

One measure to save time is the contractor's decision to use a continuous conveyor belt for muck removal to avoid the ever-extending haul times and passing switches required with trains. There will be a take-up unit on the surface, and sections of 1,000ft (305m) of belt can be added. A vertical conveyor will bring spoil to the surface, which will be transferred to a muck disposal pit before it is trucked off site.

Trucking is restricted from 19:00 to 7:00, to comply with noise restraints, as there is a residential area on the other side of the site. Once the TBM is installed and excavating, Stevens will run two 10-hour shifts, five days a week with maintenance carried out on Saturdays.

One concern once excavation starts is transporting grout to the face as it moves further away from the shaft. "It's really difficult to pump over five miles, the power you need," Pawlik explains, "and to control the set time so it doesn't set early."

The contractor is anticipating building its own grout plant on site, and pumping down the shaft and into the tunnel. The line will be continually charged with grout to avoid waiting, and cut down on traffic in and out of the tunnel. An admixture would be injected at the nozzle to make the grout set, so it stays just fluid enough to be pumped, but hardens with the segments.

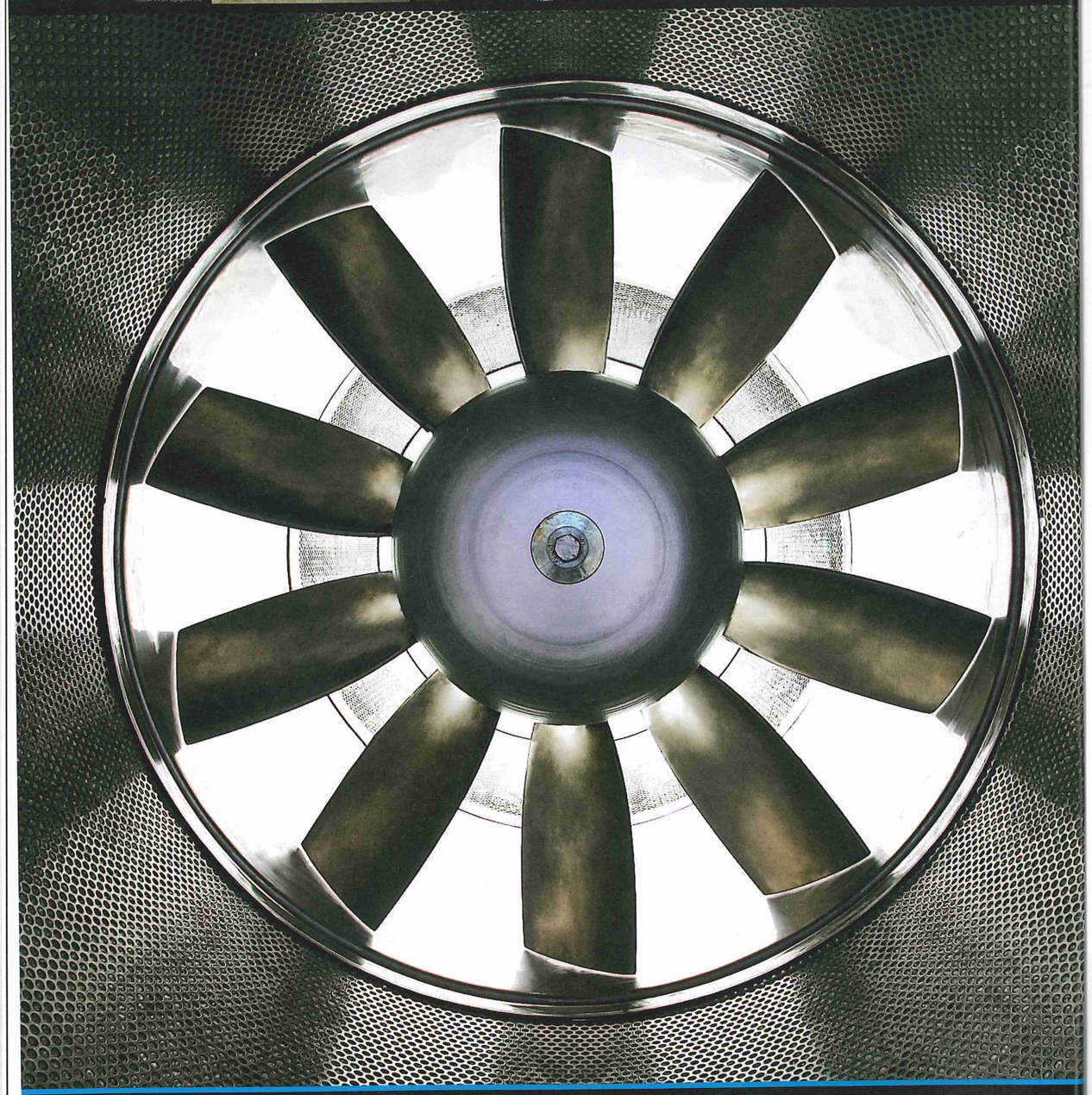
In late March, the site is bustling with activity as concrete slabs are poured for the grout plant, fan and gantry crane, among other equipment. The temporary electrical substation that will interconnect to a 115,000 volt transmission line is ready to be fired up. The TBM will take 12,800 volts once it's installed.

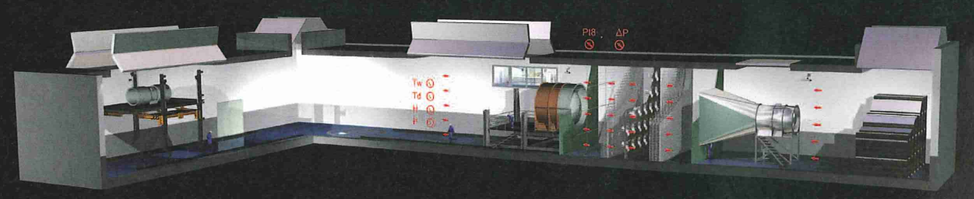
Pending its late May delivery, June and July will see assembly of the machine. With more than 700ft (213m) of trailing gear, the installation will go in stages once the machine starts mining. "We're going to go the length of the gantries," says Stevens. "We'll go a long ways before we put it all in, probably about 1,000ft (305m)."

He estimates it will take one and a half to two years to mine the tunnel. The current schedule is based on an excavation rate based on 80ft (24m) per day, although during the design process it was estimated to be around 50ft (15m). If ground conditions are good, a rate of 120ft (36.6m) per day is possible, says Mues. "If it is as anticipated from the geology, it could be 50ft a day."



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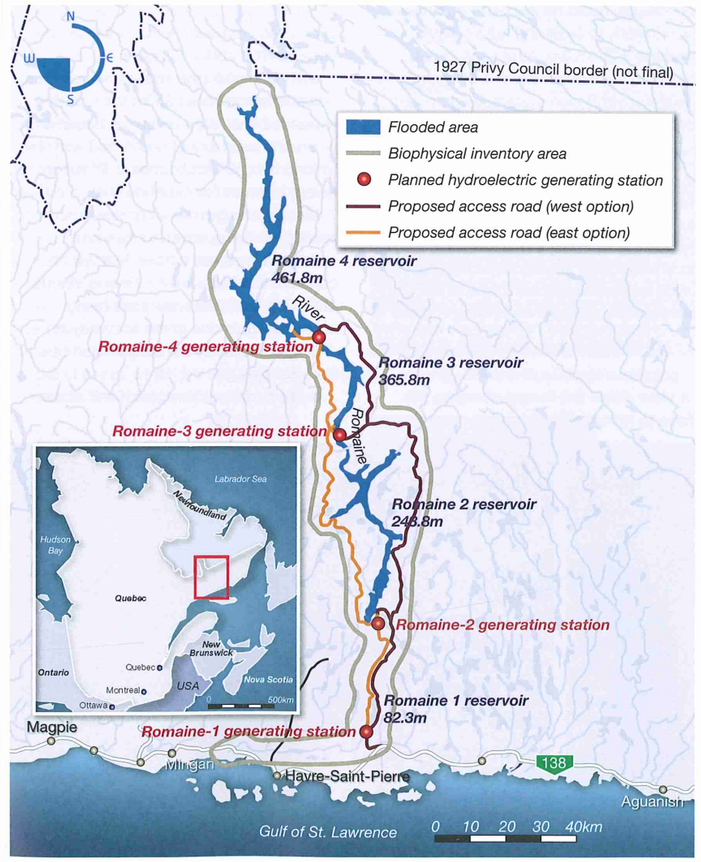


Blasting Canada's hydroelectric expansion

Construction work is storming ahead on the intake tunnel for the massive La Romaine hydroelectric complex in Quebec. Ron Glowe is working as consultant to contractor Simard-Beaudry Construction and authors this report

Construction work is well advanced on what is being called 'the biggest construction project in Canada'. The 1,550MW La Romaine hydroelectric complex will be situated on Rivière Romaine north of Havre-Saint-Pierre, in the Cote-Nord region of Quebec. Construction of the four reservoir-powered plants and a permanent 150km long road will cost an estimated CAD 6.5bn (USD 6.8bn).

Average annual production at the complex is anticipated to be 8TWh, enough to power more than 450,000 households.



In April 2010 Canadian contractor Simard-Beaudry Construction was awarded the downstream section of the Romaine 2 intake tunnel for some CAD 63M (USD 66M).

The first step in starting up this major project was putting together a strong team to build the tunnel. The team from Simard-Beaudry had just completed two other large tunnel projects – the Rupert Transfer tunnel and the Rio Tinto Alcan tunnel.

Drilling on the downstream access portal excavation of 10,400 cu m began in mid June 2010.

Blasting cycle

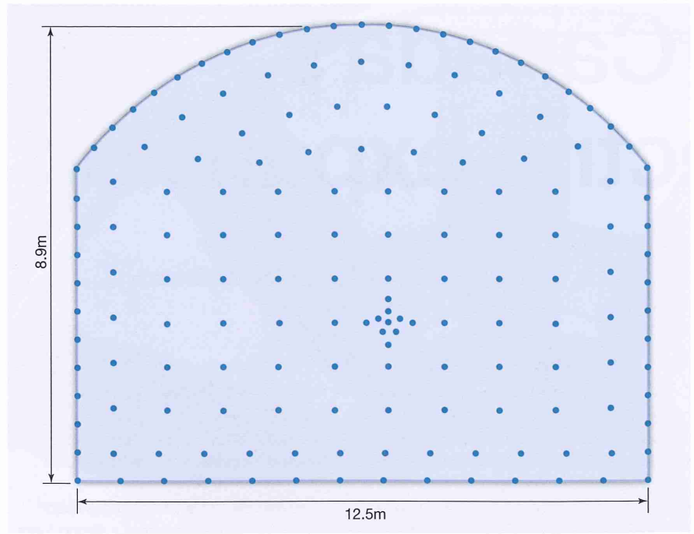
The actual access tunnel began a month later using a pilot and slash technique with two, three boom Sandvik jumbos drilling a 9.5m by 12m wide full face heading for 460m down to the main tunnel. Work began on the main tunnel in November 2010 driving towards the penstocks and in the other direction towards the access tunnel for the surge shaft and beyond.

The full face top heading 12.5m wide by 8.9m high is being driven using two Sandvik three boom jumbos drilling 57mm dia blast holes with 5.8m long steel with an average 159 blast holes and five 100mm relief holes per round as shown in Figure 2 (page 24).

Once drilling is complete, Simard-Beaudry moves in two Skylift platforms that are used by the blasting crew to pneumatically load AMEX using Orica ANFO Mizers to control the loading rate and avoid overloading in central holes. The use of ANFO Mizers helps to reduce spillage of ANFO and results in lower levels of AN in mine wastewater, thereby reducing the environmental impact.

To reduce micro fractures in the

Left: Figure 1, the Romaine reservoir flood area and the hydro projects



Left: Figure 2, typical full face top heading drill round with 57mm dia. holes

remaining rock, cartridge explosives were loaded in buffer and perimeter holes to a typical powder factor of 2.6 kg/cu m. Holes were initiated using Orica 6m Exel Long delay non-electric detonators.

The full face, round when in dry conditions, could be loaded in about two hours ready to blast and advance an average 5.2 to 5.3m. After venting out fumes in 20 to 30mins with a 96-inch (2.4m) diameter ventilation system, work moved onto the next stage of the cycle.

Muckout and support

This involved watering down the muck pile and beginning the excavation of blasted rock using a Komatsu WA-600-6 or Cat 988H (6.4cu m) loader filling the 50-ton Cat 773 trucks.

Once the mucking is complete - in typically three to four hours - a Cat 345 shovel with a large ripper tooth is brought in to scale the face removing any loose rock ready for inspection for rock bolt support and wire mesh installation. This step is carried out using either a two or three boom Sandvik jumbo drilling 4m deep holes for typically six rock bolts per round.

The bolts are installed using two custom designed sliding lift platform trucks also used for the installation of the wire mesh. Once the wire mess is installed up to the face the survey crew can come in and layout the face for the next round and shoot the laser to line up the data drill jumbos to begin the cycle once again. When conditions are good the full cycle can be completed in about 15 hours.

Driving the full face intake towards the powerhouse at about 250m the tunnel is expanded in an area called the transition where the main tunnel is widened and split to form two penstock tunnels. These are being driven as full-face headings 7.35m by 7.45m for a length of 245m. Here shorter rounds are being driven to minimise overbreak for these tunnels that will be concrete lined to a finished inside diameter of 6.45m. Excellent results are being achieved again due to the accuracy of drilling provided by the data drill jumbos from Sandvik.

As part of the downstream end of the tunnel another important part of this contract will be the massive surge shaft excavation. The access tunnel top heading has been excavated 45m to the base of the future surge shaft.

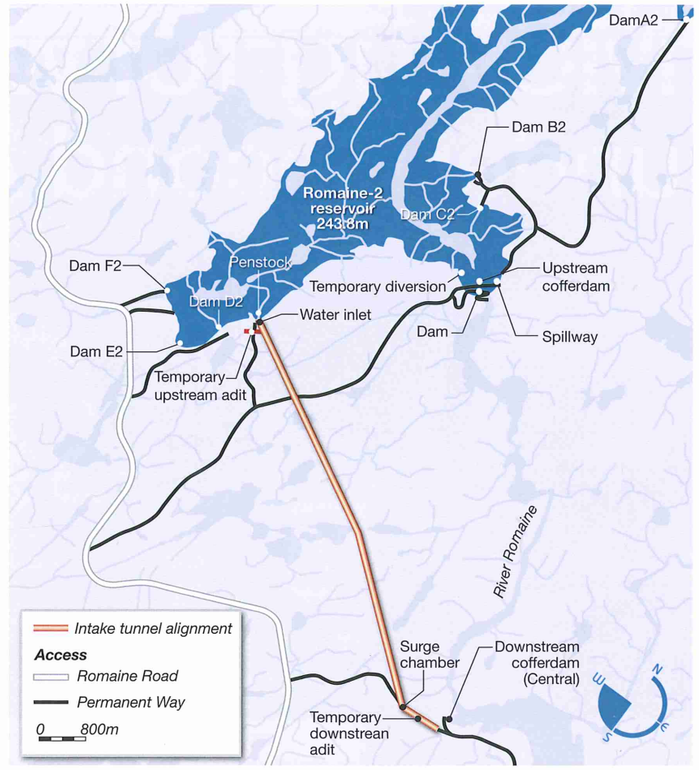
Work is just beginning on excavating a 3m diameter raise to the surface using an Alymak raise climber. This work has been sub contracted to CMAC Thyssen to drive this 163m raise to the surface.

Once the raise is completed Simard-Beaudry will begin blasting the upper surge chamber 32m in diameter in shallow benches down 62m using the 3m diameter raise as a muck chute. Once this section has been excavated, walls bolted and covered in wire mesh then CMAC Thyssen will return to sink the lower surge chamber slashing out to an 8.5m diameter using a custom built Galloway drill platform with two booms. To complete the surge shaft the lower access tunnel will be deepened by a 10m bench.

In June 2010 Simard-Beaudry was awarded the CAD 73M (USD 76M) contract for construction of the intake end of the tunnel. Work began on excavating rock for the access tunnel portal (18,200 cu m) in mid-July. This access tunnel was also driven full face, starting mid-September. It is 12m by 9.5m high using two more three-boom Sandvik data drill jumbos down to the main tunnel, with work beginning after Christmas break on the top heading of the upstream end of the main tunnel.

Work has now been completed towards the intake end awaiting warmer weather prior to breaking out into the open cut intake channel, which will require an additional 94,200cu m of rock excavation.

Right: Figure 3, Romaine 2 general layout and intake tunnel alignment



Main work as of March 2011 is focused on driving the two top headings full-face rounds towards each other with an anticipated meeting early next year to complete the 5.5km top heading and removal of 538,000 cu m of rock.

Currently Simard-Beaudry is averaging over 100m per week in the top heading in current good rock conditions which makes it one of the fastest advancing hard rock tunnels in the world for this size of heading.

Once the top heading is complete, work will then shift to driving the remaining 10m deep bench 11.5m wide to complete the tunnel and removal of an additional 632,500 cu m of rock by the fall of 2013.

Geology

The rock in the area of Romaine 2 is part of the Canadian Precambrian Shield where the predominant rock type is a Quartz Monzonite with some zones of Syenite. This project is the first to constructed by client Hydro-Quebec using a geotechnical baseline report where the rock has been divided into four classifications with pricing submitted for each classification of rock. So far in the downstream end of the tunnel most of the rock excavated has been a Class A type rock and very good quality. In the upstream sections of the tunnel there have been some areas of poorer quality rock resulting in Class B which has required additional rock bolts.

Hydro-Quebec

The owner of the Romaine 2 Intake tunnel is Hydro-Quebec (H-Q). H-Q is a Provincial Crown Corporation, owned by the people of Quebec. It serves 3.6M customers in the Province of Quebec and exports energy to New England, New York State and the Province of Ontario through 18 high voltage interconnections. It also imports energy from those same markets, buying somewhat more than it sells, using a concept it pioneered, that of 'energy-banking', which follows the old stock-market maxim of 'buy low-sell high'. Low-cost night-time power purchased from nuclear and coal-fired must-run plants allows H-Q to conserve water in its reservoirs, then sell peak power back later in the day.

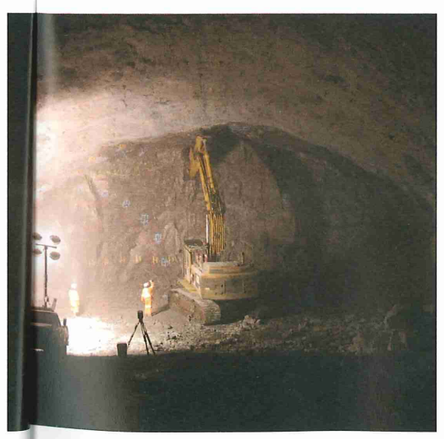
H-Q is the largest hydroelectric generator in the world. It currently operates 59 hydroelectric powerhouses, equipped with 336 turbines, and producing 33,680MW. Three projects involving seven new powerhouses are under construction at this time, planned to come into service between 2011 and 2020, adding a further 2,468MW. They are: Eastmain-1-A, 768MW, in service by late 2011; La Sarcelle, 150MW, in service by late 2011; La Romaine, 1,550MW, in four power plants, the first to be in service by 2014, the second in 2016, the third by 2017 and the fourth plant in 2020.

Within the last decade, H-Q has brought on line seven new plants, totalling to 2,643MW, with 25 turbines. They are: Sainte-Marguerite-3, 884MW; Toulnustouc, 526MW; Eastmain-1, 480MW; Peribonca, 385MW; Grand-Mere, 230MW; Rapide-des-Coeurs, 76MW and Chute-Allard, 62MW.

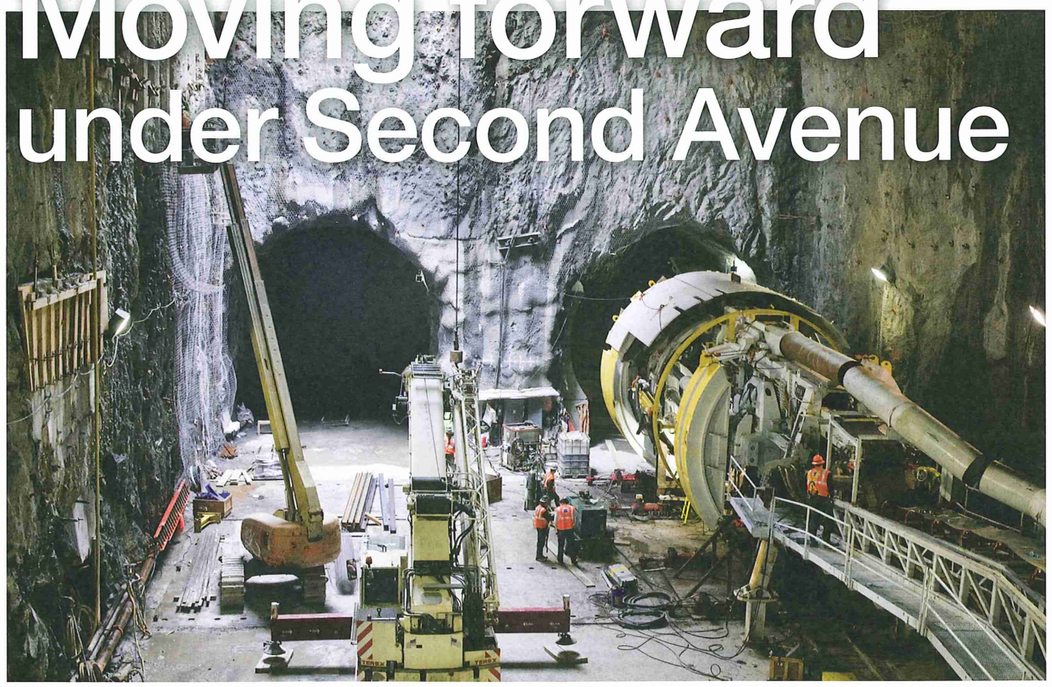
Below from left: Drilling full face top heading; a view down the tunnel showing the 2.4m diameter venilation system; scaling the face to remove loose rock







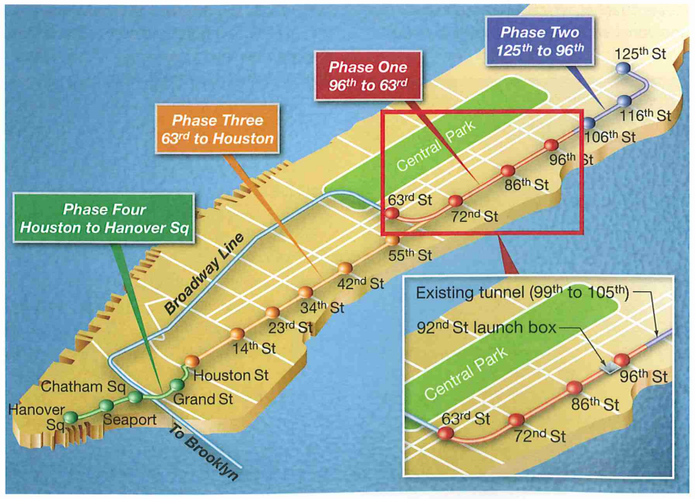
Moving forward under Second Avenue



The hustle and bustle of New York's streets doesn't stop at the pavement. Beneath the city a number of subway projects are taking shape to provide transit for more than eight million residents plus the tourists who flock there every year. Nicole Robinson reports on tunnelling for the new subway line beneath Second Avenue

It'd be an understatement to say the Second Avenue Subway is long-awaited by New York's residents. There have been plans and proposals dating back to 1929, and in the early 1940s the elevated trains along Second and Third Avenues were even demolished to make way for future development.

Fast forward to 2011—certainly some would dispute the use of the word 'fast'—when the city saw the first breakthrough of the first phase to construct the line. And some may scoff at celebrating this step toward completion. The city has seen



Above: The TBM mined the western bore before being drawn back almost fully assembled to work on the eastern bore
Right: Figure 1, the Second Avenue Subway will be built in four phases; Phase One (inset) is schedule to be operational by 2016

several sections of tunnel built for the Second Avenue Subway since the 1960s and '70s that never materialised into a working line due to budgetary issues. But the New York Metropolitan Transportation Authority Capital Construction (MTACC) reports the project is on schedule to finish in December 2016.

Phase One

Phase One entails a two-track line connecting 105th Street and Second Avenue to existing services at 63rd Street and Third Avenue, with new stations at 96th, 86th and 72nd Streets.

Although the full length of the Second Avenue line won't be completed, when Phase One finishes in five and a half years, the subway service is projected to carry more than 200,000 weekday riders. Future Phases Two through Four will complete the line from 125th Street down to Hanover Square in lower Manhattan with 16 new stations (Figure 1).

A Skanska, Schiavone and Shea joint venture (S3 Tunnel Constructors) secured the contract to build new tunnels between 92nd and 63rd Streets, excavation of the TBM launch box and excavation of access shafts at 69th and 72nd Streets. These shafts will be used for constructing the 72nd Street station, which is part of a different contract. Likewise, excavation of the 96th and 86th street stations come under separate contracts, as does the connection to existing tunnels from 99th to 105th Streets (see Current Contracts box). DMJM Harris and Arup is providing design and engineering services.

Tunnelling started at 92nd Street to make use of the Manhattan Schist, which continues to the south (Figure 2 below). The launch box measures roughly 810ft (247m) going north to south, approximately half in rock at the southern end and half in soil at the northern end (Figure 3, p20). In the rock cut, the width is around 66ft (20m), and in the soil cut, the width is 58ft (17.7m).

The box walls consist of two different types of construction, secant walls at the southern half and slurry walls at the northern half. The slurry walls at the middle portion of the box are founded within rock. Northward from there, the slurry walls are founded within the soil with approximately 40ft (12m) of toe below the final excavation limits. From the southern end to the middle portion of the box, the walls are constructed with secant piles founded within the rock.

S3 had been awarded the contract in March 2007, but it wasn't until early 2010 that the contractor was ready to begin underground work. "We had to perform a significant amount of utility and other preparatory work in order to build the walls of the box and that took about a good year, year and a half, " explains Julio Martinez, project engineer with Schiavone Construction Co., working in the S3 JV. "And then we had to install decking on top of the future excavation since traffic still had to be able to transverse above us while we excavated within the box."

Monitoring movement

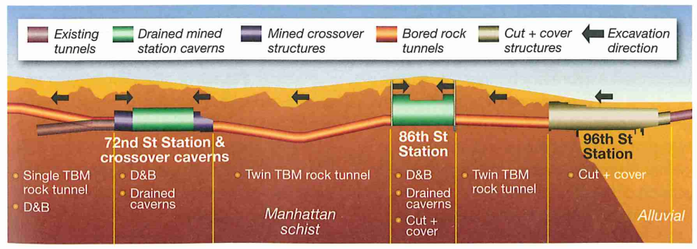
MTACC surveyed 225 buildings on Second Avenue that could be affected by tunnelling work, and 51 buildings were deemed 'too fragile' in autumn 2010. These are primarily located near the TBM launch box, and are four- to five-storey brick buildings built in the 1800s with shallow foundations, supported on soil or timber piles.

Martinez describes them as basically floating on the soil, which is a mix of sand, silt and clays. Prior to the construction of these buildings, this part of Manhattan was shoreline, which was then reclaimed to amplify the city's limits. "This fill was not controlled. It wasn't compacted as fill is placed in modern times. So whatever soil you move, it's actually going to react much quicker," he says.

The buildings were affected by work to excavate the launch box and construct its walls, and there were some so sensitive, they started to move while S3 was doing utility work. Reinforcement is being undertaken by the MTA. When it came to surveillance and monitoring the owner was prudent, says Martinez, "That's what kept the problem from getting worse."

But these buildings and the

Below: Figure 2, Phase One TBM excavation started at 92nd Street to take advantage of the Manhattan Schist



Current contracts

Contract: C-26002
Contractor: Skanska/Schiavone/Shea JV (S3)
Award date: March 2007
Work: TBM tunnels between 92nd Street and the existing Lexington Avenue/63rd Street Station; construction of a TBM Launch Box from 92nd to 95th street and access shafts at 69th and 72nd Streets.
Bid: USD 337M

Contract: C-26005
Contractor: E.E. Cruz/Tully Construction Co. JV
Award: May 2009
Work: Utility relocation, demolition of existing buildings, underpinning, slurry wall construction, excavation, and station invert slab of the 96th Street main station box, entrances and ancillary facilities. (To be followed by Contract C-26010)
Bid: USD 325M

Contract: C-26006
Award date: January 2011
Contractor: Judlau Contracting
Work: Rehabilitation of 63rd Street/Lexington Avenue Station and construction of entrances
Award Amount: USD 176.5M

Contract: C-26007
Contractor: Schiavone/Shea/Kiewit JV
Award: October 2010
Work: Construction of the 72nd Street station cavern and G3/G4 tunnels to the existing 63rd Street/Lexington Avenue Station, includes tunnel mining, tunnel lining, station cavern, station entrance and elevator shafts.
Bid: USD 447.2M

Contract: C-26013
Contractor: J. D'Annunzio & Sons
Award: July 2009
Work: Utility relocation, open excavation and road decking for the 86th Street Station. The scope of this contract is to prepare the site and provide access for the subsequent Cavern and MEP contracts.
Bid: USD 34M

Recently opened:

Contract: C-26008
Work: 86th Street Station cavern mining and heavy civil structure
Lowest bid: Skanska/Traylor JV of USD 301.86M



Above: Figure 3, the launch box is 247m long. Secant walls are used in the southern half, which is founded in soil and slurry walls for the northern half in rock

reinforcement work have affected excavation operations. The MTA initially predicted a progress of 50ft (12m) per day, and *T&TI* reported in November 2010, TBM excavation was progressing at 40ft (12m) per day.

Besides buildings there are utilities overhead—between 40ft to 20ft (12.19 to 6.1m) away as the tunnel's elevation changes through the alignment. Lengths and feed pressures on drilling and probing have to be less aggressive.

"We've had to do more probes than what we normally would have with a machine at a deeper depth, which increased the mining cycle a little bit," says Chris Cosenzo, tunnel superintendent with Schiavone Construction Co.

He later explains, "We put up a lot more ribs and major rock support that we didn't expect to have to put up, which in turn slows the mining process down. Which is when you don't get to see the production you expect because you're constantly trying to fight through the bad zones and put up proper rock support."

One down, one to go

The tunnels range in depth from 60 to 100ft (18.3 to 30.5m) from the surface, and each bore has a diameter of 22ft (6.7m) with an 18ft (5.5m) rock pillar separation between them. TBM excavation for the 7,215ft (2.3km) western bore finished in February at 65th Street.

S3 is using the same TBM for both bores to save space in the launch box and to avoid the logistics of doubling the electricity, water, ventilation and other services required. The JV is using a reconditioned open-face main beam gripper machine with 44 cutters, 17in in diameter, from Shea's fleet—a decision that saved time in a tight schedule. Working with Herrenknecht, it took roughly five to six months to rebuild the machine.

"We took advantage of it when we bid this work, and that's why we were the low bidder," Martinez says.

To save time, the contractor wanted to bring the machine back through the western tunnel fully assembled, with the hydraulics and electricity still hooked up. The only disassembly needed was to remove the four segments of the cutterhead around the perimeter, the roof supports and the side supports.

S3 considered jacking up the machine to insert a sliding plate underneath. This would allow the TBM to be transported back through the tunnel under its own power. Instead the decision was made to fit the machine with transport dollies and tow it back to the launch box using the project's locomotives.

With the TBM tunnelling the eastern bore, as of late March, S3 has started work to treat select stretches of the western bore with a PVC membrane waterproofing system, prior to receiving its 13.5in (342.9mm) thick lining of concrete with steel and polyethylene fibers.

Freezing ground

The 7,793ft (2.4km) eastern bore has proven to be more complicated than its western counterpart. While tunnelling started here in March, Moretrench of New Jersey has been providing ground freezing services since January for an area approximately 147ft (44.8m) long at the portal of the east bore (around 91st Street).

While doing secondary support for the starter tunnels, S3 encountered soil and water. "We notified the owner and performed exploratory borings," Martinez says. "In the process we did find that part of the alignment, the crown, was in soil-like material. In light of these findings the owner prudently elected to freeze this stretch of the alignment."

Approximately 110 freeze pipes of 3in (76.2mm) internal diameter have been installed around the tunnel alignment at depths of approximately 75ft (23m), at varied angles.

"We had to angle as much as 30 degrees off of the vertical in order to avoid water lines, gas lines, all the utilities," says Kenneth Wigg, senior engineer with subcontractor Moretrench.

He explains. "We couldn't get exactly where we wanted to be. So we had to really look at the placement of the freeze pipes, and in some places we had to add freeze pipes, to get those pockets we couldn't reach because of the utilities."

Freeze operations are using calcium chloride brine, and as the machine bores the east tunnel a thin interliner is being installed to seal off and support the tunnel crown prior to the thaw. Within the next three months, subcontractor Moretrench should be able to dismantle its surface level freeze plant.

It should take between six to 10 months to breakthrough at the 63rd Street Station. However at the end of the east bore, the TBM makes a tight compound curve to meet up with existing tunnels and train services at 63rd Street.

"I think it's probably in the extreme range of what the machine can do. It's a pretty tight radius," says Martinez. "It starts around 830ft (252.98m) radius and ends about 620ft (188.98m) radius. The reason they had to keep it so tight is because of eminent domain and zoning issues."

Working in such a densely-populated city has created other constraints for the project. Trucking for the project's spoil removal and deliveries have limited hours from 7am to 7pm because the area is residential. There is also limited space in the launch box.

"We can't stack or store large volumes of materials. We have to truck them in and out of the tunnel as we receive them. It's a constant chess game to get materials into the tunnel and keep everything in a productive manner," Cosenzo says.

Martinez hopes the eastern bore will complete later this year.

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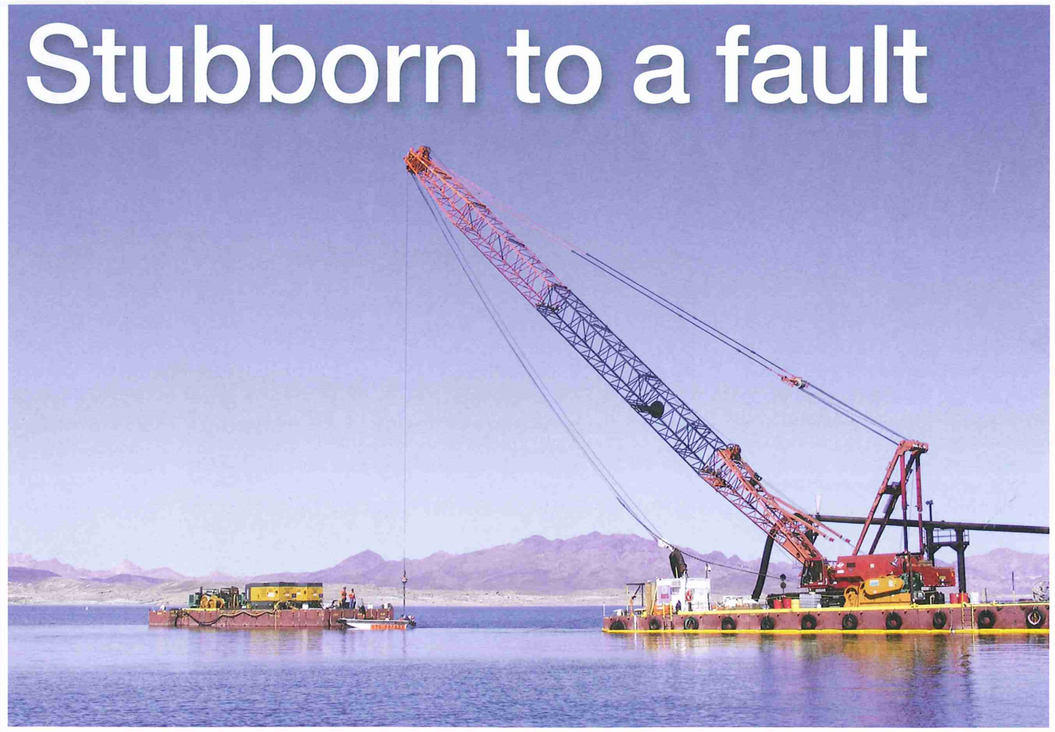
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Stubborn to a fault



Construction of Intake No. Three at Lake Mead, Nevada, requires tunnelling beneath the lake and blasting at Saddle Island. With a deadline driven by the region's drought conditions and drinking water at stake, progress on the project's longest tunnel has been marred by a fault near the starter tunnels as Nicole Robinson reports from site

Reflecting the cloudless Nevada sky, the blue waters of Lake Mead are the physical embodiment of a diamond in the rough, glistening amidst the dramatic desert landscape. Far from the brash bustle – and debauchery – of Las Vegas, framed by mountains, it's a recreational haven often dotted with boats and the gentle waves of their wake.

Increasingly, those boats are spotted among previously submerged landmasses. Driving along the shoreline, from Boulder City one can spot an auxiliary building leftover from the construction of Hoover Dam. Once a popular spot for divers, it now sits in the sun in the middle of the lake.

The United States' largest reservoir was created by the construction of Hoover Dam in the 1920s and '30s and it provides 90 per cent of the Las Vegas Valley's water supply. That's about two million residents.

A severe drought in the past 10 years has caused water levels to drastically recede, leaving the lake marked by a grayish and white ring.

Normal elevation in 2000 was 1,200ft (365.7m), explains Erika Moonin, project manager with the Southern Nevada Water Authority (SNWA), an agency that procures and treats water for its seven regional member agencies. "At 1,060ft (323m) we'll be about 10ft (3m) above losing Intake No. One, but we'll start seeing impacts on water quality, which does cause problems with our capacity for processing and treatment," she explains.

With two intakes in operation, SNWA began planning to construct Intake No. Three. Studies carried out during this time indicated that should the drought continue at the same rate of severity, water levels could recede to 1,050ft (320.04m) as early as 2013 or 2015.

"It did get dangerously low already," says Moonin. In autumn 2010, the lake reached its lowest point ever since it was filled after construction of the dam, 1,083ft. "We typically do see a rise in the winter as the demands decrease. It comes up about 10 to 15ft [3.05 to 4.57m]. And then we'll see a drop of 10ft [3.05m], possibly 20ft [6.1m] or even 25ft [7.62m] like we saw this summer."

As of late March, Lake Mead had a 1,096ft (334.06m) elevation, already starting to drop.

To protect the water supply, the SNWA chose to undertake a four-year project to build Intake No. Three, which includes three tunnels (Figure 1, opposite). Vegas Tunnel Constructors (VTC), a joint venture of Impregilo and their subsidiary, S.A. Healy, has a USD 488M design-build contract for a 4.5km tunnel and the intake structure. Renda Pacific, a joint venture of Oscar Renda Contracting and Southland



Contracting, is excavating the connector tunnel (around 860m), a contract worth USD 45M. In spring 2010, Barnard of Nevada completed a small tunnel (174m) that will connect the new Intake No. Three with the existing Intake No. Two. That contract was worth USD 32M. Engineering services for Intake No. Three include program manager Parsons Corporation, and a joint venture of MWH and CH2M-Hill is the designer.

Stops and starts

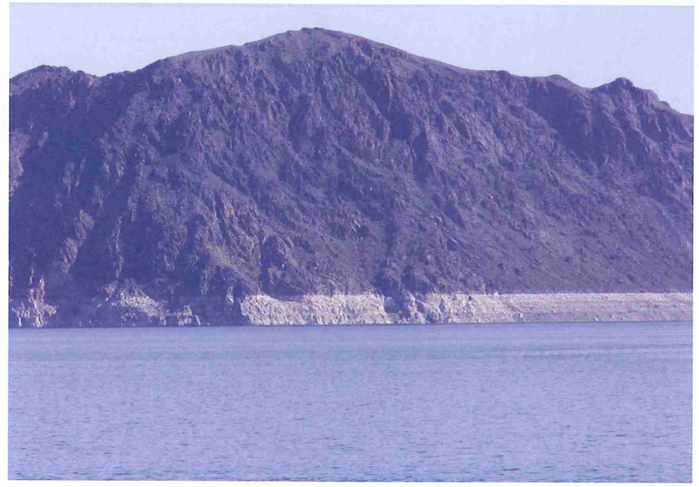
Several locations were looked at for the intake to ensure water quality before the options were narrowed down to three. The 14,904ft (4.5km) tunnel was the preferred alternative with its comparatively lower cost, despite having more difficult construction (Figure 2). A straight alignment had also been considered once the intake location had been chosen, but the curved alignment afforded better geological conditions, Moonin explains. "We get into what is called the Muddy Creek formation earlier, and that is less fractured."

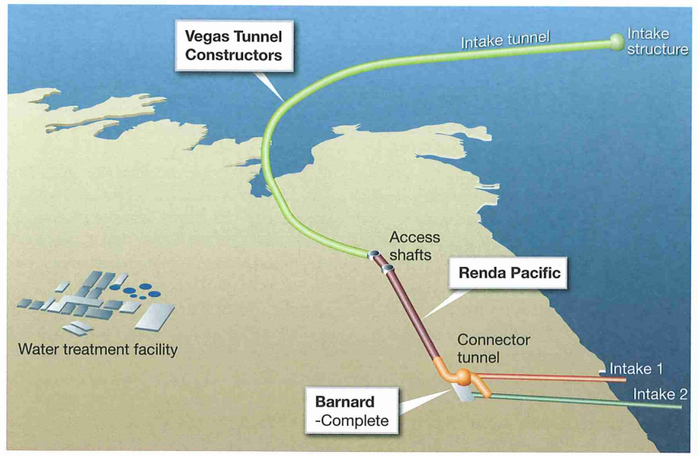
In addition to the urgency of protecting capacity if the first intake is out of commission, one of the main challenges of the project is dealing with varying ground conditions of solid to weak and highly fractured rock, with the potential for high water pressure up to 17bar.

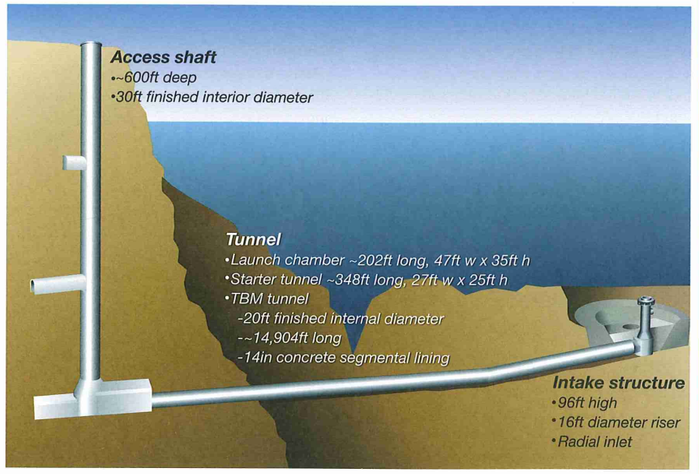
VTC did its first blast at the surface in June 2008 to start excavation of the 600ft (183m) deep access shaft with a 30ft (9m) internal diameter. In September the shaft hit water and the contractor began pre-excavation grouting, reaching the bottom by February 2010. The 200ft (61m) long launch chamber is 47ft wide by 35ft tall (14.3m by 10.6m).

Initially, the 348ft long starter tunnel (modified horseshoe shaped 27ft (8.23m) wide by 25ft (7.62m) tall) only required rock bolts and shotcrete for support, but soft ground was eventually encountered. In March 2010 VTC started installing steel ribs after finding loose ground, and in late June, about 150ft (45.7m) into the starter tunnel excavation, water started coming in, bringing ground with it over a period of four days.

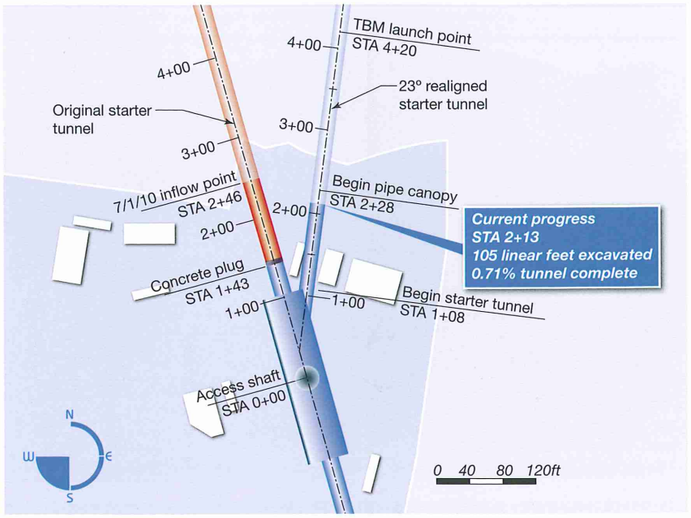
"It would come in gushes," says Moonin. "The ground would arch, the







Top right: **A distintive grey and white band round the lake shows the drop in water level**
Middle right: **Figure 1, The layout of the tunnels and shafts at the project site**
Bottom right: **Figure 2, The VTC tunnel and intake riser structure**



Left: Figure 3, A new alignment has been approved 23 degrees off of the original

water pressure would build back up and come again."

VTC made the decision to allow the underground space to flood, and allowed the water to come 150ft up the shaft to help equalise the water pressure and stop the material from coming into the starter tunnel. The contractor mobilised drills on the surface over the alignment within one week to locate any voids and found one that was filled with 3,000 cubic yards of concrete. During July and August, drilling continued and 26 holes were grouted at the original face of tunnel, from the surface.

Going back

In September VTC returned underground to clean out the material that flowed in and recover lost equipment. As work started to continue toward the face—almost at the same location, within a metre or so—there was another inflow on October 27. Similar to the event earlier that summer, water flowed in bringing rock material mixed with amounts of clay.

This time VTC had a pre-fabricated temporary bulkhead it was able to install to minimise flows to the rest of the starter tunnel. Recovery work started again, but on December 31 there was another inflow, burying the drill VTC was using for grouting. This inflow was smaller than the other two, but the contractor decided to back up and bulkhead it off.

VTC recommended to SNWA the tunnel be realigned because of the challenges of the ground and presented a proposed alignment and geotechnical investigations. In January, it carried out three horizontal cores and 15 surface holes before selecting an alignment 23 degrees offset from the original (Figure 3 above). SNWA negotiated a change order for USD 40M, approved on February 25.

The first starter tunnel has been filled in with concrete—plus a concrete bulkhead and roughly 15ft (4.5m) concrete pillar at the chamber. At the time of *T&TI*'s visit to the site in March, VTC had excavated 120ft (36.58m) of the new starter tunnel.

Jim McDonald, VTC project manager, explains the launch chamber needed to be widened another 20ft (6m) to get a face to start a new tunnel. "It's a very challenging project, but it's getting better," he says. "We had a difficult time there with the ground conditions, but with any luck we're past that."

In waiting

Arriving at the job site in the Lake Mead national recreational area, there is a sea of pre-cast segments awaiting installation. Made in nearby Sloan, Nevada, all of the 6ft (1.8m) long steel-reinforced segments will be produced by mid May. Among the stacks of five segments plus a keystone are portions of the Herrenknecht TBM's gantry, having been delivered (on time) in September 2009 via the Port of Long Beach and shipped to the site by 61 trucks.

McDonald says he hopes to start installing the TBM in September. "We'll put a little more than half in and mine 400 to 500ft (122 to 152m) then we'll stop and put the rest of it in. We should be launching the TBM by the end of year."

The 23.5ft (7.16m) diameter TBM is a slurry and hard rock hybrid, roughly 190m long. There will be a continuous conveyor throughout the length of the tunnel, as well as a full slurry system. McDonald estimates 70 per cent of the tunnel will be done in open mode, with the last stretch, at least 2,000ft (609m), in closed mode. Mining operations will be 24-hour, and overall average progress rates of 35 to 40ft (10 to 12m) per day are expected. The project is scheduled to finish construction in 2015.

After completing the tunnel, the TBM will drive into the bottom section of the concrete intake riser at the bottom of the lake. This structure has steel reinforcement, overall, with fibreglass where the TBM will mine and dock. Once the connection is sealed and watertight, the TBM's shield will be welded into a 30ft (9m) steel ring in the structure and left in place.

The other component of VTC's contract is marine operations to excavate by drill and blast the hole for the intake riser, some 300ft (91.44m) below the surface of the water. Lake excavations are projected to complete by the end of 2011.

Once the intake riser is in place, surveying its location is critical for the TBM to make its connection within 12in (0.31m) considering there are no access shafts along the alignment. McDonald says it should be possible within 2 to 3in (51 to 76mm).

At the other end, back on land, VTC's tunnel will connect with those being built by the Renda Pacific joint venture.

Connections

Renda Pacific has excavated by drill and blast a 26ft (7.9m) diameter shaft and lined it with block concrete to a depth of 450ft (137m). This is the depth at which the JV will build a 320ft (97.5m) tunnel to VTC. In the other direction, it is excavating by drill and blast a 2,500ft (762m) tunnel to the existing pump station.

Both tunnels are supported with 8ft long CT bolts on 5ft (1.5m) centres, and lined with 4in (100mm) of fibre-reinforced shotcrete. There is a 6in (152mm) concrete slab at the bottom. The shorter tunnel to VTC is 20ft by 20ft (6m) and for the most part flat, while the longer tunnel to the pump station is 16ft tall by 14ft wide (4.9 by 4.2m) with a 3.3 per cent grade. There are also two curves, each with a 160ft (48.7m) radius.

Ground conditions vary from highly fractured to fairly good, quality rock. To complete each excavation cycle, Renda Pacific drills and grouts for 80ft (24.4m) but only excavates 60ft (18.3m).

"Water is a big part of this job," says Michael Cash, project manager for the Renda/Southland JV, who explains the grout program is owner-directed and the JV meets daily with the construction manager to discuss the ground.

"The last grout cover, we put in over 80t of grout for an 8ft (2.4m) section," he explains. "Interestingly, you can actually see the grout in the face when we excavate."

The bigger, but shorter tunnel to VTC hasn't hit much water, but the opposite is true for the smaller, longer tunnel. "Of the four months excavating, approximately three months of it has been just drilling and grouting," Cash says. It can take as few as two days to do the 80ft (24.38m) covers. "However if we do hit a lot of water, it has been taking us up to three weeks."

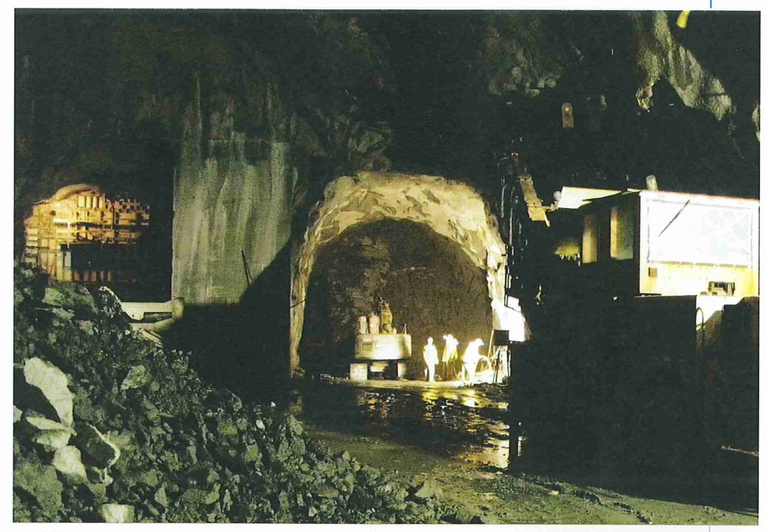
Renda Pacific is using one Terex Jumbo, diesel over hydraulic, with two drill booms for both tunnels. For the drill and blast, 12ft (3.6m) holes on a 3ft by 3ft (0.9m) spacing are drilled out. It takes around one to one-and-half weeks to do the 60ft of excavation in each cycle. As of *T&TI*'s visit, the JV had completed the 450ft (137.16m) of shaft excavation, and another 450ft of tunnel excavation. Cash says they're looking at two more months of excavation in the shorter tunnel, and another nine months on the other side—though that estimate doesn't account for the time needed for grout if required.

"The grouting program on this job, although being very time-consuming, has been a great success in what it has achieved," Cash says. "We probe out and get massive amounts of water from the probe holes—a couple hundred gallons a minute from a single 2in (50mm) hole."

Toward the end of its contract, the JV will install a temporary steel bulkhead between the VTC tunnel and Renda's shorter tunnel to allow the completed connection to be flooded. Separately, a bulkhead will be installed at the bottom of the shaft to all water to be conveyed in the tunnel during future construction of a pumping station for Intake No. 3 that had been put on hold.

Three contracts for the pumping station, a discharge pipeline and associated electrical work have been deferred in response to declining revenue for SWNA since 2006.

Right: The new tunnel alignment on the right runs 23 degrees off the original
Bottom right: A rig operator copes with inflows of water as he advances





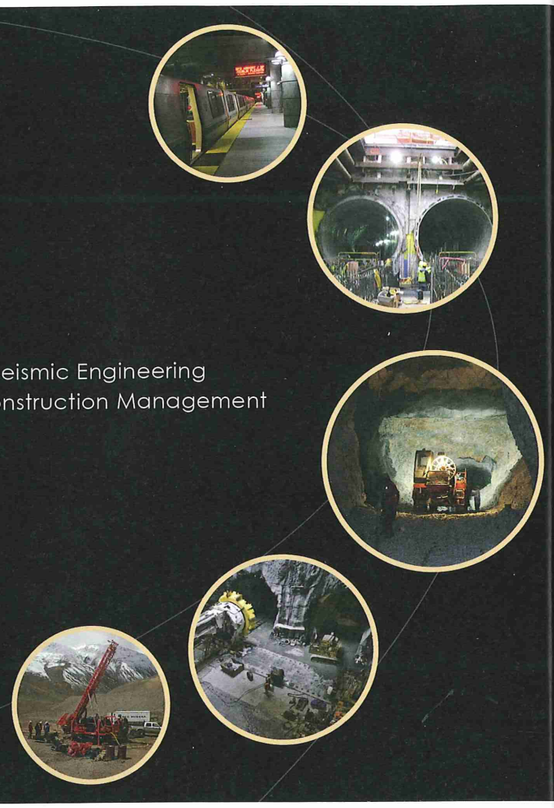
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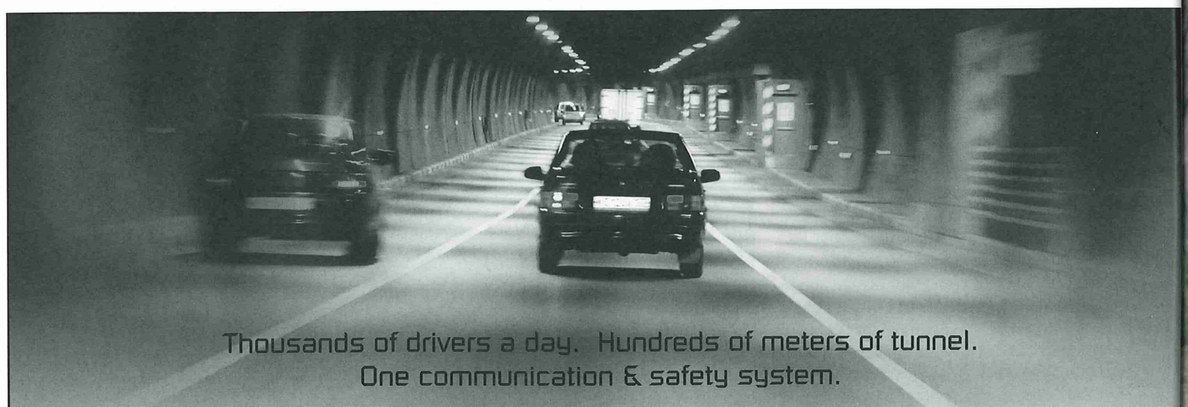
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South East Asia

Booming demand and environmental need is driving a market that refuses to be eclipsed by nearby India and China

The Larut Tunnel is one of two tunnels excavated in Malaysia's Perak region for the Ipho-Padang Besar railway (see feature, p41)



Breakthrough of Double Shield TBM, Ø 12.34m, Clem Jones Tunnel, Brisbane


China, Mixshield, Ø 15.43m


Spain, EPB Shield, Ø 15.20m


Italy, EPB Shield, Ø 15.55m



Australia, Double Shield TBM, Ø 12.34m

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Construction companies have successfully excavated more than 320 kilometers of traffic and utility tunnel with diameters of more than 10 meters using Herrenknecht technology. In Shanghai the two world's largest Mixshield TBMs, Herrenknecht S-317 and S-318, Ø 15.43m, excavated three-lane road tunnels under the Yangtze River. The two giants finished their 7.5km drives one year ahead of schedule and the tunnels could be opened to the public in time for the 2010 WorldExpo. Brisbane is reducing above-ground road traffic significantly by investing in efficient underground infrastructure. Two Herrenknecht Double Shield TBMs (Ø 12.43m) tunnelled under the Brisbane River for the Clem Jones Tunnel and two even larger Herrenknecht EPB Shields (Ø12.45m) are being used for Brisbane's Airport Link. The world's largest tunnel boring machine, the EPB Shield for the Galleria Sparvo road tunnels in Italy with a diameter of 15.55m has successfully passed workshop acceptance at the Herrenknecht headquarters in December 2010.

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Perforating the Pacific

Fairytale projects are being put to tender. Underground defences against drought and flooding, surface to seabed drives through magnificent artificial islands and socio-economic unity through high-speed rail. The tunnelling industry in South East Asia refuses to be eclipsed by the mammoth markets in India and China. Alex Conacher explores the latest trends



Left: One of the Herrenknecht TBMs used on the Singapore DTL project

Progress of the tunnelling market in South East Asia is solid, and creatively so. Though not able to command the vast resources of China, building beyond-grand underground solutions to its problems, seen particularly in the Yellow River diversion project, or the sheer scale of India's infrastructure and hydropower ambitions, South East Asia is still rolling out a number of large-scale projects, with enough new records and 'first uses of' to steal the limelight away from the neighbouring behemoths.

Project and national trends

Malaysia

Large-scale projects are more limited in Malaysia. The recently completed 9.7km Kuala Lumpur Stormwater Management and Road Tunnel (SMART) and the major Pahang-Selangor Water Transfer Tunnel (see below) are two key projects. Both relate to water management. There has been ecological concern over the Pahang-Selangor tunnel in particular relating to deforestation.

Hong Kong

The Hong Kong Special Administrative Region boasts some of the most interesting and impressive projects in South East Asia, several of which are listed below. These range from grand flood-defence schemes to a record-breaking bridge-tunnel that dives to the ocean floor through an artificial island. Unfortunately one of these projects in particular, the express rail link (below), has resulted in anger from several groups in Hong Kong over environmental impact, as well as the accusation that it is the decision of a rich, elite minority. The dispute saw the Legislative Council Building of Hong Kong besieged by protestors in January 2010.

Singapore

With the now completed Circle Line project and the ongoing Downtown Lines (DTL) of Singapore (see below), the zeitgeist is clearly in metro works. Indeed, the Land Transport Authority (LTA) of Singapore has set a 2020 target for doubling the nation's metro network to 278km. Despite this, there is variety and scope in the Singaporean market to rival that in Hong Kong. Listed below are some ongoing key projects ranging from hydrocarbon bulk storage to water supply.

The local tunnelling society, the Tunnelling and Underground Construction Society of Singapore (TUCSS) has bid to be the host nation for the World Tunnel Congress (WTC) 2014, Leslie Pakianathan, chief resident engineer with Mott MacDonald as well as an ICE and TUCSS member, tells *T&TI*. With all of the work that is happening in this hub of South East Asia tunnelling activity, it is a strong bid and, if chosen, is likely to be well-attended.

Vietnam

Although there are a dizzying variety of projects underway in South East Asia,



some trends have emerged. Vietnam, like India, is getting into hydropower in a big way. Vietnamese heavy construction contractor Cavico is scooping up the majority of hydroelectric tunnelling work in the country.

Pick of the projects

Pahang-Selangor water transfer tunnel
The Malaysian Ministry of Energy, Green Technology and Water is investing in underground solutions to provide drinking water to a growing population. This project, running for an exhaustive 44.6km at 5.2m in diameter will provide for the needs of 7.2M people by 2013 in Selangor, Kuala Lumpur and Putrajaya, where water shortage is expected after 2012. Dealing with the hard, abrasive granitic rock of the Titiwangsa mountain range, wireless cutter monitoring is of paramount importance to the SNUI JV of Shimizu, Nishimatsu, UEM Builders and IJM Construction. The three TBMs were assembled by their respective adits and then carefully brought down the six to 10 per cent grade slopes to the NATM-excavated launch tunnels.

Excavation of the MYR 9bn (USD 2.98bn) project will complete in 2014.

Hong Kong-Zuhai-Macau bridge-tunnel
A 6.7km, 37.95m wide immersed tube tunnel, the world's longest, will form part of the 29.6km link between the three Chinese islands. An immense engineering challenge, the China Communications Construction Company will connect the tunnel and elevated bridge through artificial islands.

"Since the artificial islands and tunnel will be constructed in sea environment, it is anticipated that the technical difficulties and challenges will be of world-class level," says a spokesman for the Hong Kong Highways Department. "This takes into account the long distance ventilation and safety design, prefabrication and marine transportation of huge pipe segments, joining pipe segments under high water pressure as well as construction of the west and east artificial islands."

Early estimates place the total construction cost at USD 9bn.

Guangzhou-Shenzhen-Hong Kong Express Rail Link (XRL) tunnel
The 142km XRL includes a total of around 26km of underground track through six sections of tunnels ranging from 2.0-7.6km along the route from the new West Kowloon terminus in Hong Kong to Huanggang. Designed by Arup and Atkins, much of the tunnelling work was awarded to Leighton Asia, local subsidiary of Leighton Holdings. Hong Kong MTR and the Hong Kong Institute of Environmental Impact Assessment (HKIEIA), aided by consultant Aecom, identified the technical necessity for the consideration of unknown ground conditions along the alignment, specifically the avoidance of soft ground and the associated safety and building settlement issues. The line will be opened in phases between 2011 and 2016.

Tsuen Wan Drainage Tunnel
The 5.1km, 6.5m id single drive tunnel and three intake structures were designed by Mott MacDonald and will intercept excess stormwater to protect Hong Kong from flooding. Running 100-200m below ground, it is designed to cope with a once-in-200-years storm. Ecological requirements presented a challenge and the drain was created to only intercept water flows caused by rainfall exceeding 30mm per hour. Spiral ramp structures are being built in the shafts.

"The slope on the spirals is gentle so the water runs down into the tunnel in a smooth, controlled stream," says Sidney Lui, Mott MacDonald project manager. "That prevents pockets of air from being forced into the tunnel, which could cause water back up, and overtop the channels."

The tunnelling contract was valued at HKD 1.12bn (USD 144.17M).

Hong Kong West Drainage Tunnel
The 'longest drain in Hong Kong' achieved breakthrough in February. The 10.5-km, 6.25 to 7.25m-diameter tunnel project involved the first use, in Hong Kong, of raiseboring and reverse circulation to construct dropshafts, of which there are 32, as well as 34 intakes. The raiseboring method was employed to reduce disturbance at the surface. The main tunnel was excavated by two TBMs, with horizontal adits by drill and blast.

Like the Tsuen Wan Drainage Tunnel, it will protect Hong Kong from stormwater surges and flooding.

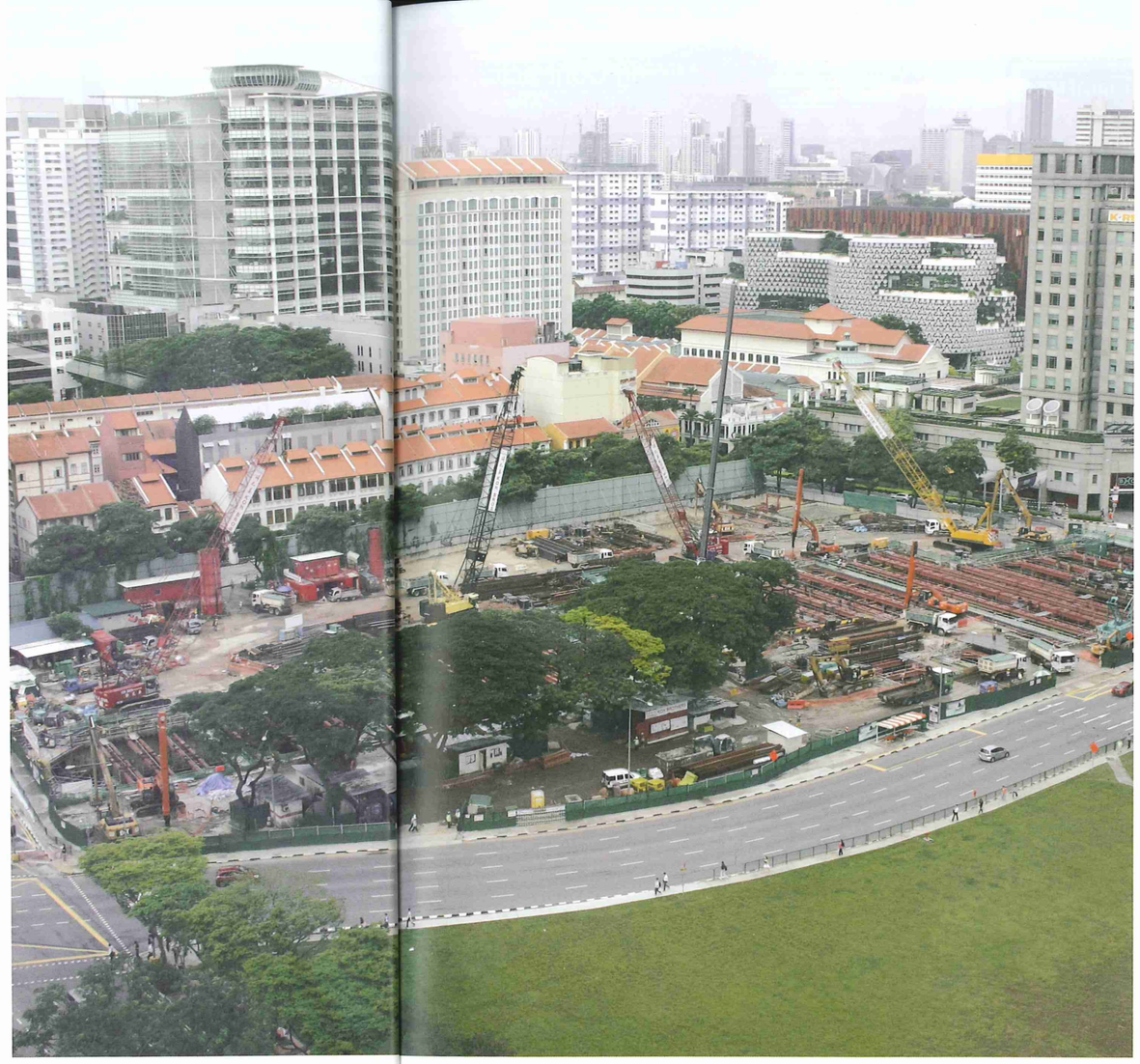
The project cost total is around HKD 3bn (USD 385.4M) and construction should finally complete in late 2011.

Downtown Line (DTL)
The driverless DTL metro of Singapore will serve half a million passengers daily and run for over 40km when completed in 2016. Broken up into three phases, tunnelling on the first has already been completed. The third stage alone requires 28 TBMs according to Ow Chun Nam, president of the TUCSS. "The entire DTL is expected to become operational in 2018," says Chun Nam, president of TUCSS.

Herrenknecht, which is supplying 10 of the 19 TBMs for the DTL 2 project tells *T&TI*: "Mixed ground conditions pose different problems and challenges. To avoid clogging while still being able to break the hard Bukit Timah granite, we designed a cutting wheel equipped with heavy duty disc cutters and more gauge cutters in order to perform optimally in the variable ground conditions."

In addition to this, eight of the machines are fitted with double-chamber airlocks in order to reduce downtime during the regular cutterhead intervention and cutter tool changes.

Jurong Cavern
The first underground hydrocarbon bulk storage facility in South East Asia is being constructed in Jurong Island, Singapore. The contract was awarded to Hyundai E&C in 2009 for 8km-long tunnels and five caverns from the two completed access shafts. Each cavern is made up of two storage galleries of 20m(W) x 27m(H) x 340m(L). The overall storage capacity is approximately 1.47M cubic metres. Phase one of this project should be completed by 2014.

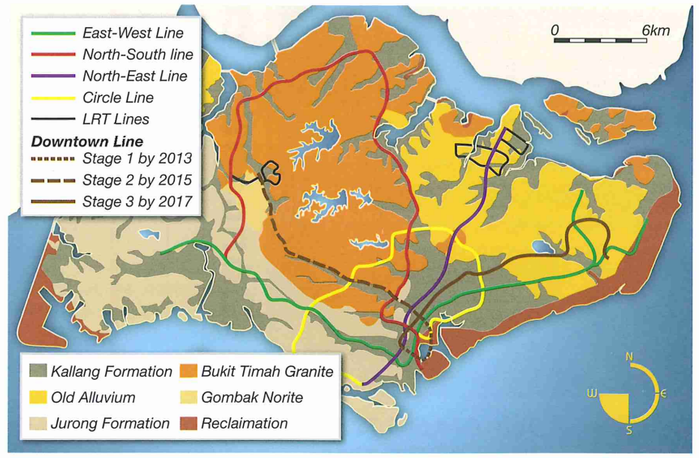


Left: **Construction site for first TBM launch on the Singapore DTL phase two**

Newater Infrastructure Plan Transmission Mains Extension
"The Public Utilities Board (PUB) is undertaking a water supply programme known as the Newater Infrastructure Plan Transmission Mains Extension," Chun Nam tells *T&TI*. "This project is to extend the Newater transmission network to Jurong Island, to meet the increasing demand of industries on Jurong.

"It consists of the installation of approx 5.5km of 2.2m-diameter and 9km of 1.6m-diameter Newater pipelines on the mainland and Jurong Island by surface laying and pipe jacking methods.

"The construction of an approximately 3km long, 6-metre diameter undersea tunnel, with twin 2.2m-diameter pipelines from Jurong Island to mainland Singapore forms part of this project. The contracts were awarded in 2010."



Right: **Map of Singapore showing main railway network and geology**

Marina Coastal Expressway
The dual five-lane, 5km long Marina Coastal Expressway (MCE) will be the tenth expressway in Singapore when completed in 2013. It will form a key element of the strategic island-wide road network to support the long-term growth of Singapore. In January 2009, the Land Transport Authority awarded the last of six major civil construction works contracts for the MCE. Works for the MCE commenced in April 2009 following the ground breaking ceremony at Marina South.

Mott MacDonald, in a design consultancy role with construction responsibilities, says that a particular challenge comes from the need to tunnel under the seabed from the Marina Barrage, a dam that at times needs to be opened to allow water to flow out.

Sentosa Gateway Tunnel
"LTA will be building a new 1.3km two-lane road tunnel to deal with expected growth in traffic from the continued development in the Sentosa Island and Harbour Front areas," says Chun Nam.

"The Sentosa Gateway Tunnel will complement a suite of road improvement measures that LTA announced in February 2008 to cater for the increase in traffic demand from the Resorts World development at Sentosa. Construction of the tunnel is expected to complete by end of 2015."



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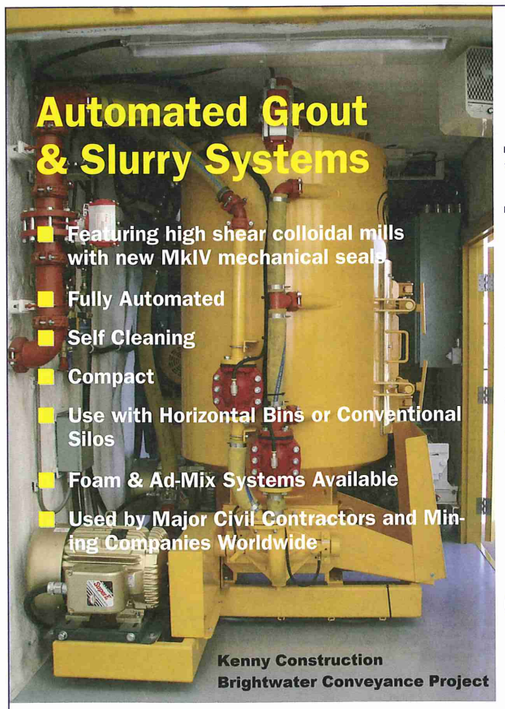
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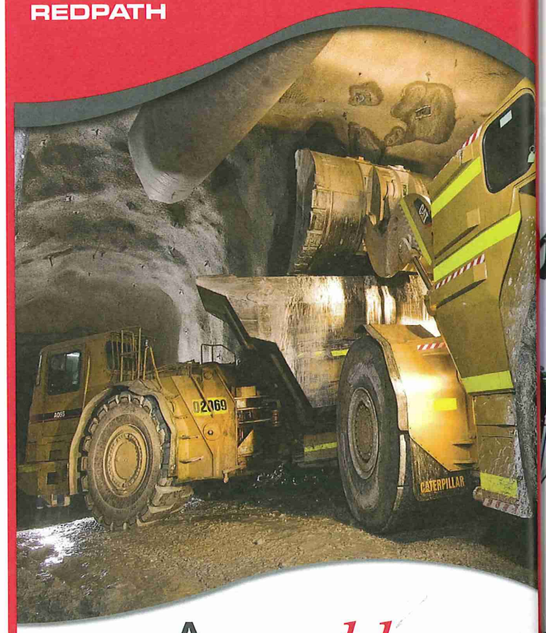
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One of two drill jumbos used on the project's 2.5km twin bore tunnel

Burrowing under Berapit

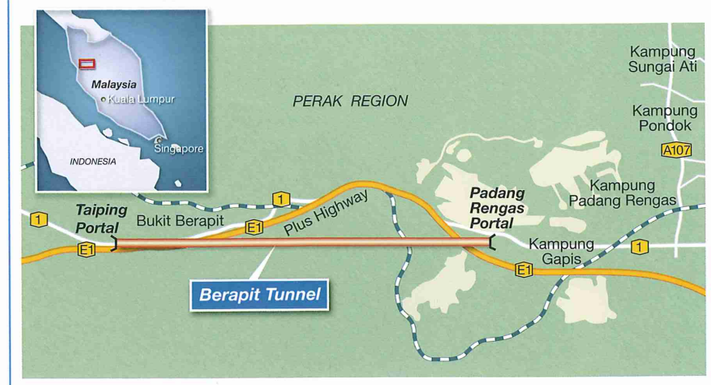
Workers on South East Asia's longest drill and blast rail tunnel are finishing works. Jon Young looks at the challenges the project faced

Workers are racing to complete the longest drill and blast rail tunnel in South East Asia ahead of its scheduled opening at the end of the year. Blasting was completed late last year on the 2.5km, twin tube Berapit tunnel in Malaysia. The tunnel is a key feature on the electrification and double-track upgrading of the 329km Ipoh-Padang Besar railway line and, when coupled with the shorter (390m) Larut tunnel, will replace four tunnels and two bridges on the existing single track.

Breakthrough on the twin tunnel was completed in November last year and workers are now finishing the waterproofing membrane installation, casting the final 500mm concrete lining and fitting drainage, ventilation and rail track for opening at the end of the year.

Location

A joint venture between two Malaysian heavy civil engineering contractors, Gamuda and MMC, was awarded the contract to electrify and double-track the 329km Ipoh-Padang Besar railway line at a



Above: Figure 1, the twin bore alignment twice has to pass under the Plus Highway and once under a trunk road

fixed cost of MYR 12.5bn (USD 4bn). The project will allow train travel up to 160km/h.

Gamuda head of tunnelling Don Hall explains the Berapit tunnel forms part of the northern stretch of the line running along the Malaysia-Thai border as part of the planned rail link running from Singapore to Kunming in China.

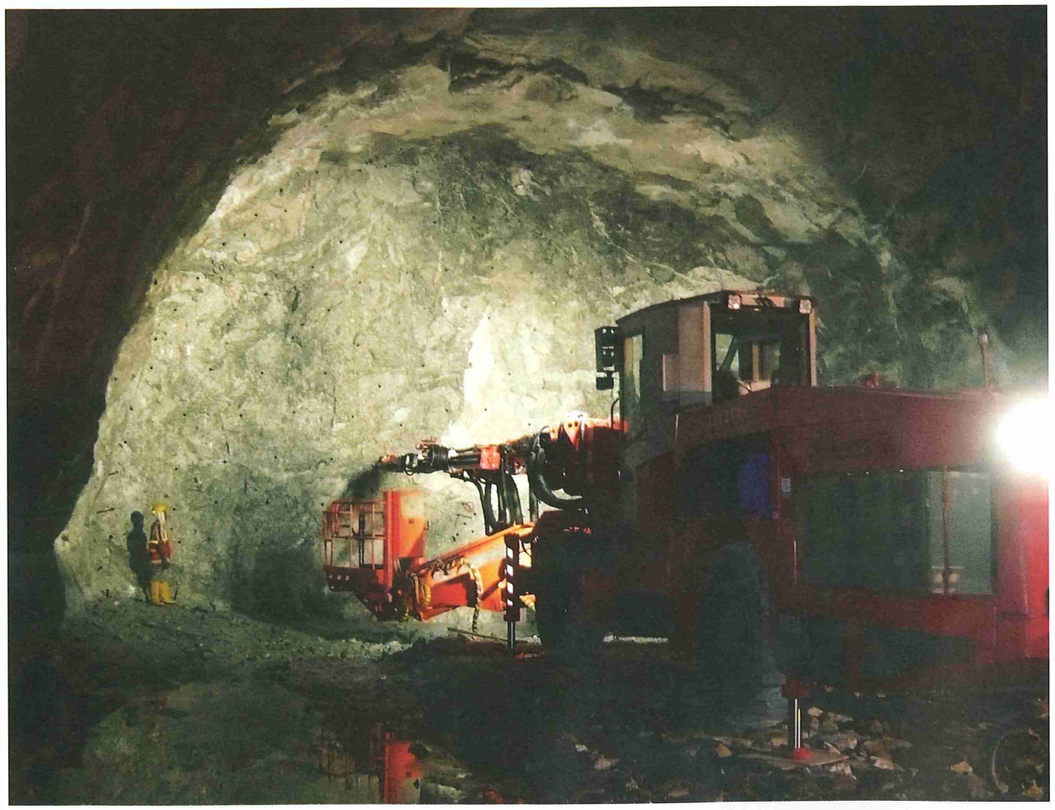
The Berapit and Larut tunnels are situated between the towns of Padang Rengas and Taiping on the edge of the hilly Perak region. The Larut tunnel sits at the northern end of Perak and 10km to the south is the Berapit tunnel. The new alignment cuts under the existing single track as it twists and turns though the Perak hills. The tunnels also have to twice pass under the Plus Highway and a trunk road.

Portals

At either end of the Berapit tunnel the portals offered challenges. Hall explains that the western Taiping portal required diversion of the federal trunk road and of a river for a length of about 1.5km. Land acquisition for construction of the south portals was a key issue with numerous owners of small land parcels creating a complex matter to resolve.

To start excavation of the Padang Rengas portals, massive earth works were required as well as diversion of a stream, which in storm conditions would have caused flooding of the works. The initial 150m advance of tunneling was in very soft, poor ground conditions in which high water flows, several large boulders, and

Below: The bores were excavated using two Sandvik jumbos, one of which was also used on the shorter Larut Tunnel



alluvium and highly weathered granite were encountered.

To reduce the water in flow, dewatering pipes were drilled from within the tunnel and wells were installed on the surface.

Pipe umbrellas were installed for tunnelling through the highly weathered granite residual soil. These comprised 114mm diameter by 10mm wall thickness steel pipes, installed on a 3m overlap.

The pipes were inclined at four degrees and were inserted at spacings of 300mm, 400mm and 500mm depending on the quality of the ground. Each set of 10 pipes installed was fully grouted before the next set was inserted.

Fibreglass face nails were also used to increase stability and in extremely poor ground conditions, the pipe umbrella overlap was increased.

Excavation of a top heading was then carried out in 1m rounds with steel ribs and shotcrete support and the bench was excavated once the tunnel was in competent granite. Boulders, when encountered, were either removed mechanically or blasted.

The twin tunnels were constructed about 80 per cent by drill and blast with the balance by cut and cover. The tunnels encountered varying geology ranging from extremely hard granitic rock to residual soil and included unpredictable interfaces between rock and conglomerate.

Drill and blast

Once into competent ground, drill and blast was used to advance the tunnel. Two Sandvik DT820-SC tunnelling jumbos were selected for the project. The jumbo drills were hydraulic two-boom machines able to drill a cross-section of 12-110m². They were equipped with cabins and TCAD instrumentation, providing drill bit positions and a feed direction measurement system. One jumbo was deployed for each tunnel, and each was equipped with a 45mm diameter Sandvik RT300 button bit and 4.9m T38-H35-R32 drifter rods.

Tunnelling work began on 4 October, 2009 by main contractor MMC-Gamuda, with OTA Tunnel Squad as tunnelling sub-contractor. The first breakthrough took place on 1 October, 2010, with the second breakthrough following exactly a month later, on 1 November. The contractor completed tunnelling work a total of 55 days ahead of schedule.

At a height of 8m and a width of 7m, the tunnels have a face area of between 50 and 60 sq m. The two bores were approximately 20m apart.

Kana, managing director of OTA Tunnel Squad, says the tunnellers carried out the drilling and blasting on the full face cross section. Hall adds that the drill pattern comprised a total 134 drill holes of 45mm diameter plus a set of 110mm diameter burn holes. Emulex 150 cartridges and Bulk Emulex 1000 UG explosive was used. Emulex is an emulsion explosive consisting of droplets of saturated oxidizer solution tightly packed in a homogenous fuel mixture. A typical blast consumed about 365kg of explosive and 134 detonators. About 400t of explosive was used on the twin Berapit tunnels.

The jumbos took around one minute on average to drill 1.5-2m of rock, which was granite of greatly variable hardness, ranging from 50 to 200MPa with the hardest section being a stretch of about 300m.

Working on a 24/7 basis and using ANFO explosive cartridges, the contractor operated two shifts with an average blast cycle of 1.5. Advance per blast was between 3.8m and 4.5m, with the highest advancement achieved in a one-month period being 516m.

The tunnel also has nine cross passages, 350m apart, and 30-35 sq m in area.

Kana says the drill bits were rebored on site after between 300 and 350 drilled metres, a process that added between 10 and 15 percent to the service life of the bits. Total volume of rock and soil excavated on the two tunnels was 1.32Mt and the total tunnelling days amounted to 1,032. Peak manpower on site was 240.

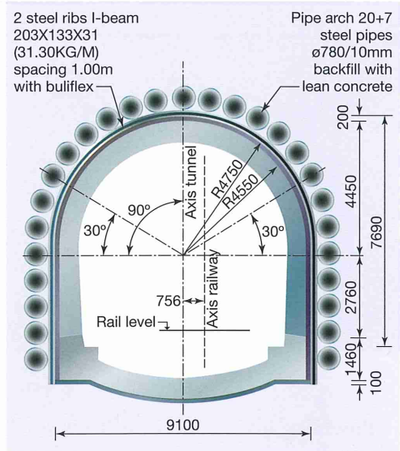
Crossing Plus Highway

The Plus highway underpass offered the contractor a complex challenge, explains Hall. The crossing required construction of pipe arch presupport for each tube. To make way for this work an existing 3m by 3m drainage box culvert had to be demolished and the drainage flow of a river and several streams diverted.

Hall says that drainage calculations revealed that the box culvert needed to be replaced by three 3m diameter pipes microtunnelled under the highway. With only 4m overburden, this was celebrated as a major achievement for the project.

The three pipes were constructed using a bentonite slurry microtunnelling/ pipejacking machine, with the slurry pressure being used to support the face and to avoid any resultant surface settlement of the highway.

With no granite found during site investigation, a RASA 3.5m diameter machine with soft ground cutterhead was chosen to work through compacted fill and alluvium. Constant surface monitoring was



Above: Figure2, crossing Plus Highway used a pipe roof to minimise settlement

carried out during the drives and only minimal settlement was recorded.

Once completed and the river and streams diverted to their new course, the existing box culverts under the highway were demolished and back-filled to allow for the construction of the two pipe arches.

At another passing under the Plus Highway, extremely low cover of only 3m required extra support measures to avoid settlement. The solution was to pipe-jack an arch of presupport. Each arch comprised steel pipes of 6m long by 780mm diameter by 10mm wall thickness welded together for each 90-92m long drive. Once installed, the full pipe length was backfilled with lean mix grout. A total length of 4,400m of pipe jacking was installed to presupport both tunnel tubes.

Hall adds that unfortunately the geological condition varied with granite at one end of the drive coming to within 2m of the crown.

Due to the small 780mm diameter of the machine, disc changes were not be possible and there was the possibility that excessive wear could bring the machine to a standstill with retrieval unlikely from under the highway.

To avoid this problem, a Herrenknecht-manufactured AVN 500 microtunnelling machine was chosen with a sacrificial skin that upgraded to an AVN 600 for the correct cutting diameter.

Should the machine be unable to continue, the outer ring of the cutterhead and the sacrificial skin could be discarded and the main body of the machine pulled back through the pipe.

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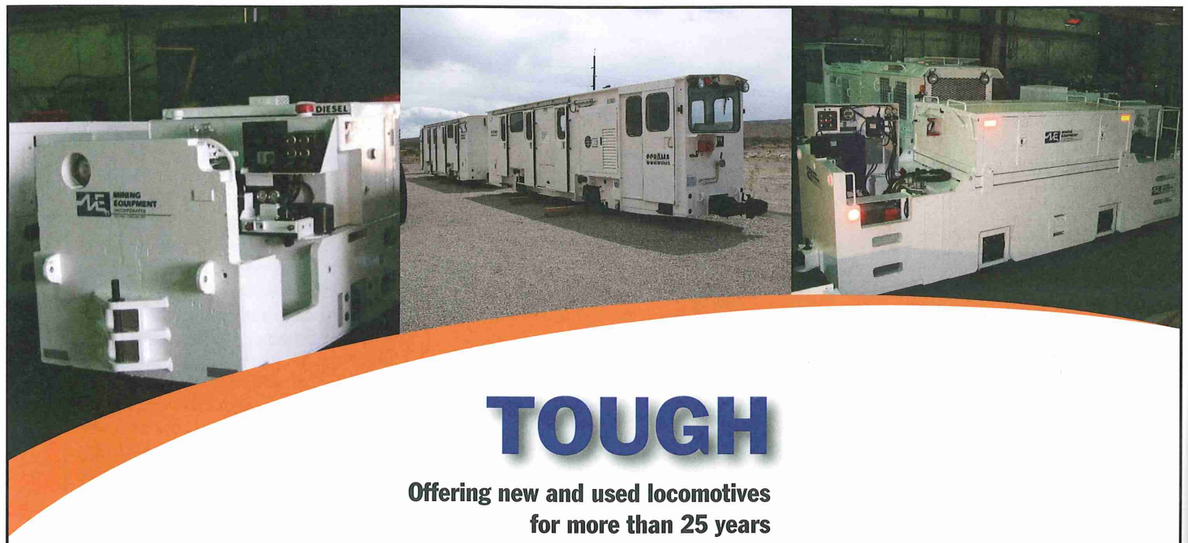
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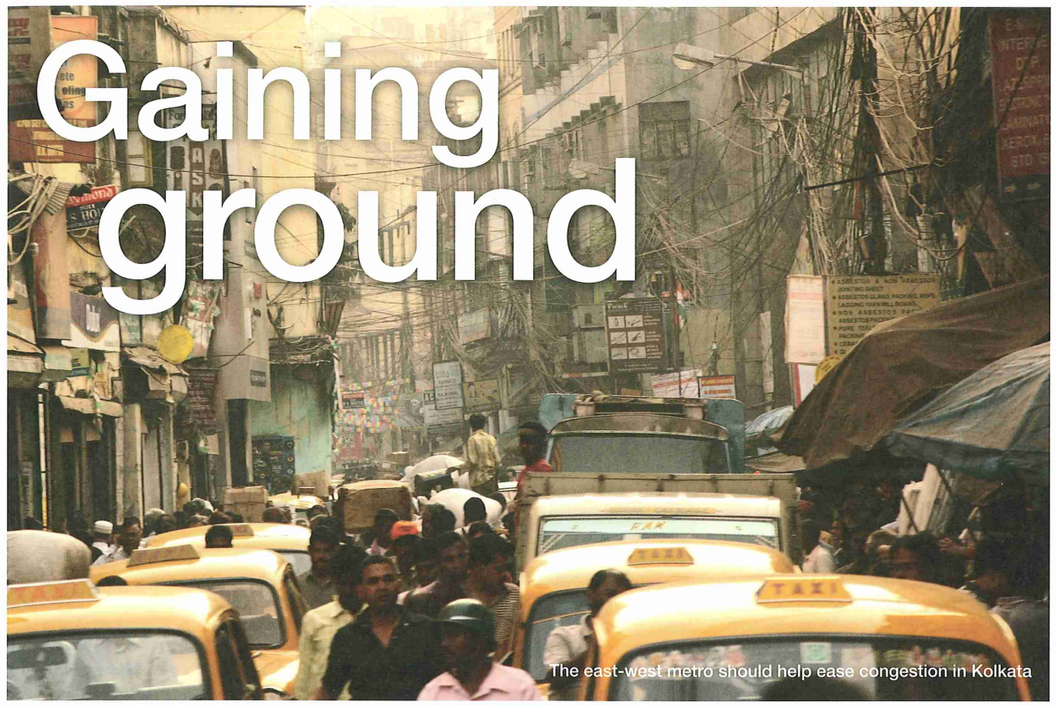
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Gaining ground



The east-west metro should help ease congestion in Kolkata

Congested streets, dilapidated buildings, limited access to the worksite, delays in gaining land and a river crossing are but some of the challenges facing contractors on Kolkata's east-west metro line. Jon Young reports from site

Kolkata, formerly Calcutta, was once the Indian capital and a centre for modern education, science, culture and politics in India. But by 1911 under British rule the capital had been moved to New Delhi as nationalism grew in the region. Post independence, the city witnessed economic stagnation for nearly 50 years until at the turn of the century an economic rejuvenation led to an acceleration in the city's growth.

Now as the capital of the West Bengal state, Kolkata is the commercial capital of eastern India. Located on the east bank of the Hooghly River the city's metropolitan area has a population exceeding 15 million, making it the third most populous metropolitan area in India and the 13th most populous urban area in the world. The city is also classified as the eighth largest urban agglomeration in the world.

But like other metropolitan cities of India, Kolkata continues to struggle with urbanisation problems such as poverty, pollution and traffic congestion.

Relieving congestion

Heavy traffic and congested streets are hindering further economic growth in the city. Formerly three lane highways have been encroached upon by shop fronts and market traders, reducing traffic to a single lane.

To tackle the problem, the government put forward a plan to expand the city's metro network, which at present has just one line running north-south that was built and extended over the past 30 years.

The new 14.67km east-west line will carry traffic between the busy Howrah Railway Station in the west, which serves continental rail, Central Station, which connects with the existing north-south line, and Sealdah Railway Station in the east, which serves local rail. Shortly after Sealdah the metro line becomes elevated and continues on to Salt Lake Stadium and Central Park. The line is 8.90km underground and 5.77km elevated (see figure 1, p46).

UG1

The underground section has been broken into two contracts. UG1 runs from Howrah Maiden in the west, through a crossover box to Howrah Station, under the river to Mahakaran Station and ends just before Central Station. UG2 picks up with Central Station, runs through Sealdah Station, into a crossover box before Phool Bagan and ends at the interface with the elevated section.

Paul Verrall is senior manager for tunnels with the Transtonnelstroy-Afcons joint venture that was in March 2010 awarded contract UG1. "The program is to launch the TBMs by August/September but I don't think it is realistic," says Verrall. The project has hit difficulty because land needed to begin construction works has not been handed over by the client. The client has

had trouble negotiating with the community on the hand over of the land.

The EPB TBMs for UG1 will be launched from the crossover box between Howrah Maiden and Howrah stations, into the silty clay ground (see Geology box, p48). But only a fraction of the land needed to excavate the box has been handed over. Verrall explains, "The problem at the moment is we only have one small section and so we can only do one side of the box wall. The other side is in the middle of the street and on the other side of the street are a load of tenants that have to be removed by the authorities."

The city is due to hold elections in May, which could see a new government taking charge of the project. Contractors across the project hope that the land issue is resolved ahead of the elections to avoid further delays.

"If we were given all the land as per tender we would need six months to do the diaphragm walls, put the shaft down; we'd need six to eight months to do the full site installation and we'll be ready to launch the TBMs. We would need anywhere between eight and 12 months from total handover to when we start the TBMs. It's a lot of work," says Verrall.

Howrah and under Hooghly

When the 6.35m Herrenknecht TBMs do finally get going they will launch out of the crossover box toward Howrah Station and the Hooghly River. From launch the TBM will have approximately 700m to drive until it reaches Howrah Station on the riverbank. Verrall says, "we need the first 100-150m for the assembly of the TBM and the commissioning. Once one TBM is away we'll start commissioning the second. They should run with approximately a 50-ring lag between them.

"Howrah station definitely will not be done when the TBM arrives. So we need to have the two diaphragm head walls done and we will just pass through."

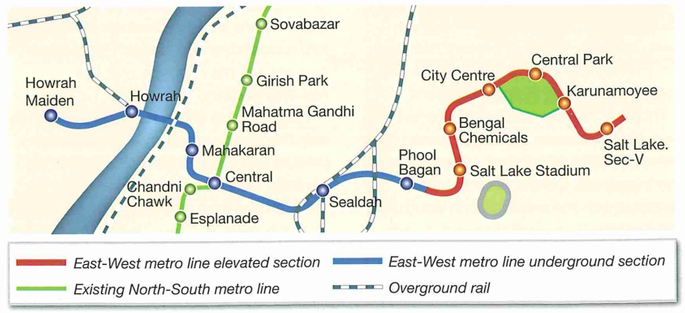
As the TBMs exit the east side of Howrah Station the depth of the base slab will be about 25m and the overburden approximately 18m. "We'll dive down on a three per cent gradient under the Hooghly River," says Verrall, "where we'll have an overburden of 40-45m – about 20m of soil cover and 20m of water cover."

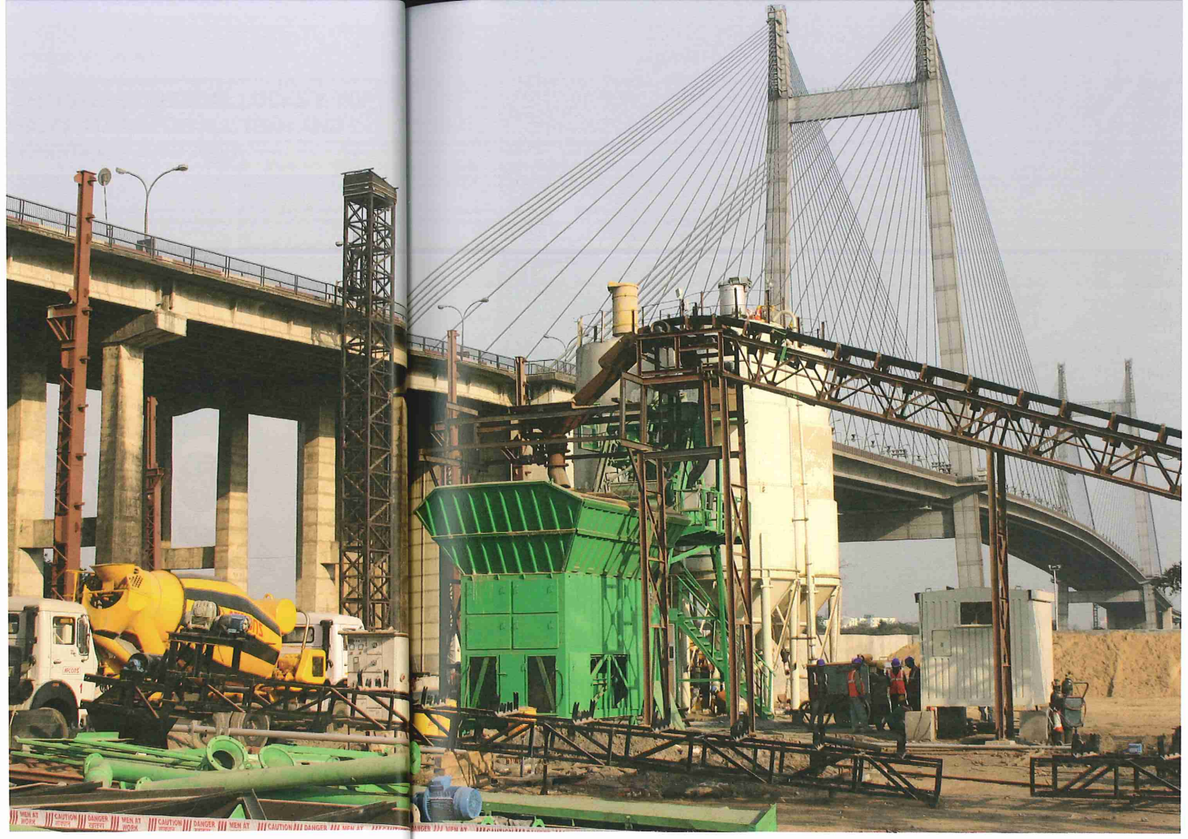
Verrall doesn't foresee any problems with crossing the river but adds, "once we get under the river I have no intention of stopping whatsoever, we will keep going until we are out the other side." So before Verrall takes the dive under the river he will first make sure there is nothing that can stop the TBM once it gets going.

Muck disposal is vital to the approach Verrall takes to the crossing. The crossover box where the TBMs launch from is the logistics hub for the contract. Everything going in or out of the tunnel must pass through this box. But the box is not ideally located; it is locked in a congested area of the city with narrow, overcrowded roads located on all sides.

At the peak of TBM production some 1,800-2,000cu m per day will need to be removed via the crossover box and, due to heavy traffic conditions during the day, this all must be done at night. "Based on that, you need about 120 trucks to carry away the earth and two excavators to load the trucks otherwise you'll never be able to load them fast enough" says Verrall.







Below left: Figure 1, alignment of the east-west metro; Above: The UG1 work site sits in the shadow of Howrah Bridge

He adds, "Before we get to the river both TBMs should be under full production and we'll see how the logistics are working. If we are not able to keep up with muck removal because of traffic congestion in the city, the TBM that is not under the river will be slowed down completely and we'll continue with the one under the river at full production. When out the other side of the river the TBM will slow and the second TBM will make its crossing at full production. If everything on the logistics is running very smoothly then I'll let one get halfway across the river before the second enters the crossing."

They will run for six days a week with two 12-hour shifts and on Sundays will shut down for maintenance. The TBMs will be set up for one ring an hour and should be capable of achieving those speeds but removing the muck from the site is going to be the main barrier to advance rate. Muck removal is often the bottleneck on all city projects. "We need to advance 12m per day to keep on schedule. Each shift could advance 15m, but achieving a 30m advance rate a day is not possible because we could never get the excavated material away from the site." Cutting just 15 rings per day will produce 2,200cu m of muck.

Each ring is made up of five segments and a key. A ring's internal diameter is 5.5m and it is 275mm thick. It is a universal ring constructed with M50 concrete, 1.4m wide and bolted together. An EPDM gasket with a separate hydrophilic strip will be used to seal the gap between segments.

Lining up

When the TBMs pull up and out of the river crossing they will need to turn south for Mahakaran station and then east out of Mahakaran for Central Station. Mahakaran Station is not expected to be constructed before the arrival of the TBMs so the operators will plough through the head walls when they reach them.

There are several buildings in the region of Mahakaran Station and Central Station that are dilapidated. Some of the oldest buildings are thought to be found on piles about 25m deep. The overburden on this stretch is only 15-18m.

The tunnel alignment through these turns has been restricted by utilities, the position of the stations, narrow roadways and sensitive buildings. The combination has forced the TBMs to make some tight curves along the route. In revisiting the alignment the contractor is hoping to renegotiate these radiuses.

"The TBM will theoretically allow a radius of 220m, but that is theoretical, I don't believe that you would maintain 220m. If a mistake gets made or you encounter some kind of steering problem you cannot recover," explains Verrall. "Currently the alignment demands a 220m radius. So you are totally on the limit. The ring design, with a 50m taper will allow a radius of 170m. We are asking them to realign the curves to a radius of 230m to give us some more breathing space.

"With all of these alignments there is a safety factor. On the horizontal alignment the tolerance is 100mm so to be on the safe side when we come into the curves we'll start to steer on the inside of the curves staying within the 100mm tolerance." This gives the TBM operator a greater margin to play with should anything go wrong.

Verrall adds, "For the realignment we cannot move the stations back or forth but we can maybe move the stations a little to the left or right to make room for the utility diversions. The problem here is how to do it. If we keep a narrow station box, which will allow them to do a utility diversion, and increase the radius, it brings the two tunnels very close together, just 1.5m in separation. That's much too close for comfort. Usually we would want at least one and a half diameters between the two."

The closer the two tubes are the more careful the contractor has to be with the pressure exerted on the ground. "The earth pressure in this case will not only be calculated upwards but also sideways. And you have to be careful of over excavation, that you are not sucking away the material from the tunnel next to you," says Verrall.

Once successfully reaching Central Station the TBMs could be removed through the station or drawn back through the tunnel.

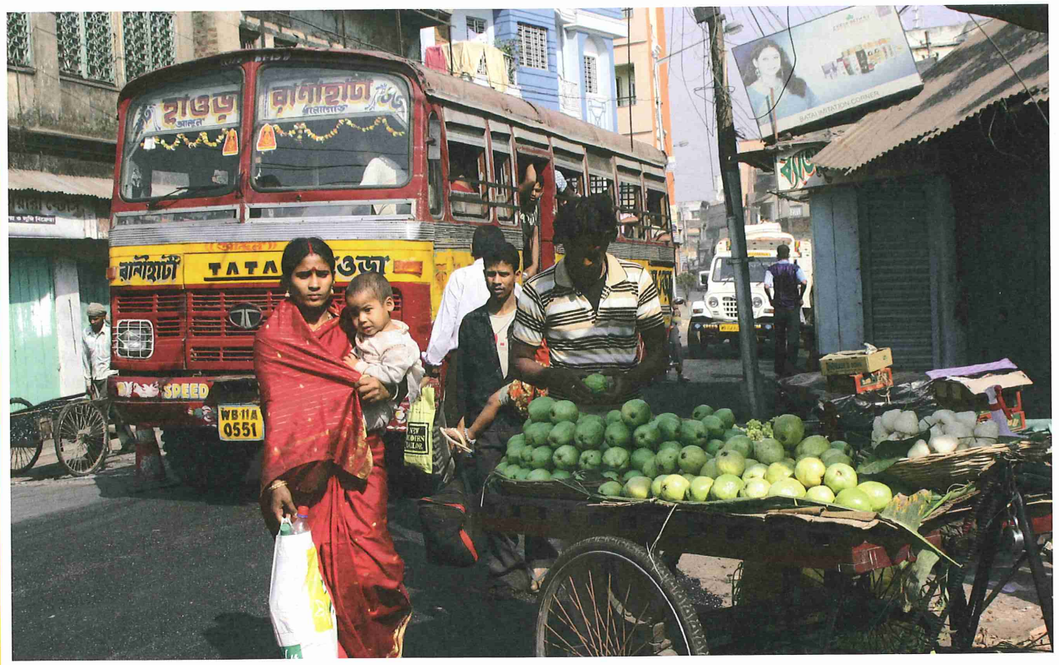
UG2

Central Station marks the interface between UG1 and UG2. A joint venture of ITD and ITD-Cem was awarded the contract for UG2 in February 2010. General consultant to the project is the Mycel joint venture of Maunsell (now Aecom), Yachiyo, CES, Egis and LHPA.

Chris Schulz of MYCEL explains that as with UG1 the stations on UG2 will be cut and cover with diaphragm walls. "Pool Bagan and Seadlah stations are each two level stations and will be 15-18m deep. Due to soil conditions at Pool Bagan the diaphragm walls will be deeper than

Below: Excavation work has begun on a small section of the crossover box





originally planned. Central is a three level station excavated to a depth of 25m. The station boxes are 220m long and 21m wide with 1.2m thick walls."

UG2 is also facing difficultly with gaining land from the client but Schulz was confident it would not affect the schedule. The TBMs will launch out of the crossover box located between Sealdah and Phool Bagan stations.

"The most difficult portions of the project will be passing under the Seadlah railway lines and passing under the north-south metro central station," says Schulz.

Engineers constructing the north-south line some 30 years earlier had planned for the possibility of an east-west line and installed diaphragm walls under the station. They had left an available space of 6m wide but in fact the new project now needs a space of 12m wide and so these diaphragm walls are causing an obstruction, making the crossing quite complicated. "There are as-built drawings showing the location of walls but the reliability of these drawings is not known," says Schulz.

He adds, "There is very little cover between the top of the new tubes and the north-south line central station above, approximately only one meter of cover. The contractor is likely to use pipe roofing to secure this for the drive but one possibility is removing that metre of material as the area already has to be excavated ahead of the TBM to remove the diaphragm walls."

Due to delays a definite deadline for tunnel excavation is unknown. But the project is scheduled to open to the public in 2014.

Above: Market traders flank the worksite creating logistical challenges when trucking muck

Geology

Boreholes were taken along the alignment and seven ground types were identified along the alignment:

Strata I – Fill/ man made ground of up to 5m in thickness is found at certain sections of the alignment composed of brick bats, silty clay with coal ash.

Strata II – Underlying the fill, the ground condition in the site comprises mainly brownish grey to greyish brown silty clay to loose clayey silt.

Strata III – Consists of very soft/ soft to medium, grey to dark grey, silty clay/clayey silt with decomposed/semi decomposed wood pieces and peat. Thickness of this layer varies from between 5m to 12m.

Strata IV – Generally made up of medium stiff to very stiff, bluish grey silty clay to clayey silt with calcareous nodules and pockets of silt sand.

Strata V – Consists of stiff to very stiff, mottled yellowish/light grey/greyish yellow silty clay to clayey silt with blue/brown and rusty spots.

Strata VI – Is of medium dense to dense, mottled yellow and yellowish brown micaceous clayey silt sand to fine sand/sandy clayey silt with silt concentration.

Strata VII- Made up of mottled brown and grey, greyish brown silty clay with ferruginous/calcareous nodules. Thin lamination of silt/fine sand also encountered.

Chris Schulz of the Mycel joint venture adds: "Ground water is between 0 and 3m below ground – hydraulic pressure but no volume because of the clay soil. There may be some water ingress issues when passing through the fine sands. We are not expecting any gravel layers so are not expecting any rushing water."




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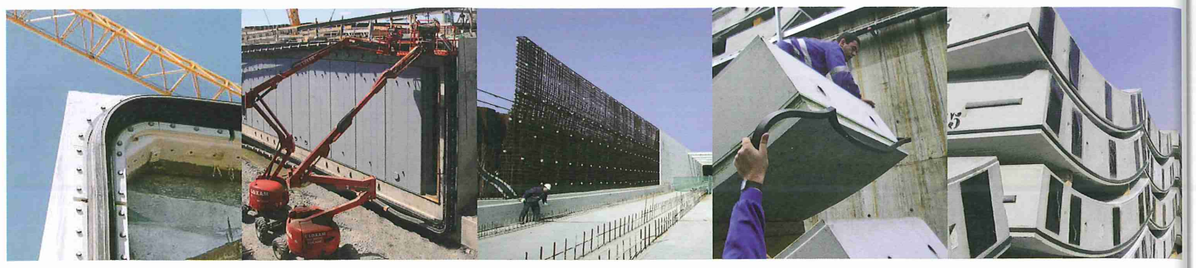
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Choices for excavation

Selection of excavation method is one of the most complicated and vital decisions in tunnel construction planning. It cannot even be considered in isolation since there are also complex relationships with other functions and factors such as structure – support introduced and natural – groundwater, surface settlement, safety, and useful tunnel life.

Developments over recent years in tunnel excavation methods have greatly increased the capabilities of tunnelling overall, but they have rarely simplified choice, depending on project conditions.

While there are enough considerations to fill a small library, modern developments have been focussed on important factors such as:
1) Tunnel sectional area and shape;
2) Tunnel length in a single drive;
3) Progress rates;
4) Accuracy of alignment and profile;
5) Disturbance of the surface, such as settlement and vibration;
6) Handling a variety of ground conditions;
7) Presence of groundwater;
8) Project cost control;
9) Operational safety.

The major methods that have been tackling these requirements are:
1) Drill-and-blast;
2) TBMs;
3) Roadheaders;
4) Open-face conventional mining.

In this two-part review *T&TI* is concentrating on the first three, since efficient conventional mining is mainly a matter of good support procedures, with excavation carried out by normal earthmoving techniques. Some more specialised plant models have been developed for tunnelling, based on standard models, to cope with restricted space for manoeuvring and the harsher environment, but their use has been limited. The broad range of possibilities within conventional excavation includes hydraulic excavators and hammers.

The second part will cover some of the factors involved in choosing the TBM (full-face mechanised excavation) method, and the choice of TBM type, and try to draw some conclusions. This month we cover drill and blast and roadheaders.

Bigger and better?

Some technical developments have intensified competitive claims between promoters of the methods involved. For example, now could be described as the age of the monster TBM as manufacturers, and clients, compete to 'go bigger' more often, whereas project developers were formerly satisfied with multiple tubes of more standard size to accommodate needs. The chief users of the largest diameter TBMs are multi-lane highway projects, especially with accommodation for escape routes, but they have also been used for water projects.

Fans of drill and blast and conventional excavation have questioned the desirability of a large-diameter closed-face system in mixed ground, especially when 'something goes wrong' and face intervention is needed, citing the advantages of being able to see what is going on. Away from the face the comparatively systematic support procedures of TBMs in erecting the tunnel structure have to be compared with the usually more tailor-made (and thus more human-error-prone) methods of drill and blast and other open-face methods.

Ground control is the main concern when considering interaction with the surface, but excavation vibration, mainly in urban areas, is increasingly a 'battleground' between the main excavation methods. Naturally it is also of public concern although its affects can often be exaggerated.

Continuous mechanical excavation, as with TBMs or roadheaders, should produce relatively low vibration – arguably much less than the public perception of how they may be affected, unless a rock tunnel is particularly shallow. The vibrations generated by blasting can be large, but explosives manufacturers and consultants have been making major efforts to reduce vibration measured at the surface.

There is a tendency for all three main types of tunnel excavation equipment to be equipped with additional functions, chiefly for additional support needs or probing, especially for rock bolting, grouting and spraying concrete.

Accuracy

Other than a simple reference laser beam, more complex laser guidance used to be the reserve of TBMs, but now blast-drill jumbos and roadheaders can be equipped with systems that not only ensure accurate alignment of excavation progress but incorporate pre-programmed profiles that assist operators in avoiding over- or underbreak. Blast hole rig systems include pre-designed drill patterns that can, if required, be employed as the basis for practically fully automatic operation.

Both drill-rig and roadheader profile controls may also incorporate geological information, which is likely to be more useful for drill-rig operators to predict drilling performance and blast requirements. While all main excavation methods benefit from consistency in geology, both longitudinally and across the face, advances in the use of earth-pressure-balance TBMs (use of additives, better control systems and increased tolerance of higher groundwater pressures) have made this method particularly tolerant of mixed ground, though not infallible.

Flexible shape

With the exception of certain designs produced for conditions in Japan, reportedly prompted by the high costs of surface disruption, land values and the reaming head produced by Aker Wirth, TBMs are intolerant of changed section shape, meaning that junctions, stations, cross-passages, etc have to be excavated separately. Drill and blast and roadheaders are relatively adaptable to changed sections and ancillary work, although the bigger the equipment, the less this is so. There is a natural balance between flexibility and potential productivity in method choice.

Cost vs. distance

It's a well-established principle that the financial investment in tunnel excavation plant must suit the length of the tunnels to be driven. Thus, although TBMs are generally the more expensive, the project progress achievable makes the investment worthwhile if there are time restrictions on project completion. It is generally accepted that drill and blast cannot compete with TBMs for drives longer than 3km.

The relative competitive positions of drill and blast and roadheaders are closer, although the latter can offer an almost continuous process whereas drill and blast is cyclical by nature.

Maurice Jones

The more accurate good neighbour

It's long since drill and blast lost its exclusivity for hard-rock tunnelling, but, in various forms, the method still retains the majority of the market by constant development to meet the usual and new demands. Maurice Jones reports

At a time when you might think the technology should be in maturity, it is still being developed in many respects. This is a remarkable testament in itself to the efforts of drill-and-blast engineers in meeting the competition with mechanical excavation in advance rates, as well as increasing environmental concerns. It also shows that a well-managed cyclical process can compete with a more continuous one in many circumstances.

Starting point

Jorma Kalliomaki of Sandvik Mining and Construction says that the starting point for the most economical tunnelling method selection has to be the ground or rock condition (see figure 1, right), especially in terms of strength and stability, but also abrasivity. The size of the project, in all dimensions and locations, is also a crucial factor. The diagram indicates the capabilities of and relationships between three popular excavation methods for medium-to-hard rock. Drill and blast has a wide possible application in harder rock in various states of stability. Despite improvements in roadheader capabilities the diagram still shows a major advantage in hard rock.

Method/criteria	Drill and blast	Roadheaders	Hydraulic hammers
Ground conditions	UCS > 20MPa – rock	UCS < 150MPa – rock inc. mixed ground	UCS < 150MPa – fractured rock
Operation	Versatile. Fast start up. Cyclical.	Continuous method	Fast start-up. Continuous method.
Working environment	Vibration. Noise.	Dust (requiring suppression/extraction)	Dust
Investment costs	Relatively low	Medium levels	Low

Above: **Table 1, selection criteria for drill and blast compared to roadheaders and hammer excavation (Sandvik)**

Use of hydraulic hammers is only really effective in looser, fractured rock, but security considerations about explosives in some countries has prompted their use in preference to blasting. They can also be useful for small sections such as pumping chambers and sub-stations.

Once the most economical method has been chosen, it may be considered that the project schedule, such as related to financial return on investment and cashflow, may require a more productive method, if any, that may be less economical.

Dimensions

Drill and blast can be applied to a wide range of dimensions, depending on the size of the drilling equipment chosen. A limit for mechanised drilling at the lower end is determined by safety considerations when working around machinery for drilling and loading out in a narrow space. Thus the smallest possible mechanised drill and blast tunnel is about 2.5m by 2.5m (although maybe non-mechanised drilling could be used).

The largest section that can be covered by a drill-rig from a single lateral position is about 200m², although rigs could be used in parallel or in sequential excavation. Whether a large number of booms (up to four are available on mobile rigs) is desirable is a subject of much debate between contractors. Clearly an efficient computerised operational system can make the best use of the maximum number of drills, but some contractors question whether a fourth produces much advantage in most tunnelling.

Rock condition is an important consideration in deciding whether or not to use drill and blast since movement on joint planes, voids, and even changes in rock hardness can seriously affect drilling and blasting efficiency. Modern drilling control systems can be set up to automatically adjust for some unusual boring progress to avoid stuck bits and broken drill steel, pulling back slightly when difficulties are encountered. MWD (measurement-while-drilling) results can be used to provide data to determine charging.

Another way of coping with poor ground in drill and blast is to reduce the drill round length. In good rock conditions the maximum is about 6m as the longest drill steel are 21ft (6.44m) long. Round lengths are progressively reduced for poorer rock from 5.1-4.6m in good rock, 4.0-2.0m in fair rock and 2.0m or less in poor rock.

Round shortening is mainly a matter of reducing the length of initially exposed ground if the rock is poor, to maintain natural support. However, it follows that the shorter the hole drilled, the less likelihood there is of drilling problems in one hole due to ground instability. Shorter rounds tend to increase cycle times and therefore tunnelling progress. This is also affected by extra time for additional ground support unless, perhaps, it is possible for one drill rig to work on more than one face, depending on the tunnel project layout. This may not be so much of a problem with a TBM unless the ground is blocky.

The effects of ground conditions on drill and blast in various rocks are in Table 2.

Saving by accuracy

It has long been recognised that accuracy could be a major issue for drill and blast, and manufacturers have been working on ways to improve it (see feature, p50). Good blast design, combined with drill patterns, is important to avoid overbreak and other disturbance of the surrounding ground.

With good guidance, profile accuracy should be inherent in TBM tunnelling and, with electronic profile guidance, also be easy to follow with roadheaders (see feature p55). As such support costs should be quite predictable with these methods unless the ground is unexpectedly poor.

Large cost savings are possible by achieving a smooth blast profile chiefly through rig data controls. An example offered by Sandvik was for a 770m-long rock cavern top heading with planned sectional dimension of 10m by 20m (approx. 153m²), thus requiring an excavation of 118,000m³ solid. With a small extra drilling cost, savings were achieved in concrete to fill overbreaks (EUR 720,720 – USD1.05M), and in lower sprayed concrete use (EUR 103,448 – USD 150,129), but also in mucking out and explosives, to total EUR 972,868 (USD 1.41M). The same work was also completed nearly a month early.

Below: **Table 2, average advance rates for single- or multiple-face operation of blasthole drilling**

Conditions	Average advance rate (m/month)	
	Single heading	Multiple headings
Easy • competent rock • minimal rock support (some rock bolts)	200-300	300-450
Average • variable rock conditions • regular support (rock bolts, some sprayed concrete)	150-250	200-350
Difficult • soft/fractured rock • heavy rock support necessary (rock bolts, sprayed concrete, steel mesh, steel arches	< 150	100-200

Blast improvements

Not all improvements in the drill and blast process are to do with drilling. Leading explosives companies have put a lot of work into blast design and initiation techniques to reduced vibration, as a major example. Vibration is often mentioned as a problem with drill and blast, although it does seem to be a 'topical concern' as regards to underground excavation in urban areas. This does, however, ignore the many urban tunnels that have been completed successfully in the past with few problems.

Jorma Kalliomaki cites the example of Helsinki, where the World Tunnel Congress will be held this month, where a city built on hard rock has 500km of tunnels beneath it, all excavated by drill and blast.

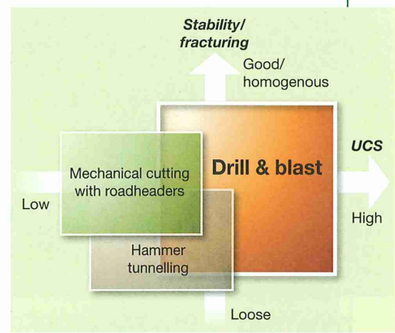
The use of bulk explosives for easier handling and charging has also become more refined. The use of explosive materials that are not explosive until charged have improved the safety and security situation.

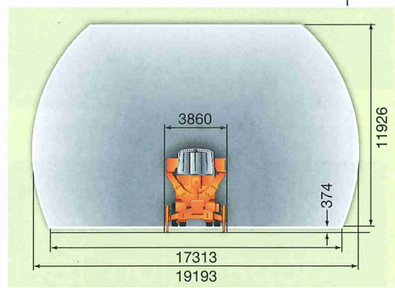
Preference for safety

You might think that, with the destructive nature of blasting, and the need for miners to work at the face on frequent occasions, that the process is inherently hazardous. But, with ingrained safety conscience among experienced miners, established safe methods of working, plus good training and supervision, there is no reason why safety should not be maintained.

Personal operator and contractor preference can play a big part in the choice of excavation method and equipment. This should not be discounted since familiarity with equipment can greatly increase productivity. On the other hand it should not be a block to taking on new methods and technology, or there would be no progress.

Bottom: **Figure 1, Effect of rock condition on capabilities of three major excavation methods**
Below: **Figure 2, ection coverage possible from one position by a Sandvik DT1230i drill-rig. All measurements are in mm.**





Development drivers

The recent functions of drill and blast development include:

- Increasing speed and reliability of hydraulic drills for increased productivity and penetration;
- More accuracy through rig structural improvements such as more rigid booms;
- More accuracy through electronic guidance and drill-pattern systems, leading to less overbreak;
- Extensive instrumentation of the drilling process possible, which can be used for more automatic control, and input to blast design;
- New developments in blast design and initiation.

Acknowledgement

The author is grateful to Jorma Kalliomaki of Sandvik Mining & Construction, Tampere, Finland and colleagues for much of the data used in this article, plus some related opinions.

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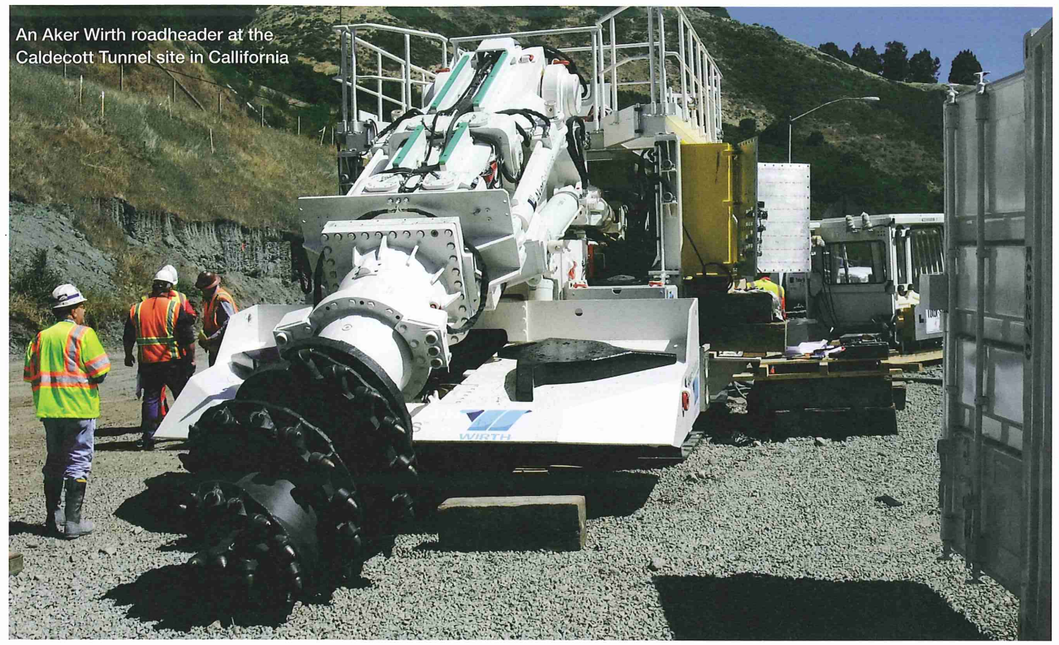
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An Aker Wirth roadheader at the Caldecott Tunnel site in California

Flexible and forceful

Another tunnel excavation method that has been utilising design improvements to successfully push the limits of operational efficiency is the use of roadheaders. Originally developed as relatively soft-ground machines, particularly for sedimentary deposit mining, they are being used increasingly in harder rock excavation. They are also challenging drill-and-blast for places in projects requiring flexibility and suitability for urban tunnelling, especially with regard to vibration and accuracy. Maurice Jones reports

Although there is still a sustained trend to model versatility, as demonstrated by Sandvik's latest MT520 model, there is also a wide range of models available for economical tackling of ground from coal and soft rock (Sandvik MR200 to MR600 series) to the MH600 Series hard-rock machine (formerly the AHM 105 IC). In the middle are those models used most often for tunnelling from the MT300 (former ATM 75) to the MT700 Series (former ATM 105 C) and including the MT520.

New power

Part of the versatility of the MT520 is as a result of its modular design. At 115t it is comparatively light for a cutter motor power of 315kW. The key to its cutting power and stability is the speed of the cutter, and layout of major components rather than the weight of the machine.

Further versatility in dealing with different types of rock can be introduced by changing the set-up of the cutterhead itself, especially the gearing. There are four types available for Sandvik's MT720/MT620 roadheader with its 300kW cutter drive. For the hardest rocks (110-180MPa), the possible net cutting rate (CR) using the R400-TC87 cutterhead is slim and, obviously, low at around 10-18 solid cubic metres per net cutting hour. At the other end is the R400-TC38 that can excavate up to at least 160 solid cubic metres per net cutting hour if the material is no harder than 60MPa. As an example, the typical use range for the Bilbao Metro in solid limestone has been up to 100MPa and cutting rate up to 30 m³/net cutting hour using the R400-TC72 cutterhead.

Sections

Although roadheaders are relatively mobile, with a tramming speed of up to 15m/min, and can therefore work efficiently in excavating junctions and non-standard profiles, for main tunnel drives it is more efficient to use a roadheader on the same longitudinal alignment. Therefore the cutter boom should be able to reach the full design section of a tunnel, unless two roadheaders work side-by-side for larger sections. Compared to larger TBMs and

drill jumbos, roadheaders may therefore be limited in section, although the larger models do have sufficient reach for most standard transport tunnel sections.

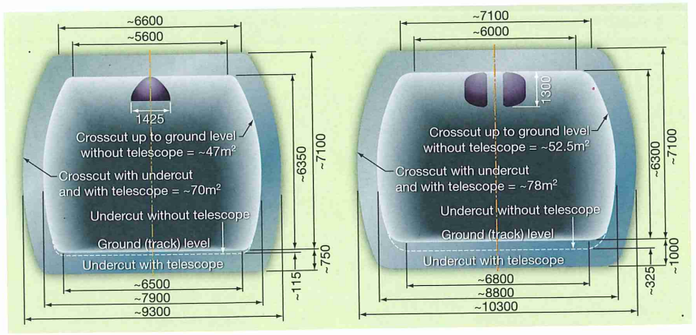
Using the Sandvik range as an example again, the new MT520 can reach up to 8m cutting height. The cutting profile of the MT720 that can cover from one position is up to 8.3m wide and 6.1m high, or 48m² face area. Using the extended telescopic boom of the cutterhead (with a sump-in force of up to 880kN and 650-mm stroke), this can be increased to 9.1m wide by 6.6m high (61m² face area), see Figure 1.

For larger sections and potentially unstable open faces, sequential excavation methods can further utilise the mobility and versatility of roadheaders by working on several 'partial' faces in sequence according to the excavation design. In this method roadheaders operate similarly to conventional hydraulic excavators but usually for harder rock.

Mobility is promoted by the availability of diesel power packs rather than having to handle high-voltage cable feeds for the electro-hydraulic drives. In the case of Sandvik MT720 the diesel drive is a Cat model C-9 rated at 224kW at 1800 rev/min. The engine is certified to the latest EPA Tier IIIA and European Community Stage IIIA emission standards.

Attachments

An alternative to roadheaders for occasional requirements is to employ cutterhead attachments for standard hydraulic excavators. Although not suitable for the demands of full-section excavation, they can find tunnelling applications for removing moderately hard rock bands from softer matrix in the SEM (using the same standard hydraulic excavator carrier), accurate profiling and scaling in harder rock, and trenching for drainage.



Above: **Figure 1, Comparison of profiles achievable with the Sandvik MT520 roadheader using inline – softer rock – and transverse cutterheads**

Accuracy

Another important factor in the choice of roadheaders as the main means of excavation is accuracy. This is now a matter of intense competition between the main excavation methods. In common with drilling for blasting, roadheaders now have guidance systems available that not only maintain the excavation in the right alignment but ensure that the design profile is reached as close as possible. Such systems are a comparatively new development for roadheaders since early attempts were hampered by vibration and carrier stability issues in relation to the survey reference points.

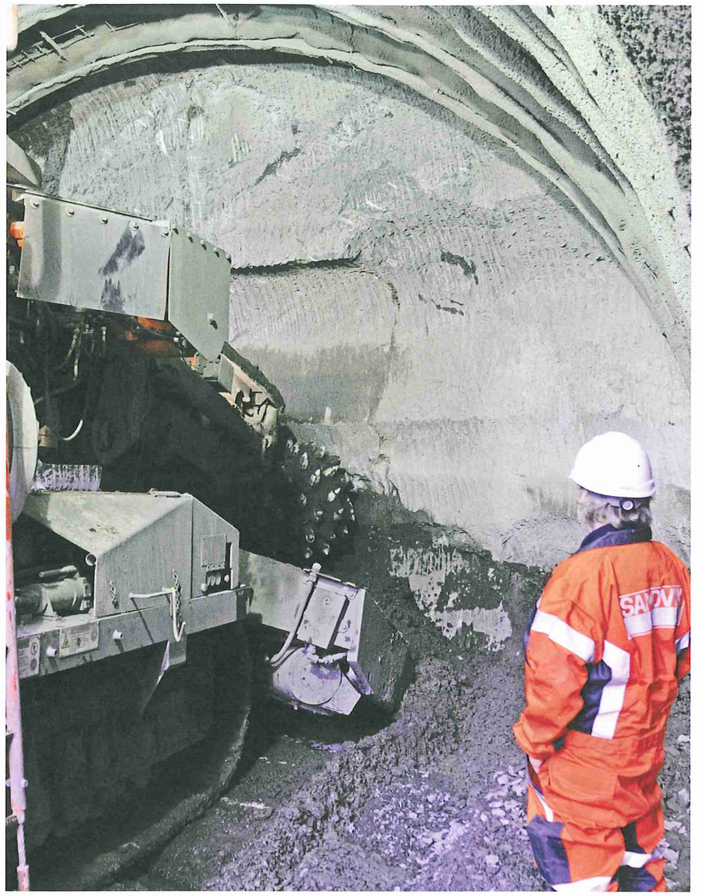
Successful roadheader guidance and profile monitoring systems have now been developed by VMT, Geodata and others. Using a console screen displaying the pre-programmed design profile, the roadheader operator can guide the cutterhead in its optimum excavation sequence up to the profile limit, using continuous calculation of the cutterhead position.

As well as the operator profile display, the Sandvik MT720 carries sensors for the cutter boom vertical position, an elongation sensor for the boom telescopic movement,





Above: **Roadheaders can work in close proximity with other systems, as here in the Mont Cenis rail tunnel, Frejus, France, which remained in operation**
Right: **A transverse cutterhead on a Sandvik MT720 roadheader, similar to that used on the Bilboa Metro in Line Three in Spain**



Above: **Construction of the Bilboa Metro Line Three employs this new Sandvik MT520 roadheader, plus the MT720**

and a two-axis inclinometer for pitch and roll. Using an on-board data processor, the values from the sensors can be used for the continuous calculation of the cutterhead position. As a survey reference, a motorised theodolite is linked visually to two reflective prisms and by radio link to the roadheader. The theodolite uses another prism on the tunnel structure as a backsight for directional reference.

With good profile control there can be savings in support materials and costs, with fewer rockbolting requirements to secure the rock and minimal concrete for both primary and permanent support according to the tunnel design.

Josef Pichler of Sandvik claims that the accurate profile achievable with roadheaders results in less disturbance of the surrounding rock mass, and so less loss of friction in the rock parting planes.

As an example of possible cost savings put forward by Pichler, with a 8m by 6m section of 40m² area and 17m circumference, a typical 200mm radial additional overprofile for support needs will result in 50-100mm using a roadheader but 250-300mm using drill and blast. The additional overcut will require around 3.4m³ of concrete per linear metre of tunnel. With a 6m advance per day, over 26 working days a month, this will require an additional (26x6x4)m³ of concrete. At a cost of EUR 140 (USD 199) per cubic metre this can result in an additional cost of EUR 74,300 (USD 105,620) per month.

Vibrations

Fans of roadheaders over drill and blast point mainly to the lower vibration levels claimed for their operation compared to blasting in urban situations. Tests of roadheader action in dolomitic limestone in Sorrento, Italy, used sensors in the tunnel to measure peak particle velocity at distances of four, seven, 12, 17 and 27m from the cutting face and at 0.5m from the wall. The peak particle velocity ranged from 2.5-3.5mm/s at the closest sensor to the face, down to 0.5-1.0mm/s, 27m away.

The transmission of cutting vibration through the body of a roadheader and into the ground is reduced by a disc support ring of the main turret that helps absorb the vibration. There will still be some vibration transmitted from the cutterhead through the rock, but this will be alleviated by a sustained cutting action helped by careful design of the cutterhead pick pattern.

There may be other situations where, for operational requirements or the proximity of neighbours, blasting is entirely impractical, unless the use of blasting mats and many other precautions is acceptable. For example, in the refurbishment of the Frejus rail tunnel, Mont Cenis, France, a Sandvik MT620 roadheader has been employed to increase the sectional capacity of the tunnel – behind barriers – whilst the existing railway continued in operation.

Major projects

Among major projects in which roadheaders are being used successfully, together with other methods, are the Brisbane Airport Link, Australia, by the Thiess-John Holland JV, and the East Side Access project in New York by the Dragados-Judlau JV. Rock compressive strengths range from as little as 1.10MPa in Brisbane Tuff, itself a very variable strata, up to 99.80MPa maximum in the Aspley Formation. This has resulted in net CR from 7-160 solid cu m per net cutting hour.

The MT520 and MT720 have been used successfully in commencing the Line Three of the Bilbao Metro (*T&TI* Oct 2010). The MT720 weighs 135t compared to the MT520's 115t, and has a 300-kW cutter motor within 533kW total drive power. The MT720 has also been used, with two units in parallel, for driving a highway tunnel in Dortmund, Germany.

Acknowledgements

This article employs material extracted from presentations by Josef Pilcher (product line manager – roadheader) and Manfred Meier (senior engineer – roadheader) of Sandvik Mining & Construction, Zeltweg, Austria, for which thanks to the authors and Sandvik communications departments in Tampere, Finland and Austria.

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Baggage Tunnel design and construction at Heathrow

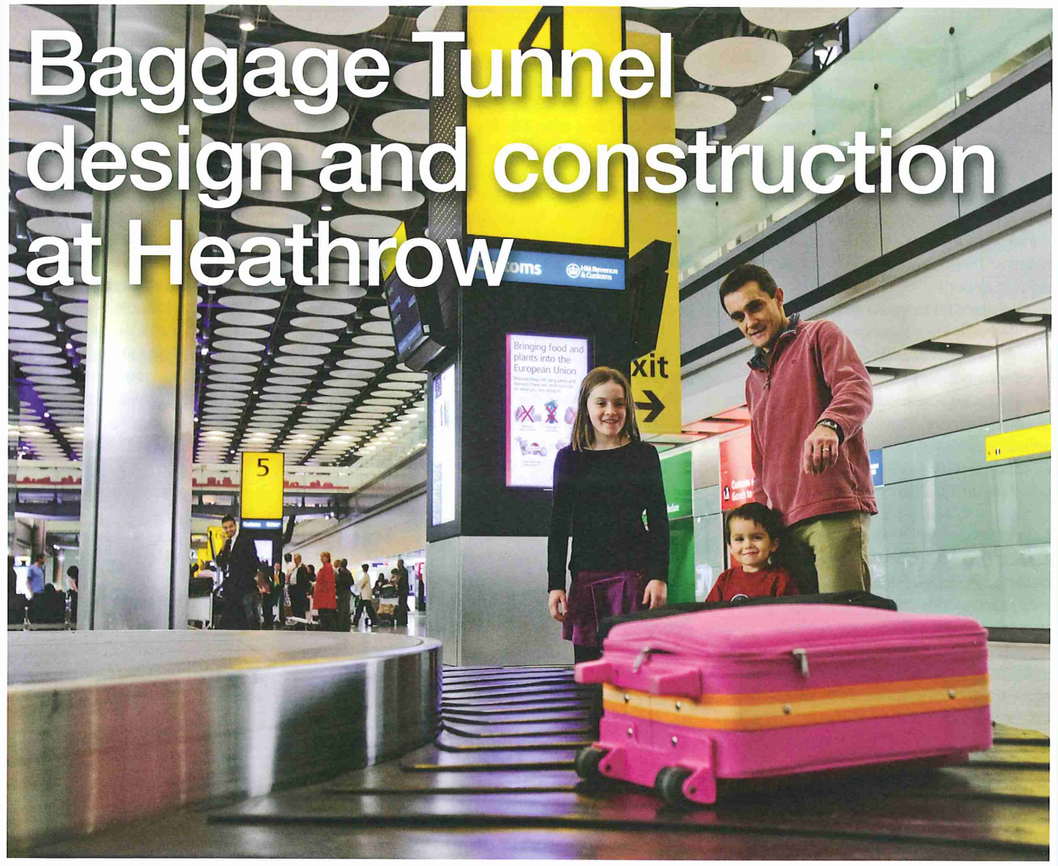
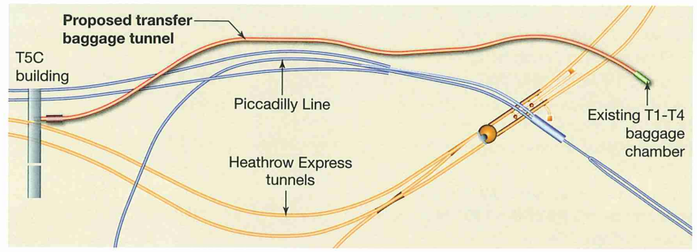


Photo credit: BAA

In December 2010 Andrew Stephenson of BAA, Enrique Blanco of Ferrovial and Arthur Darby of Mott MacDonald gave a presentation at the British Tunnelling Society on the Baggage Tunnel design and construction at London's Heathrow Airport

The baggage tunnel forms a vital link in Heathrow Airport's underground integrated transfer baggage system – a 2.1km tunnel running between Terminals Five, Three and One. The scale of the transfer baggage system is unusual and when completed it will be the world's largest.

Andrew Stephenson of airport operator BAA explains that, with five terminals, a large amount of baggage is transported by vehicle but the vision is that this will be improved and transported underground and out of sight. The value of the whole project is GBP 260M (USD 420.26M) with the tunnel element and fit out accounting for GBP 73M (USD 118M) of this. The tunnel is 2.1km long with a 5.1m internal diameter and links Terminal Five with Terminal One. It contains an automated transfer baggage system with a twin track. The transfer of the baggage will take place in a dedicated transfer facility in the basement of terminal T5C with a second



Right: Figure 1, the baggage tunnel crosses two underground railways lines

baggage transfer building at Terminal Three.

The vital benefits are that the manual handling of the baggage using vans will be put to an end, reducing the number of bags handled by people by three million a year. There will also be less congestion on the airport's roads and reduced emissions as well as it being cheaper and more reliable and predictable in operation. The improvement in the baggage handling system will help Heathrow to maintain its position as one of the world's leading airports.

At present 44 bags out of a 1,000 are not reunited with the passenger on their transfer flight. This project will reduce this to near zero. Baggage will be moved around faster so the connection time will be shorter. The reliability will also allow the airlines to be more confident in their scheduling particularly where passenger transfers are involved.

Lost baggage

The baggage system chosen was a destination coded vehicle (DCV) System which comprises one cart per bag, with the only moving parts being the four wheels on aluminium tracks. Linear motors in the trackbed move the cart at 10m/s. More traditional systems such as conveyors would be much slower. This allows the required 40 year capacity of 3,000 bags per hour to be achieved. Terminal Five also uses the same system allowing seamless integration.

Tunnelling

The launch chamber was constructed in April 2008, and the intermediate shaft beneath the western interface building serving Terminal Three later in the year. At the eastern side, there is another shaft with a ramp for the baggage to emerge to serve Terminal Two. The TBM arrived in December 2008 to start the tunnel drive two months later in February 2009 with the tunnel drive being complete in August 2009. The fitting out began in February 2010 with the whole system planned to be in operation in May 2012. A tunnel system already exists between Terminal Four and Terminal One, so the new system is really just filling the gap between existing tunnels.

Stephenson says that the tunnel drive crossing the airport was the biggest risk to airport operations. The 1994 collapse of the Heathrow Express Rail Link had not been forgotten. It would cost BAA more than GBP 4M (USD 6.47) a day if the airport needed to close.

To date there has been no impact on the operation of the airport and, with over two million man hours worked, no accidents resulting in time loss. There were over 30 different operational stakeholders all of whose risks had to be managed. The tunnel had to pass under the London Underground lines, fuel storage tanks, taxiways, Terminal One, Terminal Three and many other services vital to the operation of the airport (see Figure 1, p59). The Heathrow Express was also crossed.

Therefore the client required the highest level of assurance before work started. An assurance plan was used to communicate with the directors of the asset owners along the zone of influence of the tunnel to make sure confidence was maintained but also to achieve a sign-off before work started. Weekly readiness reviews were held for several months before work commenced to track the closure of assurance requirements (see Figure 2 below).

There were five main stages of managing the stakeholders:

- Tunnel design – finalise the route.
- Investigation and planning – understand the risks and analyse the impact.
- Sign off contingency plans by stakeholders and develop emergency preparedness plans including specific monitoring requirements for the stakeholders as well as the regular monitoring that took place.
- High level of communications and mitigation actions e.g. services being isolated before the tunnel passes under.
- Record keeping and close out.

Stakeholder services affected by tunnelling

Chainage		Structure/services	Owner	Status (RAG)	Comments
225.00		Fuel main	HHOpCo	Green	Team, spares & equipment available to excavate/repairs
229.00		Portable water	Water Services	Green	Team, spares & equipment available to excavate/repairs
229.00		Storm water	Water Services	Green	Team, spares & equipment available to excavate/repairs
230.00		High voltage	EDF	Green	None
230.00		Foul water	Water Services	Green	Team, spares & equipment available to excavate/repairs
232.00		Electrical ducting	Airside Operations	Green	None
234.00		HAL Comms	HAL Comms	Green	None
235.00		Electrical ducting	Airside Operations	Green	None
239.00		Foul water	Water Services	Green	Team, spares & equipment available to excavate/repairs
239.00		Portable water	Water Services	Green	Team, spares & equipment available to excavate/repairs
243.00		High voltage	EDF	Green	None
244.00		Electrical ducting	Airside Operations	Green	None
245.00		BT	BT		This was confirmed by Melvin Pearce from Openreach by devolution of drawings 19/02/2009
254.00		Electrical ducting	Airside Operations	Green	None
264.00		Storm water	Water Services	Green	Team, spares & equipment available to excavate/repairs
265.00		Fuel tanks - Buncefield tanks	HHOpCo/ HAFCO	Green	Support team & spares available
300.00		Fuel main	HHOpCo	Green	Support team & spares available
325.00	-325.00	Tunnel crossings- Piccadily Line Tunnel WB	LUL	Amber	Awaiting comments/ signature back from LUL
377.00	-493.00	Stand 595	Airside Operations	Green	Not affected by tunnelling activities

Right: **Figure 2, stakeholder confidence was crucial in light of the 1994 heathrow tunnel collapse**

Managing the alignment

Arthur Darby of Mott MacDonald explains the constraints of the tunnel alignment. These include the end points of the baggage interface buildings, existing buildings, ground conditions with the desired strata for tunnelling being London Clay, and tunnel construction logistics with a minimum horizontal radius of 400m and maximum gradient for the rail based transport system of 3.5 per cent.

A three dimensional model was built of the existing infrastructure. The tunnel could be above the Heathrow Express and Piccadilly Lines with a minimum separation of 3.5m and also achieve a minimum cover in the London Clay of 5m which would ease tunnel construction and waterproofing.

Stage one and two impact assessments were undertaken using standard procedures (see Figure 3) with many of these being slight or negligible. The predicted movements for the Piccadilly Line tunnels and Heathrow Express tunnels were all less than 5mm. The more critical elements were the fuel pipelines and fire mains but these had the advantage of being able to be isolated while the tunnel passed under.

Stage 1 - Impact assessment

Infrastructure affected	Owner	Initial impact assessment (based on 2.0% volume loss)
Fuel tanks and fuel mains	HHOPCo	Slight
Piccadily Line tunnels	LUL	Negligible
Heathrow Express tunnels	HEX Op Co	Slight
Main Road tunnel	HAL First & Last Impressions	Moderate
Stands & taxiways	HAL Airside Operations	Slight
Services electricity, telecoms, firemains, water	EDF, BT, Service owners	Slight – moderate
Terminal 1	HAL T1 Facilities	Slight

Above: **Figure 3, impact assessments are carried out to monitor settlement issues**

At T5C it was originally envisaged that the launch shaft would be circular with a backshunt tunnel but when Ferrovial joined the project, a rectangular box was proposed instead that would also form part of the basement structure of T5C.

The launch chamber had 1.5m thick diaphragm walls and was 46m long, heavily propped with a roof slab built afterwards.

The TBM tunnelled from T5C to the interface building at Terminal Three with a 45m ramp in a box to bring the baggage to the surface. This was built top down with the internal structure being built early to increase the rigidity of the structure and reduce ground movements.

Finally the tunnel goes through to the Terminal One interface building. This was an extremely constrained site at the time of construction and as such diaphragm walling was not feasible. A contiguous piled wall was used instead. The building here







Right: Two unexpected piles were found en route and removed
Below, right: Tunnelling through the Terminal 1 interface building was extremely constrained

will not be fitted out until the second phase of T2A is completed in several years time.

The tunnel lining was a segmental expanded lining, 200mm thick, steel fibre reinforced with polypropylene for fire resistance. This and the bolted lining were manufactured by Buchans. The bolted lining was used on the approaches to the structures with some kept in reserve if conditions dictated their use.

With the original alignment, the road tunnel into the Central Terminal Area had to be crossed. The road tunnel is about 50 years old and could not have been taken out of service if the structures or services within had been affected by tunnelling.

The alternative route for the tunnel was to go under the road bridge which was on steel columns on piled foundations. This had different risks including hitting the piles, as well as settlement effects on the structure. The best solution was to disconnect the bridge deck from the steel columns at the four piers and use jacks controlled by reference to real time monitoring to maintain the deck in position as the tunnel passed underneath. Afterwards the deck was reconnected to the columns using new make up pieces. The minimum distance to the piles was only half a metre but the advantage of the open-faced TBM was that it was possible to probe from the front and the piles were located accurately as the TBM passed.

The maximum predicted settlement was 30mm under Pier 39, however of greatest concern to the bridge was any twist effect, hence jacks were placed to compensate.

Once tunnelling was complete the last section to be completed was the link to T5C. This was constructed with sprayed concrete lining (SCL) and was about 20m long in a bench/heading layout with 1m advances. Some 750mm advances were used closer to the structures.

Choice of TBM

Enrique Blanco of Ferrovial explains that it was originally intended to use an earth pressure balance machine. However as there was good experience in this type of ground, an open face machine was chosen for the works instead.

The entire TBM was around 60m long and launched by installing a shove frame against the wall in the box at T5C. The guidance system allowed for real time monitoring. Enrique says the setup of the machine which was supplied in a traditional manner with locomotives. Two crossovers in the launch chamber allowed for multiple train movements in the tunnel.

To supply the ring segments to the train, a gantry crane was placed over the box with space on site for a week's worth of production rings.

Excavated material was removed from the tunnel by use of a conveyor belt to the box then removed in a vertical conveyor. With the tunnelling work being undertaken on the airside of the airport, all staff had to undergo daily safety procedures before entering site. A special access zone was therefore set up by BAA to allow the workers to enter site in a bus.

As well as usual tried and tested methods of applying health and safety, behavioural training was also introduced.

Four monitoring, automated systems were set up along the route and in the existing tunnels.

Two unexpected piles were found along the tunnel route. The first took 30 days to agree a method of removal and the second only six days. The removal of the piles themselves took two shifts for the first and half a shift for the second. The original purpose of the piles remains unknown.

Production averaged 22m per day, with a maximum of 52 rings in 24 hours.

Questions from the floor

Mike O'Connell of Balfour Beatty (retired)
Q: What were the tolerances of the tunnel approaching the steel columns being half a metre to the piles and did any as-built records existed under CDM regulations?
A: Arthur Darby says that drawings did exist but you can never be sure if these are a true representation particularly with regards to verticality. It was expected that the TBM would miss them and in the end it did. Andrew Stephenson added that there were no three dimensional records of the base of the piles.

David Latchford of National Grid
Q: Were any specific examples of the behavioural training?
A: Enrique Blanco says that safety issues were reviewed then specific ones targeted to identify the consequences.

Rapporteur: Andrew Hindmarch

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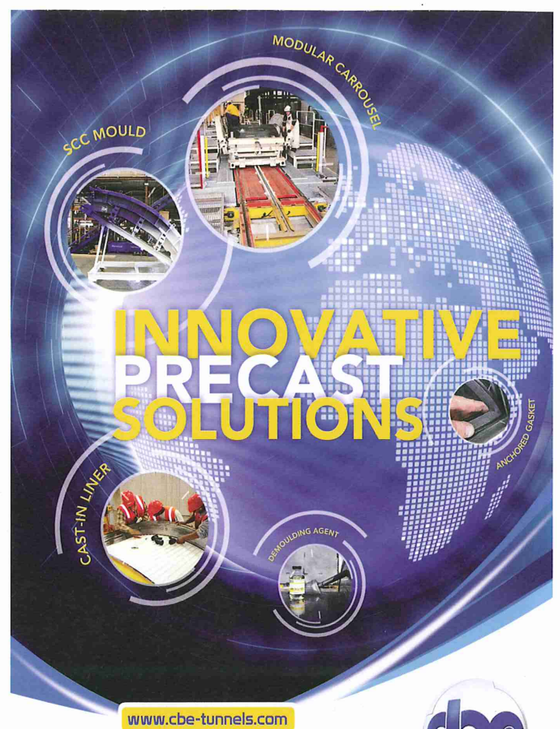
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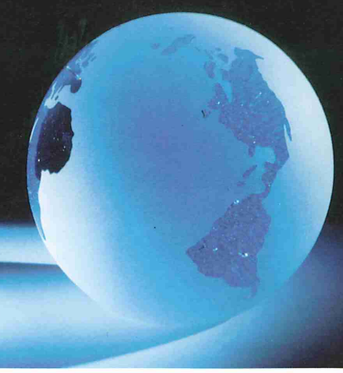


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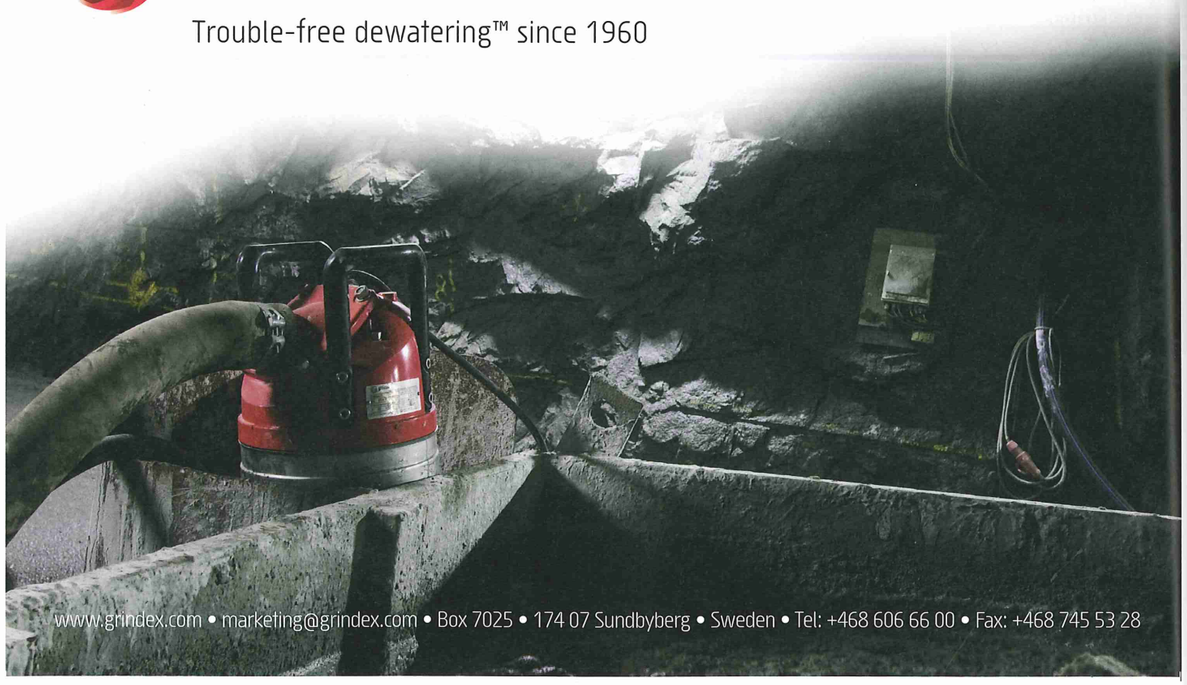
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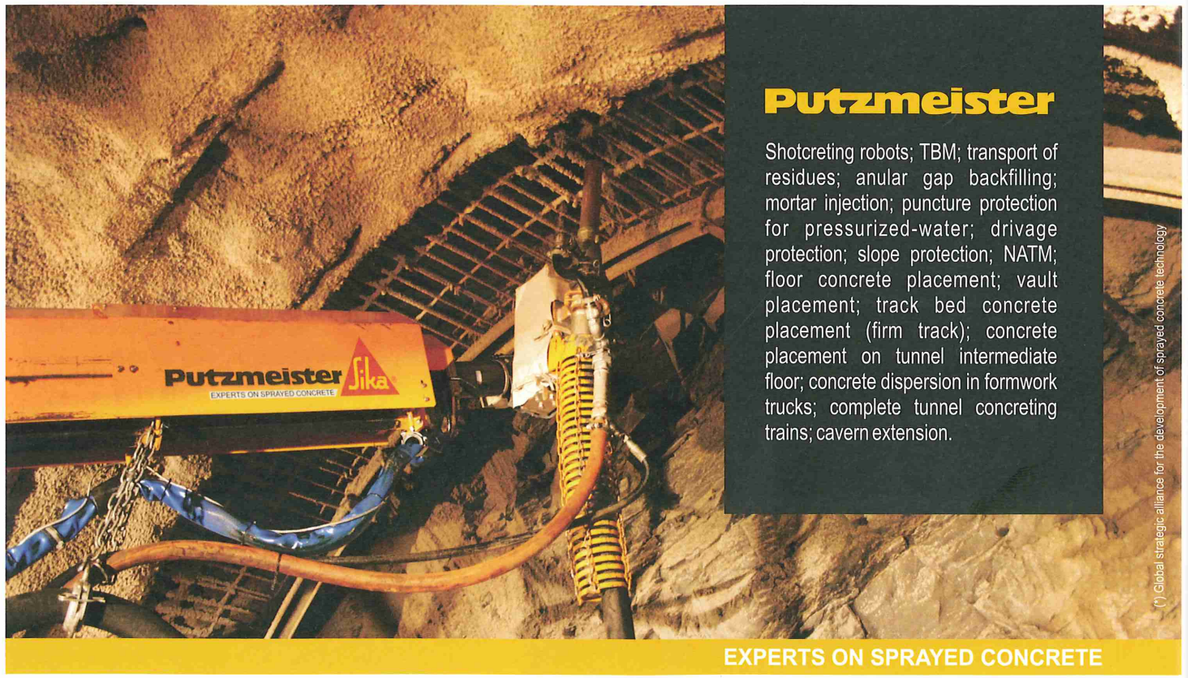
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(*) Global strategic alliance for the development of sprayed concrete technology

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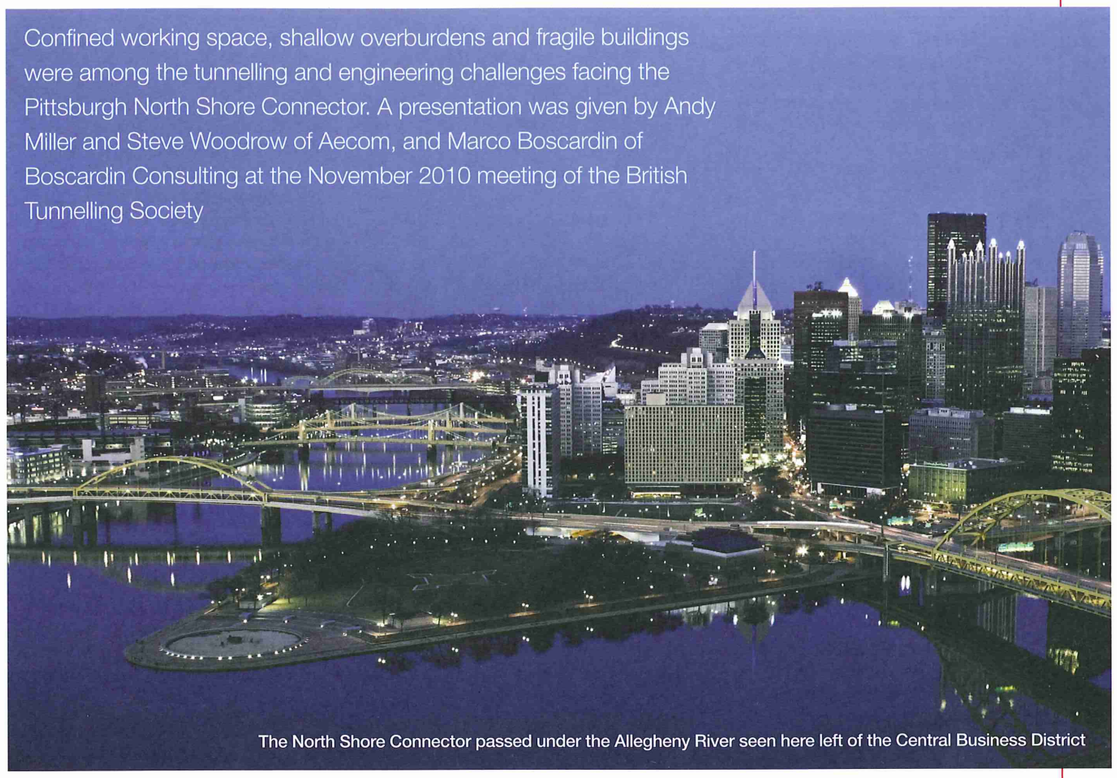
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Confined working space, shallow overburdens and fragile buildings were among the tunnelling and engineering challenges facing the Pittsburgh North Shore Connector. A presentation was given by Andy Miller and Steve Woodrow of Aecom, and Marco Boscardin of Boscardin Consulting at the November 2010 meeting of the British Tunnelling Society



The North Shore Connector passed under the Allegheny River seen here left of the Central Business District

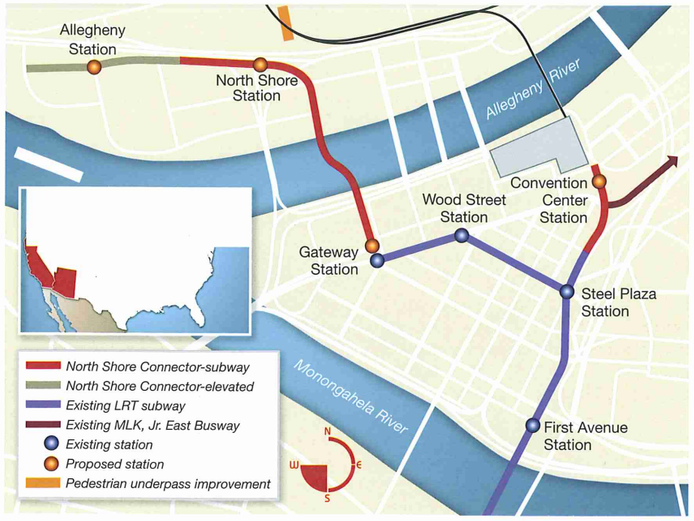
Diving under the Allegheny River

Pittsburgh in Pennsylvania is a city with a historical background of steel manufacture and use that has regenerated over the last 30 years. People who have moved into the suburbs now require public transportation to take them back into the central area, the central city triangle, formed by three rivers – the Alleghany and Monongahela rivers, which join to form the Ohio River.

The USD 435M Pittsburgh Northshore Connector project joins the redeveloped North Shore industrial area with the existing Gateway Station in the city central triangle, passing under the Allegheny River. The line travels close to two stadiums – one Baseball and one American Football – as well as other sensitive structures, with the corner of one sport stadium car park forming the main construction site, limited to about 2,000m².

The project owner is the Port Authority of Allegheny County, and the construction manager is Trigold, a consortium of HDR Engineering, Jacobs Engineering and Kwame. The client designer is Aecom, and the main contractor is North Shore Constructors (Obayashi Corporation/Trumbull Corporation). The design contract was awarded in 2002 with construction contract award mid 2006. Tunnel construction was completed in April last year.

The 800m long twin bore tunnel alignment and access shafts were constructed through a combination of fill going back to colonial times, Alluvium deposits, permeable half gravel and half sand fluvioglacial material with possible boulders towards the base of the formation, and rock. The rock consisted of Pennsylvanian coal measure type rock –



Left: Figure 1, the alignment joins the North Shore with the CBD

sandstones, siltstones, claystones. Shales and coal seams – with strengths ranging from just over 1MPa to over 80MPa.

Challenging alignment

The alignment presented some particular challenges, with shallow tunnelling under the river with only one diameter cover, constraints between historic piled structures and the need to tie into the existing system resulting in a 1m wide soil column between the two bores. Vertically the alignment followed a maximum eight per cent gradient with minimum curve radii of 180m.

Where the alignment was constrained, the narrow central pillar stability was checked by two dimensional finite element analysis with a defined limiting volume loss of one per cent to safeguard the buildings. Ground treatment using 2m diameter jet grouting columns was required for a distance of approximately 14m over the first tunnel and for about a 92m length of the second tunnel. There was also a contingency measure to use internal bracing within the first tunnel covering a 45m length at any one time.

This bracing consisted of a steel rectangular frame erected at 1.2m centres over a total length of approximately 92m, using a rolling system of dismantling and advancing the frames, aligned with the adjacent tunnel progress.

The jet grouting covered only about 75 per cent of the total ground treatment volume rather than using full-face coverage following a value engineering exercise.

There was less concern about water cut off, and the design was more concerned with ground stabilisation. The grouting was targeted to achieve 1MP matrix strength, but this did make it difficult to sample, with a weak matrix of grout and gravel. Down the hole, cameras were used to look at the continuity as well as rotosonic drilling and taking larger samples that were less likely to be severely disturbed. The size of the jet grouted column was eventually demonstrated by geophysical means of examining changing electrical characteristics of the jet grouted material, which replaced sampling methods.

Support and waterproofing

The tunnel support consisted of a prescribed lining containing a primary lining, waterproof membrane, and a cast insitu secondary lining. Space proofing, including the defined vehicle envelope, emergency access down one side, overhead catenaries, signals, track and drainage plus secondary lining, resulted in a primary segmental lining with an internal diameter of 6.1m.

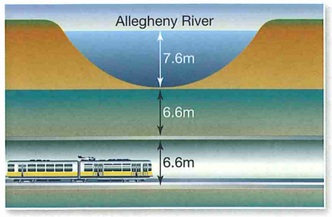
Full three dimensional finite element analysis was undertaken, taking account of ring roll and the joint arrangement, with prescriptive loadings including derailment of vehicles and explosion loading (1,000kN/m²) applied to the internal lining. A sunken vessel load (100kN/m²) under the river was also applied due to the low cover, and a design flood level set at over 6.5m above the top of river level, which might appear high but historical data showed flooding up to the 1st floor of adjacent buildings (3.65m above street level).

The bolted and gasketed reinforced precast concrete segmental lining was originally designed with seven plates and a key, 275mm thick, and 1.2m wide. Two ring types were used with differing tapers of 40mm and 60mm. The contractor offered a value engineering change to the design to six plates plus a key in order to improve on ring build time in the tunnelling cycle, and the design change was accepted. The rings were produced by Technopref through a local precast concrete company (A C Miller), and CBE moulds using a static casting system. A five day secondary cure was specified to attain the design 55MPA concrete strength at 28 days.

Below: The tunnel alignment passed close to the two sports stadiums; Below, right: The TBM was turned in the reception pit and readied for the second drive







Above: Figure 2, the tunnel has a shallow one diameter of cover under the river

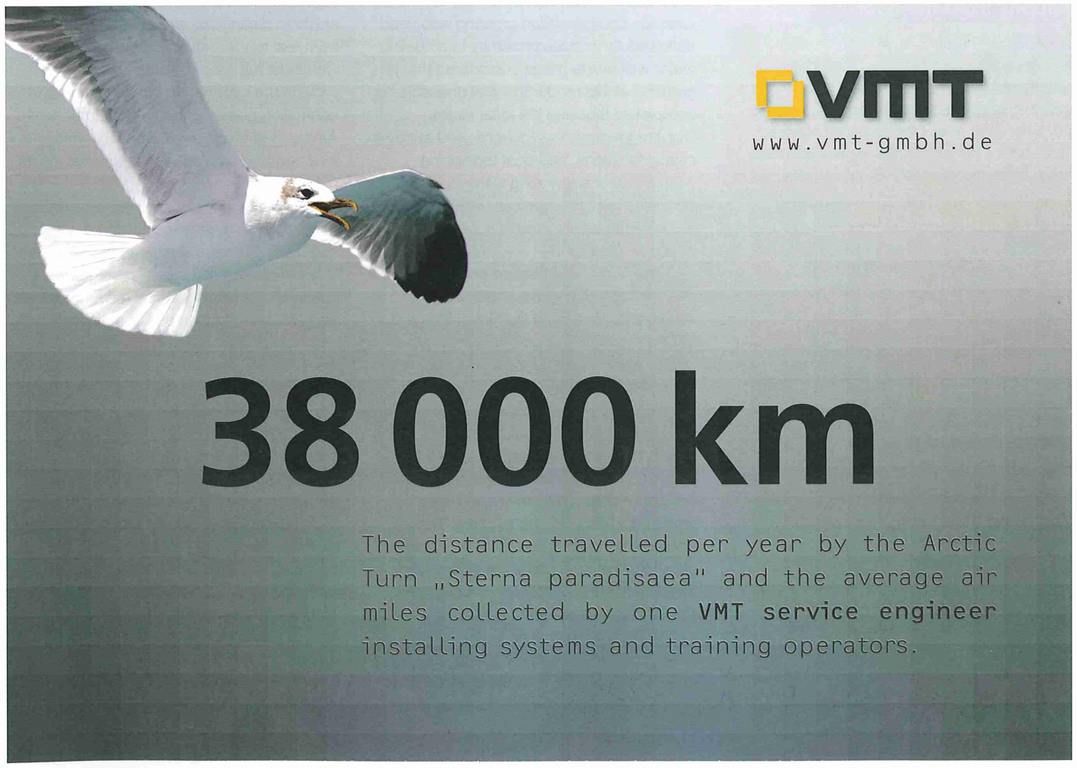
The contractor had the option to use EPB or slurry face support technology on the TBM, and decided to use a Herrenknecht slurry Mixshield with working pressure up to 3bar, 6.93m outside diameter, 8.26m long and weighing 485t. The TBM was provided with a counter rotating head (0-2.7rpm) variable frequency drive, with 27, 17inch twin cutters, and a rock crusher.

The slurry separation plant was located next to the main working site and contained 10 cyclones of 250mm and 20 cyclones of 75mm with two centrifuges capable of handling 15m³/hr of slurry.

The TBM was built at the surface and a gantry was used to lift, transport it over the shaft and lower down to launch level– a journey of about 18 hours. The single machine was driven one way – and it was anticipated that the contractor would then remove it and take it back to the same launch point. However, the contractor decided to turn the machine around at the reception pit in a very constrained space using a combination of rams and rollers. It was first turned through 180 degrees and then translated across the shaft, the thrust frame was erected and the TBM re-launched using temporary power/hydraulics and temporary backup for a distance of 45m. At this point the full back-up was moved around to the second tunnel and the machine re-launched. The average advance rate was 9.7m/day for the first drive and 10.2m/day for the second, with a maximum advance recorded of 19.5m/day.

Steady ground

Ground movement control was an important aspect of the project, and during design and assessment of infrastructure affected by tunnelling, ground loss was







Above: A view down the twin bored tunnels from the reception pit in the Central Business District; Above, right: The TBM breaks through into the reception pit

specified at 1.5 per cent in soil, and one per cent through the rock, which was slightly higher than might normally be expected due to concern over the effect of the mixed face conditions to be experienced by the TBM. Empirical and finite element settlement assessments were undertaken leading to estimates of 20-65mm settlement along the tunnel centre line route and 12-20mm at building foundation lines.

Techniques used to control and limit ground movements included ground improvement (jet grouting and compensation grouting), with the objective to cut ground movement in half. Face loss was actually kept to between one third and three quarters of the design basis value in soil (1.5 per cent), while in jet grouted areas, settlement was about half that of non treated areas.

Techniques were chosen and used based upon local requirements. For example compensation grouting was used successfully in close proximity to a cooling water well where it was considered that jet grouting would render the well unusable by completely blocking the local strata. Diaphragm cut-off walls were used at some critical locations, and post tensioning beams and underpinning were used at the elevated highway structures where some pile cutting and load transfer was also accomplished.

Where the tunnel passed under the south river walls ground movements were specified to be limited to 25mm. The wall consisted of pile support of unknown depth, which possibly extended down to tunnel level.

The design assumed that the piles would be removed and jet grouting used to support the wall, but it was confirmed during extraction that the piles were 2 to 3m above the tunnel crown, and the remaining piles were left in place. There was also concern at the north river wall about the toe level of the steel piles, and the contractor was considering stopping the TBM at that point.

This led to a more detailed investigation using magnetic geophysical testing to supplement the angle probing undertaken during the design. This demonstrated that the clearance was closer to 100mm than the originally determined 1m – but to a tolerance of +/-450mm. The timber piles behind the sheet piled wall were removed to check their depth and it was noted that the steel toe caps had corroded and that the length was not a concern for TBM advance, so construction continued with no delay to the TBM.

Monitoring progress

The instrumentation and monitoring (I&M) strategy was based on a philosophy of installing I&M early to give good baseline readings which, from experience, makes interpretation easier and enhances the ability to distinguish environmental effects from real tunnel induced movement. Continual feedback of data was used to provide the information for evaluating and controlling construction, and a Green-Amber-Red trigger level warning system was adopted with each structure having its own response level.

Generally, green represented less than threshold levels, amber between threshold and a limiting value, while red triggers were hit when greater than limiting values were achieved. Generally vertical movement data was used due to the ease of collection, use and understanding, although other instrumentation and results were available. Monitoring frequency was adjusted to suit the construction activities in the area, and response plans put in place to react to specific trigger levels.

Management of third party agreements and site access for installation and reading of instrumentation was a particular problem on the project, with property ownership changing and new owners reluctant to follow previous agreements.

Although the agreements were technically enforceable under the law, owners could still make life difficult for the team and use up valuable staff time in resolving the issues.

Questions from the floor

Neville Harrison
Q: The cross section showed a steel fabricated walkway. What were the economics of this as generally they tend to be cheaper in mass concrete?
A: Andy Miller confirms that the temporary walkway was steel, but the permanent walkway was also steel, which he considered was mainly due to the steel heritage of the area.

Gerald Skalla of Dr Sauer
Q: During design were any other construction techniques considered other than TBM?
A: Miller states that the original project development considered immersed tube but dropped this idea as there was insufficient space. One section had also considered NATM for the construction method, but that section of the project was abandoned because of cost constraints. Bored tunnelling was always the main option and was considered the best method for the ground conditions anticipated.

David Hartwell
Q: The TBM face looked more open than usual, and was this because of the expected boulders and were any found?
A: Miller says that no boulders were found and the TBM worked well with about 20 per cent opening in the head and that this was considered reasonable for the ground conditions encountered.

Rapporteur: Mike King

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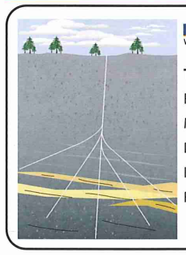
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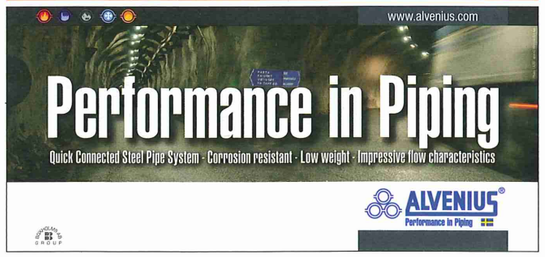
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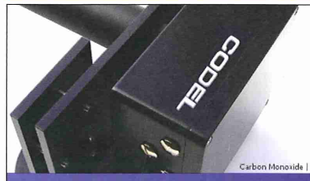
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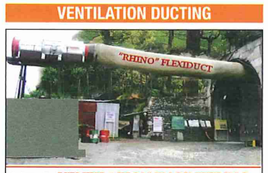
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dates & events

16 - 18 MAY 2011
TC 28: 'Underground Construction in Soft Ground', Rome, Italy
Keynote talks will be presented on: the New Mexico City deep sewerage system, the long-term performance and deformation mechanisms of tunnels in soft clay, evaluating the effects of tunnel excavation on historical buildings: the example of a new subway line in Rome and deep excavations for North-South Line, Amsterdam, an update and lessons learned. Technical visits to Line C of the Rome Underground will be available on the third day. Contact: Natalia Ramadori, Tel:+39 0699701270, Email: tc28-roma@welldonegroup.it

18 - 19 MAY 2011
10th Annual National PPP summit, Melbourne, Australia
Can Public-Private-Partnerships deliver value for money?
PPPs face adversity in a time when infrastructure development is critical to support the growing Australian population. Celebrating its 10th anniversary, the National PPP Summit presents an opportunity to discuss solutions, as well as the challenges and threats that hamper the much-needed development of infrastructure across Australia. Phone: +61 2 9080 4307
Fax: +61 2 9290 3844
Email: Adam.jones@informa.com.au

21 - 26 MAY, 2011
WTC 2011 Helsinki - Underground spaces in the service of a sustainable society
The Finnish Tunnelling Association awaits you in Helsinki. A boom in tunnelling is currently underway in Finland. In this exciting environment WTC 2011 has been organised. General subtopics to include: planning the usage of subterranean spaces, municipal services, operational technologies, traffic and logistics, geologic disposal of nuclear waste, renewable energy, project management.
Website: www.wtc11.org
Booking / accomodation enquiries:
Tel: +358-9-5607500
Email: wtc11@congrex.fi

15 - 18 JUNE 2011
6th Annual meeting of chartered civil engineers in Opatija, Croatia
The specific seminar topics, all in the civil engineering sector, include tunnels in urban areas, geotechnics and project management. The opening session and round-table discussion should, say the organisers, show which projects should be started in this immediately before and after entering the European Union. For more information see www.hubtig.com.
Contact the secretariat, Ms Dada Papista. Tel: 00385 1 6130 062, email dada.paptista@hubtig.com

19 - 22 JUNE 2011
RETC 2011 - Rapid Excavation and Tunneling Conference and Exhibit, San Francisco, California
RETC is an international forum for the exchange and dissemination of developments and advances in underground construction.
For more information contact event organiser: RETC Exhibits, 8307 Shaffer Pkwy, Littleton, CO 80127, 303-948-4213, gury@smenet.org

22 - 23 JUNE 2011
Tunnel Design and Construction Asia, Sentosa, Singapore
Featuring best practices in geotechnical investigation, EPC contracting, project funding and risk management for Asia's tunnel infrastructure. The keynote speaker will be Heinz Ehrbar, chief construction engineer of AlpTransit Gotthard. Tel:+65 6722 9388
Email: enquiry@iqpc.com.sg

29 - 30 JUNE 2011
Underground Construction Conference and Exhibition, London
The eyes of the global tunnelling industry are swivelling towards the UK with some of the world's largest underground construction projects getting underway. Event includes: technical and design developments in underground construction, tunnel operation and maintenance, sustainable development and minimising the impact of underground works, a world wide tunnelling perspective, UK projects - today and the future, ground investigation, treatment and monitoring.
Tel: +44 (0) 207 973 6695
Email: g.stringer@hgluk.com
Website: 2011.tunnellingshow.com/

12 - 16 SEPTEMBER 2011
6th International Symposium on Sprayed Concrete, Tromso, Norway
Main themes will be design, construction and durability of wet-mix sprayed concrete in underground structures. The Norwegian Concrete Association is currently revising the Publication No. 7, Sprayed Concrete for Rock Support. This will be debated during the symposium. Contact: Siri Engen Email: siri engen@tekna.no Website: www.sprayedconcrete.no

14 - 15 SEPTEMBER 2011
IUT 2011, Sargans, Switzerland
Those involved in tunnelling will get together to exchange views and inform themselves about the latest trends and technologies. The traditional IUT Evening on the first day of the fair, being held in a VSH cavern, will be a highlight: here exhibitors and visitors will be able to exchange views against a relaxed background and experience an unforgettable evening. Contact: Deltacom Projektmanagement +49 (0)40 35 72 32 - 0 info@deltacom-hamburg.de

19 - 23 SEPTEMBER 2011
Hydropower Africa 2011, Johannesburg, South Africa
Hydropower Africa 2011 is a niche meeting forum where comprehensive presentations, panel discussions and focused sessions will address the issues surrounding the financing and the implementation of hydropower projects in Africa. For further information, call: Nicolaas Loretz, Tel. +27 21 700 3555.

A DATE TO REMEMBER...

If you know of a tunnelling related conference, event, seminar or exhibition that is not listed here, we would be delighted to hear from you. Please contact the editor by post, email, fax or through our web site: Editor, 'Tunnels & Tunnelling International', Boundary House, 91-93 Charterhouse Street, London, EC1M 6HR, United Kingdom.
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Email: editor@tunnelsandtunnelling.com
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BRITISH TUNNELLING SOCIETY

19 MAY 2011: **BTS AGM + Limerick Immersed Tunnel**
The Limerick Tunnel will provide a new road crossing under the River Shannon. The tunnel comprises five 100m long immersed tunnel elements, a cut and cover tunnel and approach ramps on each bank.

29 JUNE 2011: **High Speed Railway Tunnels in Spain**
With the opening of the new Levante line, the Spanish High Speed Railway network has become the longest in the world. HSR lines with their demanding alignments require the design and construction of an unusually high number of tunnels, some of which are amongst the longest and more important in the world.
This presentation provides information of three good examples of the tunnels recently built in Spain: Guadarrama tunnel, Pajares tunnel and finally Atocha-Chamartan tunnel. This is an evening BTS Presentation being held at the "BTS Underground Conference 2011" on 29th to 30th June 2011. It is a 2 day conference being held in the Earls Court Exhibition Centre.

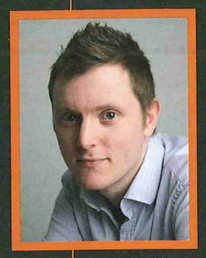
15 SEPTEMBER 2011:
Crossrail
Status update. Latest developments on this major London project.

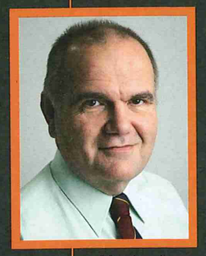
20 OCTOBER 2011:
BTS / BGA Joint Event. Towards a Specification for the Ground - The use of Geotechnical Baseline Reports in the UK
Ground References Conditions. Working title details to follow.

17 NOVEMBER 2011:
Dulles Airport Rail Tunnel, Washington DC
Dulles Transit Partners is responsible for designing and constructing Phase 1 of the Dulles Corridor Metrorail Project. An 11.6 mile extension of the existing Washington Metro to Dulles International Airport. A central feature of the project is the Tysons Tunnel.
The Tysons Tunnel is a twin-bore, two-track tunnel running at 762m in length between portals. The central 534m is being constructed by SCL.

15 DECEMBER 2011:
Cleaner Seas for Sussex
In order to treat the 95 million litres of wastewater generated each day by residents a new wastewater treatment works and 11km of new sewer were required. Now substantially complete find out how more than 11km of 1.8m and 2.4m diameter tunnels and associated shafts and pumping stations were completed.

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Tunnels & Tunnelling International is printed at Stephens & George Print Group, Merthyr Tydfil.

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Tunnels & Tunnelling International ISSN number 0041-414X is published monthly for US$226 a year by World Market Intelligence Ltd (www.worldmarketintelligence.com), a Progressive Media Group company, John Carpenter House, 7 Carmelite Street, London EC4Y 0BS, UK. Periodicals postage paid at Rahway, NJ.
POSTMASTER: send address corrections to Tunnels & Tunnelling International c/o BTB Mailflight Ltd, 365 Blair Rd, Avenel, NJ 07001.
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